HYPER-FINITE FACTORS, P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: PART II

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0.1 PREFACE

This book belongs to a series of online books summarizing the recent state Topological Geometrodynamics (TGD) and its applications. TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students at seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 37 years of my life to this enterprise and am still unable to write The Rules.

If I remember correctly, I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1977, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory. This required also the understanding of the relationship to General Relativity.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of imbedding space is 4-dimensional. During last year it became clear that 4-D Minkowski space and 4-D complex projective space CP_2 are completely unique in the sense that they allow twistor space with Kähler structure.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space (CP_2) providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, main stream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to same multiplet of the gauge group implying instability of proton.

There have been also longstanding problems.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. Furthermore, the imbeddings of Robertson-Walker cosmologies turned out to be vacuum extremals with respect to the inertial energy. About 25 years was needed to realize that the sign of the inertial energy can be also negative and in cosmological scales the density of inertial energy vanishes: physically acceptable universes are creatable from vacuum. Eventually this led to the notion of zero energy ontology (ZEO) which deviates dramatically from the standard ontology being however consistent with the crossing symmetry of quantum field theories. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of so called causal diamonds defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent.

  Equivalence Principle as it is expressed by Einstein's equations follows from Poincare invariance once it is realized that GRT space-time is obtained from the many-sheeted space-time of TGD by lumping together the space-time sheets to a regionof Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields.

  It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to dark matter. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem, and 32 years was needed to discover that what I call weak form of electric-magnetic duality gives a satisfactory solution of the problem and provides also surprisingly powerful insights to the mathematical structure of quantum TGD.

  The latest development was the realization that the well- definedness of electromagnetic charge as quantum number for the modes of the induced spinors field requires that the CP_2 projection of the region in which they are non-vanishing carries vanishing W boson field and is 2-D. This implies in the generic case their localization to 2-D surfaces: string world sheets and possibly also partonic 2-surfaces. This localization applies to all modes except covariantly constant right handed neutrino generating supersymmetry and mplies that string model in 4-D space-time is part of TGD. Localization is possible only for Kähler-Dirac assigned with Kähler action defining the dynamics of space-time surfaces. One must however leave open the question whether W field might vanish for the space-time of GRT if related to many-sheeted space-time in the proposed manner even when they do not vanish for space-time sheets.

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but the first discovery made already during first year of TGD was that these formalisms might be useless due to the extreme non-linearity and enormous vacuum degeneracy of the theory. This turned out to be the case.

- It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as 3-dimensional surfaces. Still few years had to pass before I understood that general coordinate invariance leads to a more or less unique solution of the problem and in positive energyontology implies that space-time surfaces are analogous to Bohr orbits. This in positive energy ontology in which space-like 3-surface is basic object. It is not clear whether Bohr orbitology is necessary also in ZEO in which space-time surfaces connect space-like 3-surfaces at the light-like boundaries of causal diamond CD obtained as intersection of future and past directed light-cones (with CP_2 factor included). The reason is that the pair of 3-surfaces replaces the boundary conditions at single 3-surface involving also time derivatives. If one assumes Bohr orbitology then strong correlations between the 3-surfaces at the ends of CD follow. Still a couple of years and I discovered that quantum states of the Universe can be identified as classical spinor fields in WCW. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

- TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. The somewhat cryptic statement "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly.

The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

If one requires consistency of Negentropy Mazimization Pronciple with standard measurement theory, negentropic entanglement defined in terms of number theoretic negentropy is necessarily associated with a density matrix proportional to unit matrix and is maximal and is characterized by the dimension n of the unit matrix. Negentropy is positive and maximal for a p-adic unique prime dividing n.

- One of the latest threads in the evolution of ideas is not more than nine years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. Second motivation for the hierarchy of Planck constants comes from bio-electromagnetism suggesting that in living systems Planck constant could have large values making macroscopic quantum coherence possible. The interpretation of dark matter as a hierarchy of phases of ordinary matter characterized by the value of Planck constant is very natural.

  During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck constant $h_{eff} = n \times h$ coming as a multiple of minimal value of Planck constant. Quite recently it became clear that the non-determinism of Kähler action is indeed the fundamental justification for the hierarchy: the integer n can be also interpreted as the integer characterizing the dimension of unit matrix characterizing negentropic entanglement made possible by the many-sheeted character of the space-time surface.

  Due to conformal invariance acting as gauge symmetry the n degenerate space-time sheets must be replaced with conformal equivalence classes of space-time sheets and conformal transformations correspond to quantum critical deformations leaving the ends of space-time surfaces invariant. Conformal invariance would be broken: only the sub-algebra for which conformal weights are divisible by n act as gauge symmetries. Thus deep connections between conformal invariance related to quantum criticality, hierarchy of Planck constants, negentropic entanglement, effective p-adic topology, and non-determinism of Kähler action perhaps reflecting p-adic non-determinism emerges.

  The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. It has indeed turned out that the dream about explicit formula is unrealistic before one has understood what happens in quantum jump. Symmetries and general physical principles have turned out to be the proper guide line here. To give some impressions about what is required some highlights are in order.

- With the emergence of ZEO the notion of S-matrix was replaced with M-matrix defined between positive and negative energy parts of zero energy states. M-matrix can be interpreted as a complex square root of density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in ZEO can be said to define a square root of thermodynamics at least formally. M-matrices in turn bombine to form the rows of unitary U-matrix defined between zero energy states.

- A decisive step was the strengthening of the General Coordinate Invariance to the requirement that the formulations of the theory in terms of light-like 3-surfaces identified as 3-surfaces at which the induced metric of space-time surfaces changes its signature and in terms of space-like 3-surfaces are equivalent. This means effective 2-dimensionality in the sense that partonic 2-surfaces defined as intersections of these two kinds of surfaces plus 4-D tangent space data at partonic 2-surfaces code for the physics. Quantum classical correspondence requires the coding of the quantum numbers characterizing quantum states assigned to the partonic 2-surfaces to the geometry of space-time surface. This is achieved by adding to the modified Dirac action a measurement interaction term assigned with light-like 3-surfaces.

- The replacement of strings with light-like 3-surfaces equivalent to space-like 3-surfaces means enormous generalization of the super conformal symmetries of string models. A further generalization of these symmetries to non-local Yangian symmetries generalizing the recently discovered Yangian symmetry of $\mathcal{N} = 4$ supersymmetric Yang-Mills theories is highly suggestive. Here the replacement of point like particles with partonic 2-surfaces means the replacement of conformal symmetry of Minkowski space with infinite-dimensional super-conformal algebras. Yangian symmetry provides also a further refinement to the notion of conserved quantum numbers allowing to define them for bound states using non-local energy conserved currents.

- A further attractive idea is that quantum TGD reduces to almost topological quantum field theory. This is possible if the Kähler action for the preferred extremals defining WCW Kähler function reduces to a 3-D boundary term. This takes place if the conserved currents are so called Beltrami fields with the defining property that the coordinates associated with flow lines extend to single global coordinate variable. This ansatz together with the weak form of electric-magnetic duality reduces the Kähler action to Chern-Simons term with the condition that the 3-surfaces are extremals of Chern-Simons action subject to the constraint force defined by the weak form of electric magnetic duality. It is the latter constraint which prevents the trivialization of the theory to a topological quantum field theory. Also the identification of the Kähler function of WCW as Dirac determinant finds support as well as the description of the scattering amplitudes in terms of braids with interpretation in terms of finite measurement resolution coded to the basic structure of the solutions of field equations.

- In standard QFT Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

  In TGD framework this generalization of Feynman diagrams indeed emerges unavoidably. Light-like 3-surfaces replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic 2-surfaces. The approximate localization of the nodes of induced spinor fields to 2-D string world sheets (and possibly also to partonic 2-surfaces) implies a stringy formulation of the theory analogous to stringy variant of twistor formalism with string world sheets having interpretation as 2-braids. In TGD framework fermionic variant of twistor Grassmann formalism leads to a stringy variant of twistor diagrammatics in which basic fermions can be said to be on mass-shell but carry non-physical helicities in the internal lines. This suggests the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras.

What I have said above is strongly biased view about the recent situation in quantum TGD. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 32 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

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Neither TGD nor these books would exist without the help and encouragement of many people. The friendship with Heikki and Raija Haila and their family and Kalevi and Ritva Tikkanen and their family have been kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 45 lonely years most of which I have remained unemployed as a scientific dissident. I am happy that my children have understood my difficult position and like my friends have believed that what I am doing is something valuable although I have not received any official recognition for it.

During the last decade Tapio Tammi has helped me quite concretely by providing the necessary computer facilities and being one of the few persons in Finland with whom to discuss my work. Pertti Kärkkäinen is my old physicist friend and has provided continued economic support for a long time. I have also had stimulating discussions with Samuli Penttinen who has also helped to get through the economical situations in which there seemed to be no hope. The continual updating of fifteen online books means quite a heavy bureaucracy at the level of bits and without a systemization one ends up with endless copying and pasting and internal consistency is soon lost. Tommi Ullgren has provided both economic support and encouragement during years. Pekka Rapinoja has offered his help in this respect and I am especially grateful to him for my Python skills.

During the last five years I have had inspiring discussions with many people in Finland interested in TGD. We have had video discussions with Sini Kunnas and had podcast discussions with Marko Manninen related to the TGD based view of physics and consciousness. Marko has also helped in the practical issues related to computers and quite recently he has done a lot of testing of chatGPT helping me to get an overall view of what it is. The discussions in a Zoom group involving Marko Manninen, Tuomas Sorakivi and Rode Majakka have given me the valuable opportunity to clarify my thoughts.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation in CASYS conferences in Liege has been an important window to the academic world and I am grateful for Daniel Dubois and Peter Marcer for making this participation possible. The discussions and collaboration with Eduardo de Luna and Istvan Dienes stimulated the hope that the communication of new vision might not be a mission impossible after all. Also blog discussions have been very useful. During these years I have received innumerable email contacts from people around the world. I am grateful to Mark McWilliams, Paul Kirsch, Gary Ehlenberg, and Ulla Matfolk and many others for providing links to possibly interesting websites and articles. We have collaborated with Peter Gariaev and Reza Rastmanesh. These contacts have helped me to avoid the depressive feeling of being some kind of Don Quixote of Science and helped me to widen my views: I am grateful for all these people.

In the situation in which the conventional scientific communication channels are strictly closed it is important to have some loop hole through which the information about the work done can at least in principle leak to the public through the iron wall of academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as an individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without direct support from power holders- even in archives like arXiv.org.

Situation changed as Andrew Adamatsky proposed the writing of a book about TGD when I had already gotten used to the thought that my work would not be published during my lifetime. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loophole. In particular, Dainis Zeps, Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy.

And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his 73th birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During the period when the right wing held political power this trend was steadily strengthening and the situation is the same as I am writing this. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

Karkkila, August 30, 2023, Finland

Matti Pitkänen

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Chapter 1

Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

Standard model describes rather successfully both electroweak and strong interactions but sees them as totally separate and contains a large number of parameters which it is not able to predict. For about four decades ago unified theories known as Grand Unified Theories (GUTs) trying to understand electroweak interactions and strong interactions as aspects of the same fundamental gauge interaction assignable to a larger symmetry group emerged. Later superstring models trying to unify even gravitation and strong and weak interactions emerged. The shortcomings of both GUTs and superstring models are now well-known. If TGD - whose basic idea emerged towards the end of 1977 - would emerge now it would be seen as an attempt to solve the difficulties of these approaches to unification.

The basic physical picture behind the geometric vision of TGD corresponds to a fusion of two rather disparate approaches: namely TGD as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model. After 1995 number theoretic vision started to develop and was initiated by the success of mass calculations based on p-adic thermodynamics. Number theoretic vision involves all number fields and is complementary to the geometric vision: one can say that this duality is analogous to momentum-position duality of wave mechanics. TGD can be also regarded as topological quantum theory in a very general sense as already the attribute "Topological" in "TGD" makes clear. Space-time surfaces as minimal surfaces can be regarded as representatives of homology equivalence classes and p-adic topologies generalize the notion of local topology and apply to the description of correlates of cognition.

1.1.1 Geometric Vision Very Briefly

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K3].

The basic vision and its relationship to existing theories is now rather well understood.

1. Space-times are representable as 4-surfaces in the 8-dimensional embedding space $H = M^4 \times CP_2$, where M^4 is 4-dimensional (4-D) Minkowski space and CP_2 is 4-D complex projective space (see Appendix).

2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of H to the space-time surface. Electroweak gauge potentials are identified as projections of the components of CP_2 spinor connection to the space-time surface, and color gauge potentials as projections of CP_2 Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of H and induced spinor fields just H spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2, which are the only 4-manifolds allowing twistor space with Kähler structure [A21]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

3. A geometrization of quantum numbers is achieved. The isometry group of the geometry of CP_2 codes for the color gauge symmetries of strong interactions. Vierbein group codes for electroweak symmetries, and explains their breaking in terms of CP_2 geometry so that standard model gauge group results. There are also important deviations from the standard model: color quantum numbers are not spin-like but analogous to orbital angular momentum: this difference is expected to be seen only in CP_2 scale. In contrast to GUTs, quark and lepton numbers are separately conserved and family replication has a topological explanation in terms of topology of the partonic 2-surface carrying fermionic quantum numbers.

   M^4 and CP_2 are unique choices for many other reasons. For instance, they are the unique 4-D space-times allowing twistor space with Kähler structure. M^4 light-cone boundary allows a huge extension of 2-D conformal symmetries. M^4 and CP_2 allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of embedding space coordinates and their gradients and general coordinate invariance implies that there are only 4 field-like variables locally. Situation is thus extremely simple mathematically. The objection is that one loses linear superposition of fields. The resolution of the problem comes from the generalization of the concepts of particle and space-time.

   Space-time surfaces can be also particle like having thus finite size. In particular, space-time regions with Euclidian signature of the induced metric (temporal and spatial dimensions in the same role) emerge and have interpretation as lines of generalized Feynman diagrams. Particles in space-time can be identified as a topological inhomogeneities in background space-time surface which looks like the space-time of general relativity in long length scales.

   One ends up with a generalization of space-time surface to many-sheeted space-time with space-time sheets having extremely small distances of about 10^4 Planck lengths (CP_2 size). As one adds a particle to this kind of structure, it touches various space-time sheets and thus interacts with the associated classical fields. Their effects superpose linearly in good approximation and linear superposition of fields is replaced with that for their effects.

   This resolves the basic objection. It also leads to the understanding of how the space-time of general relativity and quantum field theories emerges from TGD space-time as effective space-time when the sheets of many-sheeted space-time are lumped together to form a region of Minkowski space with metric replaced with a metric identified as the sum of empty Minkowski metric and deviations of the metrics of sheets from empty Minkowski metric. Gauge potentials are identified as sums of the induced gauge potentials. TGD is therefore a microscopic theory from which the standard model and general relativity follow as a topological simplification, however forcing a dramatic increase of the number of fundamental field variables.

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of

electromagnetic fields are nonvanishing. The correlations functions for weak fields are non-vanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.

6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.

7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality conditions. The hierarchy of Planck constants $h_{eff}/h = n$ assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by $T = 1/\hbar_{eff}G$ apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of superstring theories. This option allows the natural interpretation of M^4 type vacuum extremals with CP_2 projection, which is Lagrange manifold as good approximations for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

   Whether induced spinor fields associated with Kähler-Dirac action and de-localized inside the entire space-time surface should be allowed remains an open question: super-conformal symmetry strongly suggests their presence. A possible interpretation for the corresponding spinor modes could be in terms of dark matter, sparticles, and hierarchy of Planck constants.

It is perhaps useful to make clear what TGD is not and also what new TGD can give to physics.

1. TGD is *not* just General Relativity made concrete by using embeddings: the 4-surface property is absolutely essential for unifying standard model physics with gravitation and to circumvent the incurable conceptual problems of General Relativity. The many-sheeted space-time of TGD gives rise only at the macroscopic limit to GRT space-time as a slightly curved Minkowski space. TGD is *not* a Kaluza-Klein theory although color gauge potentials are analogous to gauge potentials in these theories.

   TGD space-time is 4-D and its dimension is due to completely unique conformal properties of light-cone boundary and 3-D light-like surfaces implying enormous extension of the ordinary conformal symmetries. Light-like 3-surfaces represent orbits of partonic 2-surfaces and carry fundamental fermions at 1-D boundaries of string world sheets. TGD is *not* obtained by performing Poincare gauging of space-time to introduce gravitation and is plagued by profound conceptual problems.

2. TGD is *not* a particular string model although string world sheets emerge in TGD very naturally as loci for spinor modes: their 2-dimensionality makes among other things possible quantum deformation of quantization known to be physically realized in condensed matter, and conjectured in TGD framework to be crucial for understanding the notion of finite measurement resolution. Hierarchy of objects of dimension up to 4 emerge from TGD: this obviously means analogy with branes of super-string models.

TGD is *not* one more item in the collection of string models of quantum gravitation relying on Planck length mystics. Dark matter becomes an essential element of quantum gravitation and quantum coherence in astrophysical scales is predicted just from the assumption that strings connecting partonic 2-surfaces are responsible for gravitational bound states.

TGD is *not* a particular string model although AdS/CFT duality of super-string models generalizes due to the huge extension of conformal symmetries and by the identification of WCW gamma matrices as Noether super-charges of super-symplectic algebra having a natural conformal structure.

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A6] [B13, B10, B11]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes an exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.

4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the embedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices - this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.

5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: *no* additional structures such as gauge fields as independent dynamical degrees of freedom are introduced: Kähler geometry and associated spinor structure are enough. "Topological" in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [B9]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the TGD Universe.

6. Twistor space - or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles - emerged originally as a technical tool, and its Kähler structure is possible only for $H = M^4 \times CP_2$. It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchy of Planck constants $h_{eff} = n \times h$ reduces to the quantum criticality of the TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last 45 years to the realization of this dream and this has resulted in 26 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

A collection of 30 online books is now (August 2023) under preparation. The goal is to minimize overlap between the topics of the books and make the focus of a given book sharper.

1.1.2 Two Visions About TGD as Geometrization of Physics and Their Fusion

As already mentioned, TGD as a geometrization of physics can be interpreted both as a modification of general relativity and generalization of string models.

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_\times CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A17, A20, A10, A19].

The identification of the space-time as a sub-manifold [A18, A24] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

It soon however turned out that sub-manifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

The choice of H is unique from the condition that TGD has standard model symmetries. Also number theoretical vision selects $H = M^4 \times CP_2$ uniquely. M^4 and CP_2 are also unique spaces allowing twistor space with Kähler structure.

TGD as a Generalization of the Hadronic String Model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

This decay vertex does not however correspond to a direct generalization of trouser vertex of string models. Indeed, the important difference between TGD and string models is that the analogs of string world sheet diagrams do not describe particle decays but the propagation of particles via different routes. Particle reactions are described by generalized Feynman diagrams for which 3-D light-like surface describing particle propagating join along their ends at vertices. As 4-manifolds the space-time surfaces are therefore singular like Feynman diagrams as 1-manifolds.

Quite recently, it has turned out that fermionic strings inside space-time surfaces define an exact part of quantum TGD and that this is essential for understanding gravitation in long length scales. Also the analog of AdS/CFT duality emerges in that the Kähler metric can be defined either in terms of Kähler function identifiable as Kähler action assignable to Euclidian space-time regions or Kähler action + string action assignable to Minkowskian regions.

The recent view about construction of scattering amplitudes is very "stringy". By strong form of holography string world sheets and partonic 2-surfaces provide the data needed to construct scattering amplitudes. Space-time surfaces are however needed to realize quantum-classical correspondence necessary to understand the classical correlates of quantum measurement. There is a huge generalization of the duality symmetry of hadronic string models.

The proposal is that scattering amplitudes can be regarded as sequences of computational operations for the Yangian of super-symplectic algebra. Product and co-product define the basic vertices and realized geometrically as partonic 2-surfaces and algebraically as multiplication for the elements of Yangian identified as super-symplectic Noether charges assignable to strings. Any computational sequences connecting given collections of algebraic objects at the opposite boundaries of causal diamond (CD) produce identical scattering amplitudes.

Fusion of the Two Approaches via a Generalization of the Space-Time Concept

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there could be "vapor phase" that is a "gas" of particle like 3-surfaces and string like objects (counterpart of the "baby universes" of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between different sheets of the space-time and possible existence vapour phase.

. What one obtains is what I have christened as many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig. 18.1** in the appendix of this book). One particular aspect is topological field quantization meaning that various classical fields assignable to a physical system correspond to space-time sheets representing the classical fields to that particular system. One can speak of the field body of a particular physical system. Field body consists of topological light rays, and electric and magnetic flux quanta. In Maxwell's theory the physical system does not possess this kind of field identity. The notion of the magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology. The existence of monopole flux tubes requiring no current as a source of the magnetic field makes it possible to understand the existence of magnetic fields in cosmological and astrophysical scales.

This picture became more detailed with the advent of zero energy ontology (ZEO). The basic notion of ZEO is causal diamond (CD) identified as the Cartesian product of CP_2 and of the intersection of future and past directed light-cones and having scale coming as an integer multiple of CP_2 size is fundamental. CDs form a fractal hierarchy and zero energy states decompose to products of positive and negative energy parts assignable to the opposite boundaries of CD defining the ends of the space-time surface. The counterpart of zero energy state in positive energy ontology is the pair of initial and final states of a physical event, say particle reaction.

At space-time level ZEO means that 3-surfaces are pairs of space-like 3-surfaces at the opposite light-like boundaries of CD. Since the extremals of Kähler action connect these, one can say that by holography the basic dynamical objects are the space-time surface connecting these 3-surfaces and identifiable as analogs of Bohr orbits. This changes totally the vision about notions like self-organization: self-organization by quantum jumps does not take for a 3-D system but for the entire 4-D field pattern associated with it.

General Coordinate Invariance (GCI) allows to identify the basic dynamical objects as space-like 3-surfaces at the ends of space-time surface at boundaries of CD: this means that space-time surface is analogous to Bohr orbit. An alternative identification of the lines of generalized Feynman diagrams is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian . Also the Euclidian 4-D regions can have a similar interpretation. The requirement that the two interpretations are equivalent, leads to a strong form of General Coordinate Invariance. The outcome is effective 2-dimensionality stating that the partonic 2-surfaces identified as intersections of the space-like ends of space-time surface and light-like wormhole throats are the fundamental objects. That only effective 2-dimensionality is in question is due to the effects caused by the failure of strict determinism of Kähler action. In finite length scale resolution these effects can be neglected below UV cutoff and above IR cutoff. One can also speak about a strong form of holography.

The understanding of the super symplectic invariance leads to the proposal that super symplectic algebra and other Kac-Moody type algebras labelled by non-negative multiples of basic conformal weights allow a hierarchy of symmetry breakings in which the analog of gauge symmetry breaks down to a genuine dynamical symmetry. This gives rise to fractal hierarchies of algebras and symmetry breakings. This breaking can occur also for ordinary conformal algebras if one restricts the conformal weights to be non-negative integers.

1.1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest objection against TGD is the observation that all classical gauge fields are expressible in terms of four embedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed. Particles topologically condense to several space-time sheets simultaneously and experience the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

Second objection is that TGD space-time is quite too simple as compared to GRT space-time due to the embeddability to 8-D embedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation makes it possible to understand the relationship to GRT space-time and how the Equivalence Principle (EP) follows from Poincare invariance of TGD. The interpretation of GRT space-time is as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Topological Field Quantization

Topological field quantization distinguishes between TGD based and more standard - say Maxwellian - notion of field. In Maxwell's fields created by separate systems superpose and one cannot tell which part of field comes from which system except theoretically. In TGD these fields correspond to different space-time sheets and only their effects on test particle superpose. Hence physical systems have well-defined field identifies - field bodies - in particular magnetic bodies.

The notion of magnetic body carrying dark matter with non-standard large value of Planck constant has become central concept in TGD inspired theory of consciousness and living matter, and by starting from various anomalies of biology one ends up to a rather detailed view about the role of magnetic body as intentional agent receiving sensory input from the biological body and controlling it using EEG and its various scaled up variants as a communication tool. Among other thins this leads to models for cell membrane, nerve pulse, and EEG.

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was “Do not quantize”. The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and have been the following ones.

World of Classical Worlds

The notion of WCW reduces the interacting quantum theory to a theory of free WCW spinor fields.

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor in the configuration space CH (“world of classical worlds”, WCW) consisting of all possible 3-surfaces in H. “All possible” means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included.

2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.

3. One must geometrize WCW as the space of Bohr orbits. In an infinite-dimensional situation the existence of geometry requires maximal symmetries already in the case of loop spaces. Physics is unique from its mathematical existence.

   WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operators, appearing in the field equations of the theory [1]

Identification of Kähler function

The evolution of these basic ideas has been rather slow but has gradually led to a rather beautiful vision. One of the key problems has been the definition of Kähler function. Kähler function is Kähler action for a preferred extremal assignable to a given 3-surface but what this preferred extremal is? The obvious first guess was as absolute minimum of Kähler action but could not be proven to be right or wrong. One big step in the progress was boosted by the idea that TGD should reduce to almost topological QFT in which braids would replace 3-surfaces in finite measurement resolution, which could be inherent property of the theory itself and imply discretization at partonic 2-surfaces with discrete points carrying fermion number.

It took long time to realize that there is no discretization in 4-D sense - this would lead to difficulties with basic symmetries. Rather, the discretization occurs for the parameters characterizing co-dimension 2 objects representing the information about space-time surface so that they belong to some algebraic extension of rationals. These 2-surfaces - string world sheets and partonic 2-surfaces - are genuine physical objects rather than a computational approximation. Physics itself approximates itself, one might say! This is of course nothing but strong form of holography.

1. TGD as almost topological QFT vision suggests that Kähler action for preferred extremals reduces to Chern-Simons term assigned with space-like 3-surfaces at the ends of space-time (recall the notion of causal diamond (CD)) and with the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Minkowskian and Euclidian regions would give at wormhole throats the same contribution apart from coefficients and in Minkowskian regions the $\sqrt{g_4}$ factorc coming from metric would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary Minkowskian action giving rise to interference effects and stationary phase approximation central in both classical and quantum field theory.

   Imaginary contribution - the presence of which I realized only after 33 years of TGD - could also have topological interpretation as a Morse function. On physical side the emergence of Euclidian space-time regions is something completely new and leads to a dramatic modification of the ideas about black hole interior.

2. The way to achieve the reduction to Chern-Simons terms is simple. The vanishing of Coulomb contribution to Kähler action is required and is true for all known extremals if one makes a general ansatz about the form of classical conserved currents. The so called weak form of electric-magnetic duality defines a boundary condition reducing the resulting 3-D terms to Chern-Simons terms. In this way almost topological QFT results. But only "almost" since the Lagrange multiplier term forcing electric-magnetic duality implies that Chern-Simons action for preferred extremals depends on metric.

WCW spinor fields

Classical WCW spinor fields are analogous to Schrödinger amplitudes and the construction of WCW Kähler geometry reduces to the second quantization of free spinor fields of H.

[1] There are four kinds of Dirac operators in TGD. The geometrization of quantum theory requires Kähler metric definable either in terms of Kähler function identified as a the bosonic action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.

2. There are several Dirac operators. WCW Dirac operator D_{WCW} appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the H Dirac operator D_H appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of D_H. The modes of $_DH$ define the ground states of super-symplectic representations. There is also the modified Dirac operator D_{X^4} acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed. D_H is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

The role of modified Dirac action

1. By quantum classical correspondence, the construction of WCW spinor structure in sectors assignable to CDs reduces to the second quantization of the induced spinor fields of H. The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified) gamma matrices defined as contractions of the canonical momentum currents of the bosonic action defining the space-time surfaces with the embedding space gamma matrices. In this way one achieves super-conformal symmetry and conservation of fermionic currents among other things and a consistent Dirac equation.

   Modified Dirac action is needed to define WCW gamma matrices as super charges assignable to WCW isometry generators identified as generators of symplectic transformations and by holography are needed only at the 3-surface at the boundaries of WCW. It is important to notice that the modified Dirac equation does not determine propagators since induced spinor fields are obtained from free second quantized spinor fields of H. This means enormous simplification and makes the theory calculable.

2. An important interpretational problem relates to the notion of the induced spinor connection. The presence of classical W boson fields is in conflict with the classical conservation of em charge since the coupling to classical W fields changes em charge.

   One way out of the problem is the fact that the quantum averages of weak and gluon fields vanish unlike the quantum average of the em field. This leads to a rather precise understanding of electroweak symmetry breaking as being due the fact that color symmetries rotate space-time surfaces and also affect the induced weak fields.

   One can also consider a stronger condition. If one requires that the spinor modes have well-defined em charge, one must assume that the modes in the generic situation are localized at 2-D surfaces - string world sheets or perhaps also partonic 2-surfaces - at which classical W boson fields vanish. Covariantly constant right handed neutrinos generating super-symmetries forms an exception. The vanishing of the Z^0 field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that the string model in 4-D space-time becomes part of TGD. Without these conditions classical weak fields can vanish above weak scale only for the GRT limit of TGD for which gauge potentials are sums over those for space-time sheets.

   The localization would simplify the mathematics enormously and one can solve exactly the Kähler-Dirac equation for the modes of the induced spinor field just like in super string models.

   At the light-like 3-surfaces the signature of the induced metric changes from Euclidian to Minkowskian so that $\sqrt{g_4}$ vanishes. One can pose the condition that the algebraic analog of the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A22, A26, A30]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

During years this naïve and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also introduced the word "world of classical worlds" (WCW) instead of rather formal "configuration space". I hope that "WCW" does not induce despair in the reader having tendency to think about the technicalities involved!

Construction of the counterparts of S-matrices

What does one mean with the counterpart of S-matrix in the TGD framework has been a long standing problem. The development of ZEO based quantum measurement theory has led to a rough overall view of the situation.

1. There are two kinds of state function reductions (SFRs). "Small" SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.

2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.

3. Also "big" SFRS (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.

4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by $M^8 - H$ duality. Unitarity is therefore replaced with isometry.

5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

The notion of M-matrix

1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of S-matrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.

2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called M-matrices defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. A biven M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.

3. M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian square root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in a well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the M-matrices commuting with S-matrix means that they span infinite-dimensional Lie algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.

4. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the CP_2 time.

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K69]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

5. I have also considered the notion of U-matrix. U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I have proposed a general representation for the U-matrix, reducing its construction to that of the S-matrix.

1.1.6 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space ("world of classical worlds", WCW), p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. The fourth thread deserves the name "TGD as a generalized number theory". It involves three separate threads: the fusion of real and various p-adic physics to a single coherent whole by requiring number theoretic universality discussed already, the formulation of quantum TGD in terms of complexified counterparts of classical number fields, and the notion of infinite prime. Note that one can identify subrings such as hyper-quaternions and hyper-octonions as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product.

The Threads in the Development of Quantum TGD

The development of TGD has involved several strongly interacting threads: physics as infinite-dimensional geometry; TGD as a generalized number theory, the hierarchy of Planck constants interpreted in terms of dark matter hierarchy, and TGD inspired theory of consciousness. In the following these threads are briefly described.

1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional WCW, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

2. The discussions with Tony Smith initiated a fourth thread which deserves the name "TGD as a generalized number theory". The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and rather fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" thread.

3. A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

The chronology based identification of the threads is quite natural but not logical and it is much more logical to see p-adic physics, the ideas related to classical number fields, and infinite primes as sub-threads of a thread which might be called "physics as a generalized number theory". In the following I adopt this view. This reduces the number of threads to three corresponding to geometric, number theoretic and topological views of physics.

TGD forces the generalization of physics to a quantum theory of consciousness, and TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations.

Number theoretic vision very briefly

Number theoretic vision about quantum TGD involves notions like adelic physics, M^8-H duality and number theoretic universality. A short review of the basic ideas that have developed during years is in order.

1. The physical interpretation of M^8 is as an analog of momentum space and M^8-H duality is analogous to momentum-position duality of ordinary wave mechanics.

2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

   The complexification of M^8, identified as complexified octonions, would provide a realization of this picture and M^8-H duality would map the algebraic physics in M^8 to the ordinary physics in $M^4\times CP_2$ described in terms of partial differential equations.

3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

   NMP is mathematically completely analogous to the second law of thermodynamics and number theoretic evolution as an unavoidable statistical increase of the dimension of the algebraic extension of rationals characterizing a given space-time region implies it. There is no paradox involved: the p-adic negentropy measures the conscious information assignable to the entanglement of two systems regarded as a conscious entity whereas ordinary entropy measures the lack of information about the quantums state of either entangled system.

4. Number theoretical universality requires that space-time surfaces or at least their M^8-H duals in M_c^8 are defined for both reals and various p-adic number fields. This is true if they are defined by polynomials with integer coefficients as surfaces in M^8 obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.

5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.

6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as $p=3$).

   The proposal is that p-adic primes correspond to ramified primes assignable to the extension and identified as divisors of the polynomial defined by the products of the root differences for the roots of the polynomial defining space-time space and having interpretation as values of, in general complex, virtual mass squared.

p-Adic TGD and fusion of real and p-adic physics to single coherent whole

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzles and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired "Universe as Computer" vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

In string model context one tries to reduces the physics to Planck scale. The price is the inability to say anything about physics in long length scales. In TGD p-adic physics takes care of this shortcoming by predicting the physics also in long length scales.

There were many interpretational and technical questions crying for a definite answer.

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *the* Physics? Should one perform p-adicization also at the level of the WCW? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.
2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

Despite various uncertainties, the number of the applications of the poorly defined p-adic physics has grown steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

The key challenge is to fuse various p-adic physics and real physics to single larger structure. This has inspired a proposal for a generalization of the notion of number field by fusing real numbers and various p-adic number fields and their extensions along rationals and possible common algebraic numbers. This leads to a generalization of the notions of embedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, embedding space, and WCW.

The corresponds of real 4-surfaces with the p-adic ones is induced by number theoretical discretization using points of 4-surfaces $Y^4 \subset M^8_c$ identifiable as 8-momenta, whose components are assumed to be algebraic integers in an extension of rationals defined by the extension of rationals associated with a polynomial P with integer coefficients smaller than the degree of P. These points define a cognitive representation, which is universal in the sense that it exists also in the algebraic extensions of p-adic numbers. The points of the cognitive representations associated with the mass shells with mass squared values identified as roots of P are enough since $M^8 - H$ duality can be used at both M^8 and H sides and also in the p-adic context. The mass shells are special in that they allow for Minkowski coordinates very large cognitive representations unlike the interiors of the 4-surfaces determined by holography by using the data defined by the 3-surfaces at the mass shells. The higher the dimension of the algebraic extension associated with P, the better the accuracy of the cognitive representation.

Adelization providing number theoretical universality reduces to algebraic continuation for the amplitudes from this intersection of reality and various p-adicities - analogous to a back of a book - to various number fields. There are no problems with symmetries but canonical identification is needed: various group invariant of the amplitude are mapped by canonical identification to various p-adic number fields. This is nothing but a generalization of the mapping of the p-adic mass squared to its real counterpart in p-adic mass calculations.

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K65].

The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to "mind stuff", the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably a brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

Infinite primes

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory.

After the realization that infinite primes can be mapped to polynomials possibly representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of complexified quaternions and octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

The infinite primes at the first level of hierarchy, which represent analogs of bound states, can be mapped to irreducible polynomials, which in turn characterize the algebraic extensions of rationals defining a hierarchy of algebraic physics continuable to real and p-adic number fields. The products of infinite primes in turn define more general algebraic extensions of rationals. The interesting question concerns the physical interpretation of the higher levels in the hierarchy of infinite primes and integers mappable to polynomials of $n > 1$ variables.

1.1.7 An explicit formula for $M^8 - H$ duality

$M^8 - H$ duality is a generalization of momentum-position duality relating the number theoretic and geometric views of physics in TGD and, despite that it still involves poorly understood aspects, it has become a fundamental building block of TGD. One has 4-D surfaces $Y^4 \subset M^8_c$, where M^8_c is complexified M^8 having interpretation as an analog of complex momentum space and 4-D spacetime surfaces $X^4 \subset H = M^4 \times CP_2$. M^8_c, equivalently E^8_c, can be regarded as complexified octonions. M^8_c has a subspace M^4_c containing M^4.

Comment: One should be very cautious with the meaning of "complex". Complexified octonions involve a complex imaginary unit i commuting with the octonionic imaginary units I_k. i is assumed to also appear as an imaginary unit also in complex algebraic numbers defined by the roots of polynomials P defining holographic data in M^8_c.

In the following $M^8 - H$ duality and its twistor lift are discussed and an explicit formula for the dualities are deduced. Also possible variants of the duality are discussed.

Holography in H

$X^4 \subset H$ satisfies holography and is analogous to the Bohr orbit of a particle identified as a 3-surface. The proposal is that holography reduces to a 4-D generalization of holomorphy so that X^4 is a simultaneous zero of two functions of complex CP_2 coordinates and of what I have called Hamilton-Jacobi coordinates of M^4 with a generalized Kähler structure.

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition $M^4 = M^2 \times E^2$, where M^2 is endowed with hypercomplex structure defined by light-like coordinates (u, v), which are analogous to z and $\overline{z}$. Any analytic map $u \to f(u)$ defines a new set of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in M^2. E^2 has some complex coordinates with imaginary unit defined by i.

The conjecture is that also more general Hamilton-Jacobi structures for which the tangent space decomposition is local are possible. Therefore one would have $M^4 = M^2(x) \times E^2(x)$. These would correspond to non-equivalent complex and Kähler structures of M^4 analogous to those possessed by 2-D Riemann surfaces and parametrized by moduli space.

Number theoretic holography in M^8_c

$Y^4 \subset M^8_c$ satisfies number theoretic holography defining dynamics, which should reduce to associativity in some sense. The Euclidian complexified normal space $N^4(y)$ at a given point y of Y^4 is required to be associative, i.e. quaternionic. Besides this, $N^4(i)$ contains a preferred complex Euclidian 2-D subspace $Y^2(y)$. Also the spaces $Y^2(x)$ define an integrable distribution. I have assumed that $Y^2(x)$ can depend on the point y of Y^4.

These assumptions imply that the normal space $N(y)$ of Y^4 can be parameterized by a point of $CP_2 = SU(3)/U(2)$. This distribution is always integrable unlike quaternionic tangent space distributions. $M^8 - H$ duality assigns to the normal space $N(y)$ a point of CP_2. M^4_c point y is mapped to a point $x \in M^4 \subset M^4 \times CP_2$ defined by the real part of its inversion (conformal transformation): this formula involves effective Planck constant for dimensional reasons.

The 3-D holographic data, which partially fixes 4-surfaces Y^4 is partially determined by a polynomial P with real integer coefficients smaller than the degree of P. The roots define mass squared values which are in general complex algebraic numbers and define complex analogs of mass shells in $M^4_c \subset M^8_c$, which are analogs of hyperbolic spaces H^3. The 3-surfaces at these mass shells define 3-D holographic data continued to a surface Y^4 by requiring that the normal space of Y^4 is associative, i.e. quaternionic. These 3-surfaces are not completely fixed but an interesting conjecture is that they correspond to fundamental domains of tessellations of H^3.

What does the complexity of the mass shells mean? The simplest interpretation is that the space-like M^4 coordinates (3-momentum components) are real whereas the time-like coordinate (energy) is complex and determined by the mass shell condition. One would have $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3 when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as a time coordinate. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to an equation of mass shell when $\sqrt{(Re(E)^2 - Im(E)^2)}$, expressed in terms of $Re(E)$, is taken as new energy coordinate $E_{eff} = \sqrt{(Re(E)^2 - Im(E)^2)}$. Is this deformation of H^3 in imaginary time direction equivalent with a region of the hyperbolic 3-space H^3?

One can look at the formula in more detail. Mass shell condition gives $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3, when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as an effective energy. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to a dispersion relation for $Re(E)^2$.

$$Re(E)^2 = \frac{1}{2}(Re(m^2) - Im(m^2) + p^2)(1 \pm \sqrt{1 + \frac{2Im(m^2)^2}{(Re(m^2) - Im(m^2) + p^2)^2}} \ . \qquad (1.1.1)$$

Only the positive root gives a non-tachyonic result for $Re(m^2) - Im(m^2) > 0$. For real roots with $Im(m^2) = 0$ and at the high momentum limit the formula coincides with the standard formula. For $Re(m^2) = Im(m^2)$ one obtains $Re(E)^2 \to Im(m^2)/\sqrt{2}$ at the low momentum limit $p^2 \to 0$. Energy does not depend on momentum at all: the situation resembles that for plasma waves.

Can one find an explicit formula for $M^8 - H$ duality?

The dream is an explicit formula for the $M^8 - H$ duality mapping $Y^4 \subset M^8_c$ to $X^4 \subset H$. This formula should be consistent with the assumption that the generalized holomorphy holds true for X^4.

The following proposal is a more detailed variant of the earlier proposal for which Y^4 is determined by a map g of $M^4_c \to SU(3)_c \subset G_{2,c}$, where $G_{2,c}$ is the complexified automorphism group of octonions and $SU(3)_c$ is interpreted as a complexified color group.

This map defines a trivial $SU(3)_c$ gauge field. The real part of g however defines a non-trivial real color gauge field by the non-linearity of the non-abelian gauge field with respect to the gauge potential. The quadratic terms involving the imaginary part of the gauge potential give an additional condition to the real part in the complex situation and cancel it. If only the real part of g contributes, this contribution would be absent and the gauge field is non-vanishing.

How could the automorphism $g(x) \subset SU(3) \subset G_2$ give rise to $M^8 - H$ duality?

1. The interpretation is that $g(y)$ at given point y of Y^4 relates the normal space at y to a fixed quaternionic/associative normal space at point y_0, which corresponds is fixed by some subgroup $U(2)_0 \subset SU(3)$. The automorphism property of g guarantees that the normal space is quaternionic/associative at y. This simplifies the construction dramatically.

2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex sub-space which corresponds to a point of sphere $S^2 = SO(3)/O(2)$, where $SO(3)$ is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in M^4 characterized by the choice of $M^2(x)$ and equivalently its normal subspace $E^2(x)$.

   These two structures are independent apart from dependencies forced by the number theoretic dynamics. Hamilton-Jacobi structure means a selection of the quantization axis of spin and energy by fixing a distribution of light-like tangent vectors of M^4 and the choice of the quaternionic normal sub-space fixes a choice of preferred quaternionic imaginary unit defining a quantization axis of the weak isospin.

3. The real part $Re(g(y))$ defines a point of $SU(3)$ and the bundle projection $SU(3) \rightarrow CP_2$ in turn defines a point of $CP_2 = SU(3)/U(2)$. Hence one can assign to g a point of CP_2 as $M^8 - H$ duality requires and deduce an explicit formula for the point. This means a realization of the dream.

4. The construction requires a fixing of a quaternionic normal space N_0 at y_0 containing a preferred complex subspace at a single point of Y^4 plus a selection of the function g. If M^4 coordinates are possible for Y^4, the first guess is that g as a function of complexified M^4 coordinates obeys generalized holomorphy with respect to complexified M^4 coordinates in the same sense and in the case of X^4. This might guarantee that the $M^8 - H$ image of Y^4 satisfies the generalized holomorphy.

5. Also space-time surfaces X^4 with M^4 projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of Y^4 allowing it to have a M^4 projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface Y^4 in terms of the complex coordinates of $SU(3)_c$ and M^4? Could this give for instance cosmic strings with a 2-D M^4 projection and CP_2 type extremals with 4-D CP_2 projection and 1-D light-like M^4 projection?

What could the number theoretic holography mean physically?

What could be physical meaning of the number theoretic holography? The condition that has been assumed is that the CP_2 coordinates at the mass shells of $M^4_c \subset M^8_c$ mapped to mass shells H^3 of $M^4 \subset M^4 \times CP_2$ are constant at the H^3. This is true if the $g(y)$ defines the same CP_2 point for a given component X^3_i of the 3-surface at a given mass shell. g is therefore fixed apart from a local $U(2)$ transformation leaving the CP_2 point invariant. A stronger condition would be that the CP_2 point is the same for each component of X^3_i and even at each mass shell but this condition seems to be unnecessarily strong.

Comment: One can o criticize this condition as too strong and one can consider giving up this condition. The motivation for this condition is that the number of algebraic points at the 3-surfaces associated with H^3 explodes since the coordinates associated with normal directions vanish. Kind of cognitive explosion would be in question.

$SU(3)$ corresponds to a subgroup of G_2 and one can wonder what the fixing of this subgroup could mean physically. G_2 is 14-D and the coset space $G_2/SU(3)$ is 6-D and a good guess is that it is just the 6-D twistor space $SU(3)/U(1) \times U(1)$ of CP_2: at least the isometries are the same.

The fixing of the $SU(3)$ subgroup means fixing of a CP_2 twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

Twistor lift of the holography

What is interesting is that by replacing $SU(3)$ with G_2, one obtains an explicit formula form the generalization of M^8-H duality to that for the twistorial lift of TGD!

One can also consider a twistorial generalization of the above proposal for the number theoretic holography by allowing local G_2 automorphisms interpreted as local choices of the color quantization axis. G_2 elements would be fixed apart from a local $SU(3)$ transformation at the components of 3-surfaces at mass shells. The choice of the color quantization axes for a connected 3-surface at a given mass shell would be the same everywhere. This choice is indeed very natural physically since 3-surface corresponds to a particle.

Is this proposal consistent with the boundary condition of the number theoretical holography mean in the case of 4-surfaces in M^8_c and $M^4\times CP_2$?

1. The selection of $SU(3)\subset G_2$ for ordinary M^8-H duality means that the $G_{2,c}$ gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the CP_2 point to be constant at H^3 implies that the color gauge field at $H^3\subset M^8_c$ and its image $H^3\subset H$ vanish. One would have color confinement at the mass shells H^3_i, where the observations are made. Is this condition too strong?
2. The constancy of the G_2 element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed $SU(3)\subset G_2$ for entire space-time surface is in conflict with the non-constancy of G_2 element unless G_2 element differs at different points of 4-surface only by a multiplication of a local $SU(3)_0$ element, that is local $SU(3)$ transformation. This kind of variation of the G_2 element would mean a fixed color group but varying choice of color quantization axis.
3. Could one consider the possibility that the local $G_{2,c}$ element is free and defines the twistor lift of M^8-H duality as something more fundamental than the ordinary M^8-H duality based on $SU(3)_c$. This duality would make sense only at the mass shells so that only the spaces $H^3\times CP_2$ assignable to mass shells would make sense physically? In the interior CP_2 would be replaced with the twistor space $SU(3)/U(1)\times U(1)$. Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have G_2 gauge fields.

   There is also a physical objection against the G_2 option. The 14-D Lie algebra representation of G_2 acts on the imaginary octonions which decompose with respect to the color group to $1\oplus 3\oplus \overline{3}$. The automorphism property requires that 1 can be transformed to 3 or $\overline{3}$ to themselves: this requires that the decomposition contains $3\oplus\overline{3}$. Furthermore, it must be possible to transform 3 and $\overline{3}$ to themselves, which requires the presence of 8. This leaves only the decomposition $8\oplus 3\oplus\overline{3}$. G_2 gluons would both color octet and triplets. In the TDG framework the only conceivable interpretation would be in terms of ordinary gluons and leptoquark-like gluons. This does not fit with the basic vision of TGD.

The choice of twistor as a selection of quantization axes should make sense also in the M^4 degrees of freedom. M^4 twistor corresponds to a choice of light-like direction at a given point of M^4. The spatial component of the light-like vector fixes the spin quantization axis. Its choice together with the light-likeness fixes the time direction and therefore the rest system and energy quantization axis. Light-like vector fixes also the choice of M^2 and of E^2 as its orthogonal complement. Therefore the fixing of M^4 twistor as a point of $SU(4)/SU(3)\times U(1)$ corresponds to a choice of the spin quantization axis and the time-like axis defining the rest system in which the energy is measured. This choice would naturally correspond to the Hamilton-Jacobi structure fixing the decompositions $M^2(x)\times E^2(x)$. At a given mass shell the choice of the quantization axis would be constant for a given X^3_i.

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that

Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E9] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems. The space-time sheets in question would carry dark matter.

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K96].

It is natural to assign the values of Planck constants postulated by Nottale to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta) possibly carrying monopole flux and identifiable as remnants of cosmic string phase of primordial cosmology. The magnetic energy of these flux quanta would correspond to dark energy and magnetic tension would give rise to negative "pressure" forcing accelerate cosmological expansion. This leads to a rather detailed vision about the evolution of stars and galaxies identified as bubbles of ordinary and dark matter inside magnetic flux tubes identifiable as dark energy.

Certain experimental findings suggest the identification $h_{eff} = n\times = h_{gr}$. The large value of h_{gr} can be seen as a way to reduce the string tension of fermionic strings so that gravitational (in fact all!) bound states can be described in terms of strings connecting the partonic 2-surfaces defining particles (analogous to AdS/CFT description). The values $h_{eff}/h = n$ can be interpreted in terms of a hierarchy of breakings of super-conformal symmetry in which the super-conformal generators act as gauge symmetries only for a sub-algebras with conformal weights coming as multiples of n. Macroscopic quantum coherence in astrophysical scales is implied. If also Kähler-Dirac action is present, part of the interior degrees of freedom associated with the Kähler-Dirac part of conformal algebra become physical. A possible is that tfermionic oscillator operators generate super-symmetries and sparticles correspond almost by definition to dark matter with $h_{eff}/h = n > 1$. One implication would be that at least part if not all gravitons would be dark and be observed only through their decays to ordinary high frequency graviton ($E = hf_{high} = h_{eff}f_{low}$) of bunch of n low energy gravitons.

Hierarchy of Planck Constants from the Anomalies of Neuroscience and Biology

The quantal ELF effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

This inspired the hypothesis that these photons correspond to so large a value of Planck constant that the energy of photons is above the thermal energy. The proposed interpretation was as dark photons and the general hypothesis was that dark matter corresponds to ordinary matter with non-standard value of Planck constant. If only particles with the same value of Planck constant can appear in the same vertex of Feynman diagram, the phases with different value of Planck constant are dark relative to each other. The phase transitions changing Planck constant can however make possible interactions between phases with different Planck constant but these interactions do not manifest themselves in particle physics. Also the interactions mediated by classical fields should be possible. Dark matter would not be so dark as we have used to believe.

The hypothesis $h_{eff} = h_{gr}$ - at least for microscopic particles - implies that cyclotron energies of charged particles do not depend on the mass of the particle and their spectrum is thus universal although corresponding frequencies depend on mass. In bio-applications this spectrum would correspond to the energy spectrum of bio-photons assumed to result from dark photons by h_{eff} reducing phase transition and the energies of bio-photons would be in visible and UV range associated with the excitations of bio-molecules.

Also the anomalies of biology (see for instance [K85, K86, K83]) support the view that dark matter might be a key player in living matter.

Dark Matter as a Source of Long Ranged Weak and Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics.

The recent view about the solutions of Kähler- Dirac action assumes that the modes have a well-defined em charge and this implies that localization of the modes to 2-D surfaces (right-handed neutrino is an exception). Classical W boson fields vanish at these surfaces and also classical Z^0 field can vanish. The latter would guarantee the absence of large parity breaking effects above intermediate boson scale scaling like h_{eff}.

1.1.9 Twistors in TGD and connection with Veneziano duality

The twistorialization of TGD has two aspects. The attempt to generalize twistor Grassmannian approach emerged first. It was however followed by the realization that also the twistor lift of TGD at classical space-time level is needed. It turned out that the progress in the understanding of the classical twistor lift has been much faster - probably this is due to my rather limited technical QFT skills.

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K111]. The reason is that M^4 and CP_2 are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [A21]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2. The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure co-incides with the twistor structure defined by the induced metric.

In fact, it is enough to generalize the induction of spinor structure to that of twistor structure so that the induced twistor structure need not be identical with the ordinary twistor structure possibly assignable to the space-time surface. The induction procedure reduces to a dimensional reduction of 6-D Kähler action giving rise to 6-D surfaces having bundle structure with twistor sphere as fiber and space-time as base. The twistor sphere of this bundle is imbedded as sphere in the product of twistor spheres of twistor spaces of M^4 and CP_2.

This condition would define the dynamics, and the original conjecture was that this dynamics is equivalent with the identification of space-time surfaces as preferred extremals of Kähler action. The dynamics of space-time surfaces would be lifted to the dynamics of twistor spaces, which are sphere bundles over space-time surfaces. What is remarkable that the powerful machinery of complex analysis becomes available.

It however turned out that twistor lift of TGD is much more than a mere technical tool. First of all, the dimensionally reduction of 6-D Kähler action contained besides 4-D Kähler action also a volume term having interpretation in terms of cosmological constant. This need not bring anything new, since all known extremals of Kähler action with non-vanishing induced Kähler form are minimal surfaces. There is however a large number of embeddings of twistor sphere of space-time surface to the product of twistor spheres. Cosmological constant has spectrum and depends on length scale, and the proposal is that coupling constant evolution reduces to that for cosmological constant playing the role of cutoff length. That cosmological constant could transform from a mere nuisance to a key element of fundamental physics was something totally new and unexpected.

1. The twistor lift of TGD at space-time level forces to replace 4-D Kähler action with 6-D dimensionally reduced Kähler action for 6-D surface in the 12-D Cartesian product of 6-D twistor spaces of M^4 and CP_2. The 6-D surface has bundle structure with twistor sphere as fiber and space-time surface as base.

   Twistor structure is obtained by inducing the twistor structure of 12-D twistor space using dimensional reduction. The dimensionally reduced 6-D Kähler action is sum of 4-D Kähler action and volume term having interpretation in terms of a dynamical cosmological constant depending on the size scale of space-time surface (or of causal diamond CD in zero energy ontology (ZEO)) and determined by the representation of twistor sphere of space-time surface in the Cartesian product of the twistor spheres of M^4 and CP_2.

2. The preferred extremal property as a representation of quantum criticality would naturally correspond to minimal surface property meaning that the space-time surface is separately an extremal of both Kähler action and volume term almost everywhere so that there is no coupling between them. This is the case for all known extremals of Kähler action with non-vanishing induced Kähler form.

   Minimal surface property could however fail at 2-D string world sheets, their boundaries and perhaps also at partonic 2-surfaces. The failure is realized in minimal sense if the 3-surface has 1-D edges/folds (strings) and 4-surface 2-D edges/folds (string world sheets) at which some partial derivatives of the embedding space coordinates are discontinuous but canonical momentum densities for the entire action are continuous.

   There would be no flow of canonical momentum between interior and string world sheet and minimal surface equations would be satisfied for the string world sheet, whose 4-D counterpart in twistor bundle is determined by the analog of 4-D Kähler action. These conditions allow the transfer of canonical momenta between Kähler- and volume degrees of freedom at string world sheets. These no-flow conditions could hold true at least asymptotically (near the boundaries of CD).

   M^8-H duality suggests that string world sheets (partonic 2-surfaces) correspond to images of complex 2-sub-manifolds of M^8 (having tangent (normal) space which is complex 2-plane of octonionic M^8).

3. Cosmological constant would depend on p-adic length scales and one ends up to a concrete model for the evolution of cosmological constant as a function of p-adic length scale and other number theoretic parameters (such as Planck constant as the order of Galois group): this conforms with the earlier picture.

   Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L82].

Twistor lift at the level of scattering amplitudes and connection with Veneziano duality

The classical part of twistor lift of TGD is rather well-understood. Concerning the twistorialization at the level of scattering amplitudes the situation is much more difficult conceptually - I already mentioned my limited QFT skills.

1. From the classical picture described above it is clear that one should construct the 8-D twistorial counterpart of theory involving space-time surfaces, string world sheets and their boundaries, plus partonic 2-surfaces and that this should lead to concrete expressions for the scattering amplitudes.

   The light-like boundaries of string world sheets as carriers of fermion numbers would correspond to twistors as they appear in twistor Grassmann approach and define the analog for the massless sector of string theories. The attempts to understand twistorialization have been restricted to this sector.

2. The beautiful basic prediction would be that particles massless in 8-D sense can be massive in 4-D sense. Also the infrared cutoff problematic in twistor approach emerges naturally and reduces basically to the dynamical cosmological constant provided by classical twistor lift.

   One can assign 4-momentum both to the spinor harmonics of the embedding space representing ground states of super-conformal representations and to light-like boundaries of string world sheets at the orbits of partonic 2-surfaces. The two four-momenta should be identical by quantum classical correspondence: this could be seen as a concretization of Equivalence Principle. Also a connection with string model emerges.

3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of M^4. Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?

4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in $calN = 4$ SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

   Braid interpretation encourages the conjecture that non-planar diagrams can be reduced to ordinary ones by a procedure analogous to the construction of braid (knot) invariants by gradual un-braiding (un-knotting).

This is however not the only vision about a solution of non-planarity. Quantum criticality provides different view leading to a totally unexpected connection with string models, actually with the Veneziano duality, which was the starting point of dual resonance model in turn leading via dual resonance models to super string models.

1. Quantum criticality in TGD framework means that coupling constant evolution is discrete in the sense that coupling constants are piecewise constant functions of length scale replaced by dynamical cosmological constant. Loop corrections would vanish identically and the recursion formulas for the scattering amplitudes (allowing only planar diagrams) deduced in twistor Grassmann would involve no loop corrections. In particular, cuts would be replaced by sequences of poles mimicking them like sequences of point charge mimic line charges. In momentum discretization this picture follows automatically.

2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adele [L63]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?

3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see http://tinyurl.com/yyhwvbqb) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see http://tinyurl.com/yyvkx7as) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?

4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or t-channel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of s to Regge form.

   The resonances had zero width, which was not consistent with unitarity. Further, there were no counterparts for the *sum* of s-, t-, and u-channel diagrams with continuous cuts in the kinematical regions encountered in QFT approach. What puts bells ringing is the u-channel diagrams would be non-planar and non-planarity is the problem of twistor Grassmann approach.

5. Veneziano duality is true only for s- and t- channels but not been s- and u-channel. Stringy description makes t-channel and s-channel pictures equivalent. Could it be that in fundamental description u-channels diagrams cannot be distinguished from s-channel diagrams or t-channel diagrams? Could the stringy representation of the scattering diagrams make u-channel twist somehow trivial if handles of string world sheet representing stringy loops in turn representing the analog of non-planarity of Feynman diagrams are absent? The permutation of external momenta for tree diagram in absence of loops in planar representation would be a twist of π in the representation of planar diagram as string world sheet and would not change the topology of the string world sheet and would not involve non-trivial world sheet topology.

   For string world sheets loops would correspond to handles. The presence of handle would give an edge with a loop at the level of 3-surface (self energy correction in QFT). Handles are not allowed if the induced metric for the string world sheet has Minkowskian signature. If the stringy counterparts of loops are absent, also the loops in scattering amplitudes should be absent.

   This argument applies only inside the Minkowskian space-time regions. If string world sheets are present also in Euclidian regions, they might have handles and loop corrections could emerge in this manner. In TGD framework strings (string world sheets) are identified to 1-D edges/folds of 3-surface at which minimal surface property and topological QFT property fails (minimal surfaces as calibrations). Could the interpretation of edge/fold as discontinuity of some partial derivatives exclude loopy edges: perhaps the branching points would be too singular?

A reduction to a sum over s-channel resonances is what the vanishing of loops would suggest. Could the presence of string world sheets make possible the vanishing of continuous cuts even at the continuum limit so that continuum cuts would emerge only in the approximation as the density of resonances is high enough?

The replacement of continuous cut with a sum of *infinitely* narrow resonances is certainly an approximation. Could it be that the stringy representation as a sum of resonances with *finite* width is an essential aspect of quantum physics allowing to get rid of infinities necessarily accompanying loops? Consider now the arguments against this idea.

1. How to get rid of the problems with unitarity caused by the zero width of resonances? Could *finite* resonance widths make unitarity possible? Ordinary twistor Grassmannian approach predicts that the virtual momenta are light-like but complex: obviously, the imaginary part of the energy in rest frame would have interpretation as resonance with.

   In TGD framework this generalizes for 8-D momenta. By quantum-classical correspondence (QCC) the classical Noether charges are equal to the eigenvalues of the fermionic charges in Cartan algebrable (maximal set of mutually commuting observables) and classical TGD indeed predicts complex momenta (Kähler coupling strength is naturally complex). QCC thus supports this proposal.

2. Sum over resonances/exchanges picture is in conflict with QFT picture about scattering of particles. Could *finite* resonance widths due to the complex momenta give rise to the QFT type scattering amplitudes as one develops the amplitudes in Taylor series with respect to the resonance width? Unitarity condition indeed gives the first estimate for the resonance width.

   QFT amplitudes should emerge in an approximation obtained by replacing the discrete set of finite width resonances with a cut as the distance between poles is shorter than the resolution for mass squared.

   In superstring models string tension has single very large value and one cannot obtain QFT type behavior at low energies (for instance, scattering amplitudes in hadronic string model are concentrated in forward direction). TGD however predicts an entire hierarchy of p-adic length scales with varying string tension. The hierarchy of mass scales corresponding roughly to the lengths and thickness of magnetic flux tubes as thickened cosmic strings and characterized by the value of cosmological constant predicted by twistor lift of TGD. Could this give rise to continuous QCT type cuts at the limit when measurement resolution cannot distinguish between resonances?

   The dominating term in the sum over sums of resonances in t-channel gives near forward direction approximately the lowest mass resonance for strings with the smallest string tension. This gives the behavior $1/(t-m_{min}^2)$, where m_{min} corresponds to the longest mass scale involved (the largest space-time sheet involved), approximating the $1/t$-behavior of massless theories. This also brings in IR cutoff, the lack of which is a problem of gauge theories. This should give rise to continuous QFT type cuts at the limit when measurement resolution cannot distinguish between resonances.

1.2 Bird's Eye of View about the Topics of "Hyper-finite Factors and Hierarchy of Planck Constants: Part II"

The book "Bird's Eye of View about the Topics of Hyper-finite Factors and Hierarchy of Planck Constants: Part II" is organized to 2 parts.

1.2.1 The organization of "Hyper-finite Factors and Hierarchy of Planck Constants: Part II"

The book "Hyper-finite Factors and Hierarchy of Planck Constants: Part II" consists of 2 parts. The 1st part of the book is devoted to the applications of the hierarchy of Planck constants to particle and nuclear physics.

1. Already at seventies evidence for states formed in heavy nucleus collisions and decaying to electron-positrons pairs emerged and the TGD expansion is in terms of lepto-hadron physics inspired by the possibility that leptons (as also quarks) might have color partial waves which are are light. Whether the masses of these states can be light, is still an open question. The observed resonances could be string like entities analogous to mesons but formed from color excitations of leptons.
2. String like entities form a fractal like hierarchy in TGD Universe and should appear in all scales. Not only elementary particles but also nuclei could be string like entities. This leads to what I call nuclear string model. In this framework one also ends up to a proposal that dark nuclei can exist and would have smaller scale of binding energy scaling like h/h_{eff}. This idea is applied to anomaly known as "cold fusion".

The 2nd part of the part II is formally devoted to condensed matter physics but overlaps with dark nuclear physics so that it is somewhat a matter of taste whether to include the chapters in 4th part to the 3rd one.

1. The TGD based view about nuclear physics does not separate nuclear and condensed matter physics to completely isolated realms. This leads to speculations concerning the reported

anomalies suggesting that these two physics indeed couple. Dark matter and dark nuclear physics would be central also for the understanding of living matter, in particular, genetic code would have a representation at the level of dark nuclei. This inspired me to write two chapters immediately after the idea about hierarchy of Planck constants emerged: these chapters are out-of-date but reflect the evolution of ideas so that I have kept them. I however added a third chapter devoted to the realization of dark realization of genetic code as sequences of 3-proton states representing genetic codons to provide a glimpse about the recent situation.

2. There are also chapters about super-conductivity and quantum Hall effect explained in terms of hierarchy of Planck constants. The last chapter is about a possible explanation of Shnoll effect.

1.3 Sources

The eight online books about TGD [K119, K112, K90, K74, K23, K70, K52, K101] and nine online books about TGD inspired theory of consciousness and quantum biology [K109, K18, K82, K16, K48, K60, K62, K100, K108] are warmly recommended for the reader willing to get overall view about what is involved.

My homepage (`http://tinyurl.com/ybv8dt4n`) contains a lot of material about TGD. In particular, a TGD glossary at `http://tinyurl.com/yd6jf3o7`).

I have published articles about TGD and its applications to consciousness and living matter in *Journal of Non-Locality* (`http://tinyurl.com/ycyrxj4o` founded by Lian Sidorov and in *Prespacetime Journal* (`http://tinyurl.com/ycvktjhn`), *Journal of Consciousness Research and Exploration* (`http://tinyurl.com/yba4f672`), and *DNA Decipher Journal* (`http://tinyurl.com/y9z52khg`), all of them founded by Huping Hu. One can find the list about the articles published at `http://tinyurl.com/ybv8dt4n`. I am grateful for these far-sighted people for providing a communication channel, whose importance one cannot overestimate.

1.4 The contents of the book

1.4.1 PART I: P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: PARTICLE AND NUCLEAR PHYSICS

Recent status of lepto-hadron hypothesis

TGD suggests strongly the existence of lepto-hadron physics. Lepto-hadrons would be bound states of color excited leptons and the anomalous production of e^+e^- pairs in heavy ion collisions finds a nice explanation as resulting from the decays of lepto-hadrons with basic condensate level $k = 127$ and having typical mass scale of one MeV. The recent indications on the existence of a new fermion with quantum numbers of muon neutrino and the anomaly observed in the decay of ortopositronium give further support for the lepto-hadron hypothesis. There is also evidence for anomalous production of low energy photons and e^+e^- pairs in hadronic collisions.

The identification of lepto-hadrons as a particular instance in the predicted hierarchy of dark matters interacting directly only via graviton exchange allows to circumvent the lethal counter arguments against the lepto-hadron hypothesis (Z^0 decay width and production of colored lepton jets in e^+e^- annihilation) even without assumption about the loss of asymptotic freedom.

PCAC hypothesis and its sigma model realization lead to a model containing only the coupling of the lepto-pion to the axial vector current as a free parameter. The prediction for e^+e^- production cross section is of correct order of magnitude only provided one assumes that lepto-pions decay to lepto-nucleon pair $e^+_{ex}e^-_{ex}$ first and that lepto-nucleons, having quantum numbers of electron and having mass only slightly larger than electron mass, decay to lepton and photon. The peculiar production characteristics are correctly predicted. There is some evidence that the resonances decay to a final state containing $n > 2$ particle and the experimental demonstration that lepto-nucleon pairs are indeed in question, would be a breakthrough for TGD.

During 18 years after the first published version of the model also evidence for colored μ has emerged. Towards the end of 2008 CDF anomaly gave support for the colored excitation of τ. The lifetime of the light long lived state identified as a charged τ-pion comes out correctly and the identification of the reported 3 new particles as p-adically scaled up variants of neutral τ-pion predicts their masses correctly. The observed muon jets can be understood in terms of the special reaction kinematics for the decays of neutral τ-pion to 3 τ-pions with mass scale smaller by a factor 1/2 and therefore almost at rest. A spectrum of new particles is predicted. The discussion of CDF anomaly led to a modification and generalization of the original model for lepto-pion production and the predicted production cross section is consistent with the experimental estimate.

TGD and Nuclear Physics

This chapter is devoted to the possible implications of TGD for nuclear physics. In the original version of the chapter the focus was in the attempt to resolve the problems caused by the incorrect interpretation of the predicted long ranged weak gauge fields. What seems to be a breakthrough in this respect came around 2005, more than a decade after the first version of this chapter, and is based on TGD based view about dark matter inspired by the developments in the mathematical understanding of quantum TGD. In this approach condensed matter nuclei can be either ordinary, that is behave essentially like standard model nuclei, or be in dark matter phase in which case they generate long ranged dark weak gauge fields responsible for the large parity breaking effects in living matter. This approach resolves trivially the objections against long range classical weak fields.

About 7 years later (2012) it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced W gauge fields. It is quite possible that this localization is consistent with Kähler-Dirac equation only in ther Minkowskian regions were the effective metric defined by Kähler-Dirac gamma matrices can be effectively 2-dimensional.

One can pose the additional condition that also classical Z^0 field vanishes - at least above weak scale. Fundamental fermions would experience only em field so that the worries related to large parity breaking effects would disappear. The proportionality of weak scale to $h_{eff} = n \times h$ however predicts that weak fields are effectively massless belong scaled up weak scale. Therefore worries about large parity breaking effects in nuclear physics can be forgotten.

The basic criterion for the transition to dark matter phase having by definition large value of $\hbar$ is that the condition $\alpha Q_1 Q_2 \simeq 1$ for appropriate gauge interactions expressing the fact that the perturbation series does not converge. The increase of $\hbar$ makes perturbation series converging since the value of α is reduced but leaves lowest order classical predictions invariant.

This criterion can be applied to color force and inspires the hypothesis that valence quarks inside nucleons correspond to large $\hbar$ phase whereas sea quark space-time sheets correspond to the ordinary value of $\hbar$. This hypothesis is combined with the earlier model of strong nuclear force based on the assumption that long color bonds with p-adically scaled down quarks with mass of order MeV at their ends are responsible for the nuclear strong force.

1. Is strong force due to color bonds between exotic quark pairs?

The basic assumptions are following.

1. Valence quarks correspond to large $\hbar$ phase with p-adic length scale $L(k_{eff} = 129) = L(107)/v_0 \simeq 2^{11}L(107) \simeq 5 \times 10^{-12}$ m whereas sea quarks correspond to ordinary $\hbar$ and define the standard size of nucleons.
2. Color bonds with length of order $L(127) \simeq\simeq 2.5 \times 10^{-12}$ m and having quarks with ordinary $\hbar$ and p-adically scaled down masses $m_q(dark) \simeq v_0 m_q$ at their ends define kind of rubber bands connecting nucleons. The p-adic length scale of exotic quarks differs by a factor 2 from that of dark valence quarks so that the length scales in question can couple naturally. This large length scale as also other p-adic length scales correspond to the size of the topologically quantized field body associated with system, be it quark, nucleon, or nucleus.
3. Valence quarks and even exotic quarks can be dark with respect to both color and weak interactions but not with respect to electromagnetic interactions. The model for binding energies suggests darkness with respect to weak interactions with weak boson masses scaled down by a factor v_0. Weak interactions remain still weak. Quarks and nucleons as defined by their $k = 107$ sea quark portions condense at scaled up weak space-time sheet with $k_{eff} = 111$

having p-adic size 10^{-14} meters. The estimate for the atomic number of the heaviest possible nucleus comes out correctly.

The wave functions of the nucleons fix the boundary values of the wave functionals of the color magnetic flux tubes idealizable as strings. In the terminology of M-theory nucleons correspond to small branes and color magnetic flux tubes to strings connecting them.

2. General features of strong interactions

This picture allows to understand the general features of strong interactions.

1. Quantum classical correspondence and the assumption that the relevant space-time surfaces have 2-dimensional CP_2 projection implies Abelianization. Strong isospin group can be identified as the SU(2) subgroup of color group acting as isotropies of space-time surfaces. and the U(1) holonomy of color gauge potential defines a preferred direction of strong isospin. Dark color isospin corresponds to strong isospin. The correlation of dark color with weak isospin of the nucleon is strongly suggested by quantum classical correspondence.
2. Both color singlet spin 0 pion type bonds and colored spin 1 bonds are allowed and the color magnetic spin-spin interaction between the exotic quark and anti-quark is negative in this case. p-p and n-n bonds correspond to oppositely colored spin 1 bonds and p-n bonds to colorless spin 0 bonds for which the binding energy is free times higher. The presence of colored bonds forces the presence of neutralizing dark gluon condensate favoring states with $N - P > 0$.
3. Shell model based on harmonic oscillator potential follows naturally from this picture in which the magnetic flux tubes connecting nucleons take the role of springs. Spin-orbit interaction can be understood in terms of the color force in the same way as it is understood in atomic physics.

3. Nuclear binding energies

1. The binding energies per nucleon for $A \leq 4$ nuclei can be understood if they form closed string like structures, nuclear strings, so that only two color bonds per nucleon are possible. This could be understood if ordinary quarks and exotic quarks possessing much smaller mass behave as if they were identical fermions. p-Adic mass calculations support this assumption. Also the average behavior of binding energy for heavier nuclei is predicted correctly.
2. For nuclei with $P = N$ all color bonds can be pion type bonds and have thus largest color magnetic spin-spin interaction energy. The increase of color Coulombic binding energy between colored exotic quark pairs and dark gluons however favors $N > P$ and explains also the formation of neutron halo outside $k = 111$ space-time sheet.
3. Spin-orbit interaction provides the standard explanation for magic numbers. If the maximum of the binding energy per nucleon is taken as a criterion for magic, also Z=N=4,6,12 are magic. The alternative TGD based explanation for magic numbers $Z = N = 4, 6, 8, 12, 20$ would be in terms of regular Platonic solids. Experimentally also other magic numbers are known for neutrons. The linking of nuclear strings provides a possible mechanism producing new magic nuclei from lighter magic nuclei.

4. Stringy description of nuclear reactions

The view about nucleus as a collection of linked nuclear strings suggests stringy description of nuclear reactions. Microscopically the nuclear reactions would correspond to re-distribution of exotic quarks between the nucleons in reacting nuclei.

5. Anomalies and new nuclear physics

The TGD based explanation of neutron halo has been already mentioned. The recently observed tetra-neutron states are difficult to understand in the standard nuclear physics framework since Fermi statistics does not allow this kind of state. The identification of tetra-neutron as an alpha particle containing two negatively charged color bonds allows to circumvent the problem. A large variety of exotic nuclei containing charged color bonds is predicted.

The proposed model explains the anomaly associated with the tritium beta decay. What has been observed is that the spectrum intensity of electrons has a narrow bump near the endpoint energy. Also the maximum energy E_0 of electrons is shifted downwards. I have considered two explanations for the anomaly. The original models are based on TGD variants of original models involving belt of dark neutrinos or antineutrinos along the orbit of Earth. Around 2008)I realized that nuclear string model provides much more elegant explanation of the anomaly and has also the potential to explain much more general anomalies.

Cold fusion has not been taken seriously by the physics community but the situation has begun to change gradually. There is an increasing evidence for the occurrence of nuclear transmutations of heavier elements besides the production of ^4He and ^3H whereas the production rate of ^3He and neutrons is very low. These characteristics are not consistent with the standard nuclear physics predictions. Also Coulomb wall and the absence of gamma rays and the lack of a mechanism transferring nuclear energy to the electrolyte have been used as an argument against cold fusion. TGD based model relying on the notion of charged color bonds could explain the anomalous characteristics of cold fusion. The basic mechanism making possible to circum vent Coulomb wall could be large h_{eff} phase for weak bosons scaling the weak length scale to atomic length scale so that proton could transform to neutron by the exchange of dark W boson with target nucleus.

Nuclear String Hypothesis

Nuclear string hypothesis is one of the most dramatic almost-predictions of TGD. The hypothesis in its original form assumes that nucleons inside nucleus form closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. It is also possible that neutrons and protons form their own strings. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests.

1. $A > 4$ nuclei as nuclear strings consisting of $A \leq 4$ nuclei

In this article a more refined version of nuclear string hypothesis is developed.

1. It is assumed ^4He nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings. $A \leq 4$ nuclei in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number of ^4He nuclei is maximal. Even the weak decay characteristics might be reduced to those for $A < 4$ nuclei using this hypothesis.
2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings.
3. In TGD framework tetra-neutron is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants. For heavier nuclei tetra-neutron is needed as an additional building brick.

2. Bose-Einstein condensation of color bonds as a mechanism of nuclear binding

The attempt to understand the variation of the nuclear binding energy and its maximum for Fe leads to a quantitative model of nuclei lighter than Fe as color bound Bose-Einstein condensates of pion like colored states associated with color flux tubes connecting ^4He nuclei. The color contribution to the total binding energy is proportional to n^2, where n is the number of color bonds. Fermi statistics explains the reduction of E_B for the nuclei heavier than Fe. Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand ^4He and lighter nuclei as strings of nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$, $A = 4$, and $A < 4$ nuclei are involved. The binding energies of also $A \leq 4$ are predicted surprisingly accurately by applying simple p-adic scaling to the model of binding energies of heavier nuclei.

3. Giant dipole resonance as de-coherence of Bose-Einstein condensate of color bonds

Giant resonances and so called pygmy resonances are interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei. The splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy. For ^4He de-coherence the model predicts singlet line at 12.74 MeV and triplet at ~ 27 MeV spanning 4 MeV wide range.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in rather good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet at ~ 8 MeV and MeV spacing is predicted. The prediction for the position is correct.

4. Dark nuclear strings as analogs of as analogs of DNA-, RNA- and amino-acid sequences and baryonic realization of genetic code

A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the hardware for topological quantum computation (TQC) represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of amino-acids coded by a given number of codons are predicted correctly. Hence genetic code would be universal rather than being an accidental outcome of the biological evolution.

Cold Fusion Again

During years I have developed two models of cold fusion and in this article these models are combined together. The basic idea of TGD based model of cold is that cold fusion occurs in two steps. First dark nuclei (large $h_{eff} = n \times h$) with much lower binding energy than ordinary nuclei are formed at magnetic flux tubes possibly carrying monopole flux. These nuclei can leak out the system along magnetic flux tubes. Under some circumstances these dark nuclei can transform to ordinary nuclei and give rise to detectable fusion products.

An essential additional condition is that the dark protons can decay to neutrons rapidly enough by exchanges of dark weak bosons effectively massless below atomic length scale. Also beta decays in which dark W boson decays to dark electron and neutrino can be considered. This allows to overcome the Coulomb wall and explains why final state nuclei are stable and the decay to ordinary nuclei does not yield only protons. Thus it seems that this model combined with the TGD variant of Widom-Larsen model could explain nicely the existing data.

In this chapter I will describe the steps leading to the TGD inspired model for cold fusion combining the earlier TGD variant of Widom-Larsen modelwith the model inspired by the TGD inspired model of Pollack's fourth phase of water using as input data findings from laser pulse induced cold fusion discovered by Leif Holmlid and collaborators. I consider briefly also alternative options (models assuming surface plasma polariton and heavy electron). After that I apply TGD inspired model in some cases (Pons-Fleischman effect, bubble fusion, and LeClair effect). The model explains the strange findings about cold fusion - in particular the fact that only stable nuclei are produced - and suggests that also ordinary nuclear reactions might have more fundamental description in terms of similar model.

Could TGD provide new solutions to the energy problem?

Topological Geometrodynamics (TGD) leads to new physics both classically and at quantum level. This new physics could provide a solution to the energy problem. Artificial photosynthesis, nuclear fission, hot fusion and also "cold fusion" have received a considerable attention as solutions of this problem. TGD has led to a model of "cold fusion" (CF), which was later generalized to a model for nuclear physics applicable also to hot fusion and to explain a 10 year old anomaly in the nuclear physics of Sun.

TGD leads also to a model of quantum biology relying on new quantum physics. This model could provide a theoretical basis for the understanding of photosynthesis. This article provides first an introduction to CF, and then a brief summary about TGD as a unification of fundamental interactions and its applications to quantum biology and to theory of consciousness as generalization of quantum measurement theory. Finally TGD based model of CF and how it could help in the development of energy technology is discussed.

What is remarkable that both CF and ordinary nuclear reactions would proceed by essentially the same mechanism as bio-catalysis made possible by quantum criticality and phase transitions changing length scale dependent cosmological constant predicted by TGD. By fractality of TGD Universe this mechanism could actually apply in all scales from astrophysics to hadron physics and even in phase transition that was expected to correspond to color de-confinement.

Comparing Electric Universe hypothesis and TGD

Electric Universe scenario in its extreme form postulates that electromagnetic fields are enough to explain gravitation and even nuclear fusion. From TGD viewpoint this vision is unrealistic. Wes Johnson however gave links to two Youtube videos related to Electric Universe telling about extremely interesting physical findings providing applications for TGD if take seriously. The first video was about the anomalies related to the craters of the Moon and second describe the claimed findings of SAFIRE team having a nice interpretation in TGD framework using the notions of monopole flux tubes and dark matter as hierarchy of phases of ordinary matter with non-standard value of Planck constant implying that electromagnetism has deep implications in arbitrarily long scales. The question in TGD is therefore not about whether electromagnetism (of gauge interactions in general) or gravitation is enough to understand cosmology and astrophysics: both are needed and in the sense of TGD.

Solar Metallicity Problem from TGD Perspective

For ten years ago it was thought that Sun is a well-understood system but more precise computations demonstrated a problem. The metallicities deduced from the spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data.

The abundances used are determined from meteorites and these estimates are more accurate and consistent with the values determined by Asplund et al using 3-D modelling of solar surface used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund et al would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic.
2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismology. Ironically, the earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

When one has a paradox one must challenge the basic assumptions. Do the metallicities outside Sun and inside solar core really mean same thing? Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand "cold fusion". In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase leads to the final state of the reaction. In ZEO "big" (ordinary) state function reduction (BFSR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than "small" state function reduction (SFSR) as TGD counterpart of "weak" measurement, ZEO would make possible nuclear fusion.

The missing nuclear matter inside core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those derived from helio-seismic data. The reason is that sound waves and photons in the core couple to both ordinary and dark matter so that helio-seismology gives metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of "cold fusion", one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume.

One can relate the model also to the model for the formation of galaxies, stars, and planets as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

The view about the role of new nuclear physics predicted by TGD in the model of solar interior gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low. The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

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Three unexpected findings in hadron and nuclear physics from TGD point of view

This chapter discusses some recent unexpected finds related to hadron- and nuclear physics.

1. The recent experiments of Dove et al confirm that the antiquark sea is asymmmetric in the sense that the ratio anti-d/anti-u is larger than unity. A model assuming that proton is part

of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture.

The TGD based model relies on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD. Virtual mesons are replaced with real on mass shell mesons but with p-adically scaled down mass, and low energy strong interactions at the hadronic and nuclear level are described topologically in terms of reconnections of flux tubes.

2. That final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood. The recent surprising findings by Wilson et al was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays.

   The TGD proposal is that the generation of angular momentum is a kind of self-organization process. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics.

   The final state nuclei have angular momenta $6-7\ \hbar$. This suggests that self-organization increases the values of h_{eff} to nh, $n \in \{6,7\}$. Quantization of angular momentum with new unit of spin would force the generation of large spins. Zero energy ontology (ZEO) provides a new element to the description of self-organization and a model for quantum tunnelling phenomenon.

3. Quite recently, empirical support for a particle christened Odderon has emerged. As the name tells, Odderon is not well-understood in QCD framework.

   Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it.

4. Eric Reiner has studied the behavior of gamma-rays emitted by heavy nuclei going through a beam splitter splitting the photon beam to two beams. Quantum theory predicts that only one detector fires. Therefore the pulses in the two detectors occur at different times. This has been verified for photons of visible light. The experiment studied the same situation for gamma-rays and the surprise was that one observes mostly half pulses in both detectors and in some cases also full pulses. Reiner has made analogous experiments also with alpha particles with the same conclusion. These findings pose a challenge for TGD, and in this chapter a TGD based model for the findings is developed.

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Cosmic string model for the formation of galaxies and stars

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The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

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1.4.2 PART II: P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: CONDENSED MATTER PHYSICS

Dark Nuclear Physics and Condensed Matter

In this chapter the possible effects of dark matter in nuclear physics and condensed matter physics are considered. The spirit of the discussion is necessarily rather speculative. The most general form of the hierarchy would involve both singular coverings and factors spaces of CD (causal diamond of M^4) defined as intersection of future and past directed light-cones) and CP_2. There are grave objections against the allowance of factor spaces. In this case Planck constant could be smaller than its standard value and there are very few experimental indications for this. Quite recently came the realization that the hierarchy of Planck constants might emerge from the basic quantum TGD as a consequence of the extreme non-linearity of field equations implying that the correspondence between the derivatives of embedding space coordinates and canonical momentum is many-to-one. This makes natural to the introduction of covering spaces of CD and CP_2.

Planck constant would be effectively replaced with a multiple of ordinary Planck constant defined by the number of the sheets of the covering. The space-like 3-surfaces at the ends of the causal diamond and light-like 3-surfaces defined by wormhole throats carrying elementary particle quantum numbers would be quantum critical in the sense of being unstable against decay to many-sheeted structures. Charge fractionization could be understood in this scenario. Biological evolution would have the increase of the Planck constant as as one aspect. The crucial scaling of the size of CD by Planck constant can be justified by a simple argument. Note that primary p-adic length scales would scale as $\sqrt{\hbar}$ rather than $\hbar$ as assumed in the original model.

Recently the hierarchy of Planck constants have been traced to the non-determinism of Kähler action predicting in zero energy ontology (ZEO) that two space-like 3-surfaces at the ends of causal diamonds (CD) can be connected by several space-time surfaces. As a matter fact, by infinite number of them related by quantum critical deformations identifiable as conformal transformations respecting the light-likeness of partonic orbits at which the signature of the induced metric changes. The number of conformal equivalence classes of space-time sheets would be integer n defining the effective Planck constant $h_{eff} = n \times h$.

1. What darkness means?

Dark matter is identified as matter with non-standard value of Planck constant. The weak form of darkness states that only some field bodies of the particle consisting of flux quanta mediating bound state interactions between particles become dark. One can assign to each interaction a field body (em, Z^0, W, gluonic, gravitational) and p-adic prime and the value of Planck constant characterize the size of the particular field body. One might even think that particle mass can be assigned with its em field body and that Compton length of particle corresponds to the size scale of em field body.

Nuclear string model suggests that the sizes of color flux tubes and weak flux quanta associated with nuclei can become dark in this sense and have size of order atomic radius so that dark nuclear physics would have a direct relevance for condensed matter physics. If this happens, it becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore.

2. What dark nucleons are?

The basic hypothesis is that nuclei can make a phase transition to dark phase in which the size of both quarks and nuclei is measured in Angstroms. For the less radical option this transition could happen only for the color, weak, and em field bodies. Proton connected by dark color bonds super-nuclei with inter-nucleon distance of order atomic radius might be crucial for understanding the properties of water and perhaps even the properties of ordinary condensed matter. Large $\hbar$ phase for weak field body of D and Pd nuclei with size scale of atom would explain selection rules of cold fusion.

3. Anomalous properties of water and dark nuclear physics

A direct support for partial darkness of water comes from the $H_{1.5}O$ chemical formula supported by neutron and electron diffraction in attosecond time scale. The explanation could be that one fourth of protons combine to form super-nuclei with protons connected by color bonds and having distance sufficiently larger than atomic radius.

The crucial property of water is the presence of molecular clusters. Tedrahedral clusters allow an interpretation in terms of magic Z=8 protonic dark nuclei. The icosahedral clusters consisting of 20 tedrahedral clusters in turn have interpretation as magic dark dark nuclei: the presence of the dark dark matter explains large portion of the anomalies associated with water and explains the unique role of water in biology. In living matter also higher levels of dark matter hierarchy are predicted to be present. The observed nuclear transmutation suggest that also light weak bosons are present.

4. Implications of the partial darkness of condensed matter

The model for partially dark condensed matter inspired by nuclear string model and the model of cold fusion inspired by it allows to understand the low compressibility of the condensed matter as being due to the repulsive weak force between exotic quarks, explains large parity breaking effects in living matter, and suggests a profound modification of the notion of chemical bond having most important implications for bio-chemistry and understanding of bio-chemical evolution.

Dark Forces and Living Matter

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether electro-weak charges of elementary particles are screened in electro-weak length scale or not. The TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale. The localization of the modes of Kähler-Dirac action to 2-D surfaces at which W fields vanish realizes this idea concretely. Also Z^0 fields can vanish and are expected to do so above weak scale.

The large value of $\hbar$ in dark matter phase implies that Compton lengths and -times are scaled up. In particular, the sizes of nucleons and nuclei become of order atom size so that dark nuclear physics would have direct relevance for condensed matter physics. It becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore. This view forces a profound re-consideration of the earlier ideas in nuclear and condensed physics context. It however seems that most of the earlier ideas related to the classical Z^0 force and inspired by anomaly considerations survive in a modified form.

The weak form of electric-magnetic duality led to the identification of the long sought for mechanism causing the weak screening in electroweak scales. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial.

The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers. Weak charges would be therefore screened for ordinary matter in electro-weak length scale but dark electro-weak bosons correspond to much longer symmetry breaking length scale for weak field body. Large values of Planck constant would make it possible to zoop up elementary particles and study their internal structure without any need for gigantic accelerators.

One can still worry about large parity breaking effects - say in nuclear physics- since the couplings of spinors to classical weak fields are there. Around 2012 it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced W gauge fields. It is quite possible that this localization is consistent with Kähler-Dirac equation only in ther Minkowskian regions were the effective metric defined by Kähler-Dirac gamma matrices can be effectively 2-dimensional.

On can pose the additional condition that also classical Z^0 field vanishes - at least above weak scale. Fundamental fermions would experience only em field so that the worries related to large parity breaking effects would disappear. The proportionality of weak scale to $h_{eff} = n \times h$ however predicts that weak fields are effectively massless belong scaled up weak scale. Therefore worries about large parity breaking effects in ordinary nuclear physics can be forgotten.

In this chapter possible implications of the dark weak force for the understanding of living matter are discussed. The basic question is how classical Z^0 fields could make itself visible. Large parity breaking effects in living matter suggests which direction one should look for the answer to the question. One possible answer is based on the observation that for vacuum extremals classical electromagnetic and Z^0 fields are proportional to each other and this means that the electromagnetic charges of dark fermions standard are replaced with effective couplings in which the contribution of classical Z^0 force dominates. This modifies dramatically the model for the cell membrane as a Josephson junction and raises the scale of Josephson energies from IR range just above thermal threshold to visible and ultraviolet. The amazing finding is that the Josephson energies for biologically important ions correspond to the energies assigned to the peak frequencies in the biological activity spectrum of photoreceptors in retina suggesting. This suggests that almost vacuum extremals and thus also classical Z^0 fields could be in a central role in the understanding of the functioning of the cell membrane and of sensory qualia. This would also explain the large parity breaking effects in living matter.

A further conjecture is that EEG and its predicted fractally scaled variants which same energies in visible and UV range but different scales of Josephson frequencies correspond to Josephson photons with various values of Planck constant. The decay of dark ELF photons with energies of visible photons would give rise to bunches of ordinary ELF photons. Biophotons in turn could correspond to ordinary visible photons resulting in the phase transition of these photons to photons with ordinary value of Planck constant. This leads to a very detailed view about the role of dark electromagnetic radiation in biomatter and also to a model for how sensory qualia are realized. The general conclusion might be that most effects due to the dark weak force are associated with almost vacuum extremals.

Super-Conductivity in Many-Sheeted Space-Time

In this chapter a model for high T_c super-conductivity as quantum critical phenomenon is developed. The relies on the notions of quantum criticality, dynamical quantized Planck constant requiring a generalization of the 8-D embedding space to a book like structure, and many-sheeted space-time. In particular, the notion of magnetic flux tube as a carrier of supra current of central concept.

With a sufficient amount of twisting and weaving these basic ideas one ends up to concrete model for high T_c superconductors as quantum critical superconductors consistent with the qualitative facts that I am personally aware. The following minimal model looks the most realistic option found hitherto.

1. The general idea is that magnetic flux tubes are carriers of supra currents. In anti-ferromagnetic phases these flux tube structures form small closed loops so that the system behaves as an insulator. Some mechanism leading to a formation of long flux tubes must exist. Doping creates holes located around stripes, which become positively charged and attract electrons to the flux tubes.

2. The basic mechanism for the formation of Cooper pairs is simple. Magnetic flux tubes would be carriers of dark particles and magnetic fields would be crucial for super-conductivity. Two parallel flux tubes carrying magnetic fluxes in opposite directions is the simplest candidate for super-conducting system. This conforms with the observation that antiferromagnetism is somehow crucial for high temperature super-conductivity. The spin interaction energy is proportional to Planck constant and can be above thermal energy: if the hypothesis that dark cyclotron energy spectrum is universal is accepted, then the energies would be in bio-photon range and high temperature super-conductivity is obtained. If fluxes are parallel spin $S = 1$ Cooper pairs are stable. $L = 2$ states are in question since the members of the pair are at different flux tubes.

3. The higher critical temperature T_{c1} corresponds to a formation local configurations of parallel spins assigned to the holes of stripes giving rise to a local dipole fields with size scale of the order of the length of the stripe. Conducting electrons form Cooper pairs at the magnetic flux tube structures associated with these dipole fields. The elongated structure of the dipoles favors angular momentum $L = 2$ for the pairs. The presence of magnetic field favors Cooper pairs with spin $S = 1$.

4. Stripes can be seen as 1-D metals with delocalized electrons. The interaction responsible for the energy gap corresponds to the transversal oscillations of the magnetic flux tubes inducing oscillations of the nuclei of the stripe. These transverse phonons have spin and their exchange is a good candidate for the interaction giving rise to a mass gap. This could explain the BCS type aspects of high T_c super-conductivity.

5. Above T_c supra currents are possible only in the length scale of the flux tubes of the dipoles which is of the order of stripe length. The reconnections between neighboring flux tube structures induced by the transverse fluctuations give rise to longer flux tubes structures making possible finite conductivity. These occur with certain temperature dependent probability $p(T, L)$ depending on temperature and distance L between the stripes. By criticality $p(T, L)$ depends on the dimensionless variable $x = TL/\hbar$ only: $p = p(x)$. At critical temperature T_c transverse fluctuations have large amplitude and makes $p(x_c)$ so large that very long flux tubes are created and supra currents can run. The phenomenon is completely analogous to percolation.

6. The critical temperature $T_c = x_c\hbar/L$ is predicted to be proportional to $\hbar$ and inversely proportional to L (, which is indeed to be the case). If flux tubes correspond to a large value of $\hbar$, one can understand the high value of T_c. Both Cooper pairs and magnetic flux tube structures represent dark matter in TGD sense.

7. The model allows to interpret the characteristic spectral lines in terms of the excitation energy of the transversal fluctuations and gap energy of the Cooper pair. The observed 50 meV threshold for the onset of photon absorption suggests that below T_c also $S = 0$ Cooper pairs are possible and have gap energy about 9 meV whereas $S = 1$ Cooper pairs would have gap energy about 27 meV. The flux tube model indeed predicts that $S = 0$ Cooper pairs become stable below T_c since they cannot anymore transform to $S = 1$ pairs. Their presence could explain the BCS type aspects of high T_c super-conductivity. The estimate for $\hbar/\hbar_0 = r$ from critical temperature T_{c1} is about $r = 3$ contrary to the original expectations inspired by the model of of living system as a super-conductor suggesting much higher value. An unexpected prediction is that coherence length is actually r times longer than the coherence length predicted by conventional theory so that type I super-conductor could be in question with stripes serving as duals for the defects of type I super-conductor in nearly critical magnetic field replaced now by ferromagnetic phase.

At qualitative level the model explains various strange features of high T_c superconductors. One can understand the high value of T_c and ambivalent character of high T_c super conductors, the existence of pseudogap and scalings laws for observables above T_c, the role of stripes and doping and the existence of a critical doping, etc...

Comparing the Berry phase model of super-conductivity with the TGD based model

Hiroyasu Koizumi has proposed a new theory of superconductivity (SC) based on the notion of Berry phase related with an effective magnetic field assignable to adiabatically evolving systems. The model shares similarities with the TGD inspired view about SC. The article also mentioned anomalies that were new to me. This motivated a fresh look in the TGD inspired model. The outcome was an integration of two separate ideas about supraphases.

1. Space-time surfaces as preferred extremals with CP_2 projection of dimension $D = 2$ or $D = 3$ would naturally correspond to 4-D generalizations of so called Beltrami flows, which are integrable flows defined by the flow lines of the induced Kähler field. The existence of a global coordinate z varying along flow lines requires the integrability of the flow. Classical dissipation is absent so that these surfaces are excellent candidates for the space-time correlates of supra flows. The exponential of z gives a phase factor associated with the complex order parameter of a coherent state of Cooper pairs as a counterpart of the Berry phase. Kähler magnetic monopole flux defines the TGD counterpart of "novel" magnetic field.
2. The identification of supra phases as dark matter as $h_{eff} > h$ phases at magnetic flux quanta (tubes and sheets) implies that Cooper pairs correspond to dark fermions associated with the members of flux tube pair, which actually combine to form a closed flux tube. Also single electrons can define supraflow.
3. The Cooper pairs must be created by bosonic oscillator operators constructed from fermionic oscillator operators by bosonization. This is possible only in 1+1-dimensional situations. Thanks to the Beltrami flow the situation is effectively 1+1-dimensional. Bosonization makes it possible to identify SU(2) Kac-Moody algebra, which has an interpretation in the TGD framework.

The assumption that Cooper pairs reside at the magnetic flux quanta solves the 4 problems of standard framework mentioned by Koizumi: high-Tc SCs have two transition temperatures; electron mass m_e instead of its effective mass m_e^* appears in Thomson moment; the reversible phase transition in an external magnetic field inducing a splitting of Cooper pairs does not involve dissipation; why the erratic calculation of the Josephson frequencies in standard model neglecting the chemical potentials gives a correct result?.

The formation of the Cooper pairs appears as a condition stabilizing the space-time sheets carrying dark matter and all preferred extremals could satisfy the conditions guaranteeing integrable flow and existence of a phase factor varying along flow lines. Could supra phases exist in all scales? Could the breaking of supra phases be only due to the finite size of the space-time sheets? Could even hydrodynamic flow involve super-fluidity of some kind - perhaps based on neutrino Cooper pairs as speculated earlier?

Quantum Hall effect and Hierarchy of Planck Constants

In this chapter I try to formulate more precisely the recent TGD based view about fractional quantum Hall effect (FQHE). This view is much more realistic than the original rough scenario, which neglected the existing rather detailed understanding. The spectrum of ν, and the mechanism producing it is the same as in composite fermion approach. The new elements relate to the not so well-understood aspects of FQHE, namely charge fractionization, the emergence of braid statistics, and non-abelianity of braid statistics.

1. The starting point is composite fermion model so that the basic predictions are same. Now magnetic vortices correspond to (Kähler) magnetic flux tubes carrying unit of magnetic flux. The magnetic field inside flux tube would be created by delocalized electron at the boundary of the vortex. One can raise two questions.

   Could the boundary of the macroscopic system carrying anyonic phase have identification as a macroscopic analog of partonic 2-surface serving as a boundary between Minkowskian and Euclidian regions of space-time sheet? If so, the space-time sheet assignable to the macroscopic system in question would have Euclidian signature, and would be analogous to blackhole or to a line of generalized Feynman diagram.

Could the boundary of the vortex be identifiable a light-like boundary separating Minkowskian magnetic flux tube from the Euclidian interior of the macroscopic system and be also analogous to wormhole throat? If so, both macroscopic objects and magnetic vortices would be rather exotic geometric objects not possible in general relativity framework.

2. Taking composite model as a starting point one obtains standard predictions for the filling fractions. One should also understand charge fractionalization and fractional braiding statistics. Here the vacuum degeneracy of Kähler action suggests the explanation. Vacuum degeneracy implies that the correspondence between the normal component of the canonical momentum current and normal derivatives of embedding space coordinates is 1- to-n. These kind of branchings result in multi-furcations induced by variations of the system parameters and the scaling of external magnetic field represents one such variation.

3. At the orbits of wormhole throats, which can have even macroscopic M^4 projections, one has $1 \to n_a$ correspondence and at the space-like ends of the space-time surface at light-like boundaries of causal diamond one has $1 \to n_b$ correspondence. This implies that at partonic 2-surfaces defined as the intersections of these two kinds of 3-surfaces one has $1 \to n_a \times n_b$ correspondence. This correspondence can be described by using a local singular n-fold covering of the embedding space. Unlike in the original approach, the covering space is only a convenient auxiliary tool rather than fundamental notion.

4. The fractionalization of charge can be understood as follows. A delocalization of electron charge to the n sheets of the multi-furcation takes place and single sheet is analogous to a sheet of Riemann surface of function $z^{1/n}$ and carries fractional charge $q = e/n$, $n = n_a n_b$. Fractionalization applies also to other quantum numbers. One can have also many-electron stats of these states with several delocalized electrons: in this case one obtains more general charge fractionalization: $q = \nu e$.

5. Also the fractional braid statistics can be understood. For ordinary statistics rotations of M^4 rotate entire partonic 2-surfaces. For braid statistics rotations of M^4 (and particle exchange) induce a flow braid ends along partonic 2-surface. If the singular local covering is analogous to the Riemann surface of $z^{1/n}$, the braid rotation by $\Delta\Phi = 2\pi$, where Φ corresponds to M^4 angle, leads to a second branch of multi-furcation and one can give up the usual quantization condition for angular momentum. For the natural angle coordinate Φ of the n-branched covering $\Delta\Phi = 2/pi$ corresponds to $\Delta\Phi = n \times 2\pi$. If one identifies the sheets of multi-furcation and therefore uses Φ as angle coordinate, single valued angular momentum eigenstates become in general n-valued, angular momentum in braid statistics becomes fractional and one obtains fractional braid statistics for angular momentum.

6. How to understand the exceptional values $\nu = 5/2, 7/2$ of the filling fraction? The non-abelian braid group representations can be interpreted as higher-dimensional projective representations of permutation group: for ordinary statistics only Abelian representations are possible. It seems that the minimum number of braids is $n > 2$ from the condition of non-abelianity of braid group representations. The condition that ordinary statistics is fermionic, gives $n > 3$. The minimum value is $n = 4$ consistent with the fractional charge $e/4$.

The model introduces Z_4 valued topological quantum number characterizing flux tubes. This also makes possible non-Abelian braid statistics. The interpretation of this quantum number as a Z_4 valued momentum characterizing the four delocalized states of the flux tube at the sheets of the 4-furcation suggests itself strongly. Topology would corresponds to that of 4-fold covering space of embedding space serving as a convenient auxiliary tool. The more standard explanation is that $Z_4 = Z_2 \times Z_2$ such that Z_2:s correspond to the presence or absence of neutral Majorana fermion in the two Cooper pair like states formed by flux tubes.

What remains to be understood is the emergence of non-abelian gauge group realizing non-Abelian fractional statistics in gauge theory framework. Electroweak gauge group defined non-abelian braid group in large h_{eff} phase weak length above atomic length scale so that weak bosons and even fermion behave as effectively massless particles below scaled up weak scale. TGD also predicts the possibility of dynamical gauge groups and maybe this kind of gauge group indeed emerges. Dynamical gauge groups emerge also for stacks of N branes and the n sheets of multifurcation are analogous to the N sheets in the stack for many-electron states.

TGD and Quantum Hydrodynamics

The purpose of this article is to consider possible applications of Topological Geometrodynamics (TGD) to hydrodynamics. The basic question is what quantum hydrodynamics could mean in the TGD framework.

The mathematical structure of TGD is essentially that of hydrodynamics in the sense that field equations reduce to conservation laws for the charges associated with the isometries of $H = M^4 \times CP_2$.

Hydrodynamical turbulence represents one of the unsolved problems of physics and therefore as an excellent test bench for the TGD based vision. How turbulence is generated and how it decays? What is the role of vortices and their reconnections? These are the basic questions. The central notion of the TGD based model is that of a magnetic body (MB) carrying dark $h_{eff} = nh_0$ phases and controlling ordinary matter. Z^0 magnetic field is proportional to the circulation in the proposed model and electroweak symmetry restoration below scaled up weak Compton length is in an essential role. This picture is applied to several problems including also the problems related to the magnetic reconnection rate and to the survival of magnetic fields in even cosmic scales. Monopole flux tubes provide the solution here.

The hydrodynamic quantum analogs is a fascinating field and TGD picture is applied to this case. The basic prediction is that the Faraday wave length playing the role of Compton wavelength corresponds to the gravitational Compton length predicted by the generalization of the Nottale hypothesis. The value is very near to the minimal value predicted by TGD.

In the TGD framework it might be possible to understand viscosity in terms of dark angular momentum unit $\hbar_{eff}$. A proposal which allows us to understand the critical values of Reynolds numbers for the generation of turbulence in terms of the gravitational Compton lengths associated with Sun and Earth is made. Also this success supports the view that new quantum theory provided by TGD is needed in order to understand the generation of turbulence.

The universality of QHD according to TGD motivates the proposal for an application to hadron and nuclear physics. The general description of quantum tunnelling could be in terms of ZEO involving two BSFRs and therefore temporary time reversal at the MB of the system of colliding particles. Quantum hydrodynamics and large values of h_{eff} would be involved with this period. A model of "cold fusion" is one practical application.

TGD Inspired Model for Freezing in Nano Scales

Freezing is a phase transition, which challenges the existing view of condensed matter in nanoscales. In the TGD framework, quantum coherence is possible in all scales and gravitational quantum coherence should characterize hydrodynamics in astrophysical and even shorter scales. The hydrodynamics at the surface of the planet such as Earth the mass of the planet and even that of the Sun should characterize gravitational Planck constant h_{gr} assignable to gravitational flux tubes mediating gravitational interactions. In this framework, quantum criticality involving $h_{eff} = nh_0 > h$ phases of ordinary matter located at the magnetic body (MB) and possibly controlling ordinary matter, could be behind the criticality of also ordinary phase transitions.

In this article, a model inspired by the finding that the water-air boundary involves an ice-like layer. The proposal is that also at criticality for the freezing a similar layer exists and makes possible fluctuations of the size and shape of the ice blob. At criticality the change of the Gibbs free energy for water would be opposite that for ice and the Gibbs free energy liberated in the formation of ice layer would transform to the energy of surface tension at water-ice layer.

This leads to a geometric model for the freezing phase transition involving only the surface energy proportional to the area of the water-ice boundary and the constraint term fixing the volume of water. The partial differential equations for the boundary surface are derived and discussed.

If $\Delta P = 0$ at the critical for the two phases at the boundary layer, the boundary consists of portions, which are minimal surfaces analogous to soap films and conformal invariance characterizing 2-D critical systems is obtained. Clearly, 3-D criticality reduces to rather well-understood 2-D criticality. For $\Delta P \neq 0$, conformal invariance is lost and analogs of soap bubbles are obtained.

In the TGD framework, the generalization of the model to describe freezing as a dynamical time evolution of the solid-liquid boundary is suggestive. An interesting question is whether this boundary could be a light-like 3-surface in $M^4 \times CP_2$ and thus have a vanishing 3-volume. A huge extension of ordinary conformal symmetries would emerge.

The Recent View about TGD and Applications to Condensed Matter

Condensed matter physics is under rapid evolution, and one might even speak of revolution. New exotic states of matter are discovered and their theoretical understanding in the existing theoretical framework is highly challenging. The findings challenge the existing reductionistic framework and it is quite possible that new physics is required. This motivates the question whether the new physics provided by TGD could provide some understanding.

The purpose of this article is to give a rough overall view about Topological Geometrodynamics (TGD) and to consider possible applications of TGD to condensed matter physics. The preparation of this article led to considerable progress in several aspects of TGD.

1. The mutual entanglement of fermions (bosons) as elementary particles is always maximal so that only fermionic and bosonic degrees can entangle in QFTs. The replacement of point-like particles with 3-surfaces forces us to reconsider the notion of identical particles from the category theoretical point of view. The number theoretic definition of particle identity seems to be the most natural and implies that the new degrees of freedom make possible geometric entanglement.

   Also the notion particle generalizes: also many-particle states can be regarded as particles with the constraint that the operators creating and annihilating them satisfy commutation/anticommutation relations. This leads to a close analogy with the notion of infinite prime.

2. The understanding of the details of the M^8-H duality forces us to modify the earlier view. The notion of causal diamond (CD) central to zero energy ontology (ZEO) emerges as a prediction at the level of H. The pre-image of CD at the level of M^8 is a region bounded by two mass shells rather than CD. M^8-H duality maps the points of cognitive representations as momenta of quarks with fixed mass in M^8 to either boundary of CD in H. Mass shell (its positive and negative energy parts) is mapped to a light-like boundary of CD with size $T=h_{eff}/m$, m the mass associated with momentum. This understanding of is crucial for the understanding of condensed matter physics since the 4-surfaces in M^8 are analogous to Fermi balls of condensed matter physics.

3. Galois confinement at the level of M^8 is understood at the level of momentum space and is found to be necessary. Galois confinement implies that quark momenta in suitable units are algebraic integers but integers for Galois singlet just as in ordinary quantization for a particle in a box replaced by CD. Galois confinement could provide a universal mechanism for the formation of all bound states, and is bound to have profound implications for condensed matter physics.

4. There is considerable progress in the understanding of the quantum measurement theory based on ZEO. From the point of view of cognition, BSFRs would be like heureka moments and the sequence of SSFRs would correspond to an analysis having as a correlate the decay of 3-surface to smaller 3-surfaces.

After a summary of TGD as it is now, the basic notions of condensed matter physics are discussed from the TGD point view, some concrete problems of condensed matter are considered, and some tests are proposed.

A Possible Explanation of Shnoll Effect

Shnoll and collaborators have discovered strange repeating patterns of random fluctuations of physical observables such as the number n of nuclear decays in a given time interval. Periodically occurring peaks for the distribution of the number $N(n)$ of measurements producing n events in a series of measurements as a function of n is observed instead of a single peak. The positions of the peaks are not random and the patterns depend on position and time varying periodically in time scales possibly assignable to Earth-Sun and Earth-Moon gravitational interaction.

These observations suggest a modification of the expected probability distributions but it is very difficult to imagine any physical mechanism in the standard physics framework. Rather, a universal deformation of predicted probability distributions could be in question requiring something analogous to the transition from classical physics to quantum physics.

TGD gives hints about the nature of the modification.

1. TGD inspired quantum measurement theory proposes a description of the notion of finite measurement resolution in terms of inclusions of so called hyper-finite factors of type II_1 (HFFs) and closely related quantum groups parameterized by quantum phase $q_m = exp(i\pi/m)$. Canonical identification mapping p-adic integers to to their real counterparts is central element of TGD. For $m = p$ one can consider also the quantum variant of p-adic integer n mapped to n_R by canonical identification. There are 2 candidates for quantum-p-adics depending on whether the pinary digits are interpreted as quantum integers as such or mapped to a product of quantum counterparts of their prime factors.
2. Adelic physics provides a possible unification of real number based physics as physics of sensory experience and various p-adics physics as physics of cognition and predicts a hierarchy of Planck constants $h_{eff} = nh_0$ and suggests the identification of preferred p-adic prime p as a ramified prime of extension of rationals associated with the adele.

p-Adicization or perhaps even quantum-padicization could explain the findings of Shnoll.

1. The universality of the modified distribution $P(n)$ would reduce to the interpretation of the integer n in the distribution $P(n|\lambda)$ of counts as a p-adic integer or its counterpart mapped by canonical identification to a real number n_R appearing as argument of $P(n|\lambda)$. Same can be applied to $n!$. The fractality implied by the quantum criticality of TGD Universe suggests that $P(n)$ should be approximately scaling invariant under $n \to p^k n$.
2. TGD can be regarded formally as complex square root of thermodynamics, which suggest the representation $P(n) = |\Psi(n)|^2$, where $\Psi(n)$ would be wave function in the space of counts expressible as product of classical part and "quantum factor". One could have wave functions in the space of counts n expressible as superpositions of "plane waves" q_m^{kn}, with k playing the role of momentum.

   A more concrete model relies on wave function proportional to $(kn)_{q_p} \propto q_m^{kn} + q_m^{-kn}$ - analog to a superposition of plane waves with momenta k propagating to opposite directions in the space of counts reduced effectively to a box $0 \leq n < p = m$ representing modulo p counter. One would have effectively wave functions in finite field G_p. The symmetries of quantum factor would correspond to a multiplication or shift of k by element r of F_p.

   Various additional rational-valued parameters characterizing the probability distribution can be mapped to (possibly quantum-) p-adics mapped to reals by canonical identification. The parameters taking care of the converge such as the parameter λ in Poisson distribution must be mapped to a power of p in p-adic context.

The model can be applied to explain the findings of Shnoll.

1. The model makes rather detailed predictions about the periodically occurring positions of the peaks of $P(n)$ as function of p based on number theoretical considerations and in principle allows to determine these parameters for given distribution. There is p-periodicity due to the fact that the lowest pinary digit of n_R gives first approximation to n_R.
2. The slow variation of the p-adic prime p and integer $m = p$ characterizing quantum integers could explain the slow variation of the distributions with position and time. The periodic variations occurring with both solar and sidereal periods could be understood in two manners.

   The value of p could be characterized by the sum a_{net} of gravitational accelerations assignable to Earth-Sun and Earth-Moon systems and could vary. If the value of p is outcome of state function process, it is not determined by deterministic dynamics but should have a distribution. If this distribution is peaked around one particular value, one can understand the findings of Shnoll.
3. An alternative explanation would be based on slow dependence of quantum factor of $\Psi(n)$ on gravitational parameters and on time. For instance, the momentum k defining the standing wave in the space of counts modulo p could change so that the peaks of the diffraction pattern would be permuted.

Part I

P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: PARTICLE AND NUCLEAR PHYSICS

Chapter 2

Recent Status of Lepto-Hadron Hypothesis

2.1 Introduction

TGD suggest strongly ("predicts" is perhaps too strong expression) the existence of color excited leptons. The mass calculations based on p-adic thermodynamics and p-adic conformal invariance lead to a rather detailed picture about color excited leptons.

1. The simplest color excited neutrinos and charged leptons belong to the color octets ν_8 and L_{10} and $L_{\overline{10}}$ decouplet representations respectively and lepto-hadrons are formed as the color singlet bound states of these and possible other representations. Electro-weak symmetry suggests strongly that the minimal representation content is octet and decouplets for both neutrinos and charged leptons.
2. The basic mass scale for lepto-hadron physics is completely fixed by p-adic length scale hypothesis. The first guess is that color excited leptons have the levels $k = 127, 113, 107, ...$ ($p \simeq 2^k$, k prime or power of prime) associated with charged leptons as primary condensation levels. p-Adic length scale hypothesis allows however also the level $k = 11^2 = 121$ in case of electronic lepto-hadrons. Thus both $k = 127$ and $k = 121$ must be considered as a candidate for the level associated with the observed lepto-hadrons. If also lepto-hadrons correspond non-perturbatively to exotic Super Virasoro representations, lepto-pion mass relates to pion mass by the scaling factor $L(107)/L(k) = k^{(107-k)/2}$. For $k = 121$ one has $m_{\pi_L} \simeq 1.057$ MeV which compares favorably with the mass $m_{\pi_L} \simeq 1.062$ MeV of the lowest observed state: thus $k = 121$ is the best candidate contrary to the earlier beliefs. The mass spectrum of lepto-hadrons is expected to have same general characteristics as hadronic mass spectrum and a satisfactory description should be based on string tension concept. Regge slope is predicted to be of order $\alpha' \simeq 1.02/MeV^2$ for $k = 121$. The masses of ground state lepto-hadrons are calculable once primary condensation levels for colored leptons and the CKM matrix describing the mixing of color excited lepton families is known.

The strongest counter arguments against color excited leptons are the following ones.

1. The decay widths of Z^0 and W boson allow only $N = 3$ light particles with neutrino quantum numbers. The introduction of new light elementary particles seems to make the decay widths of Z^0 and W intolerably large.
2. Lepto-hadrons should have been seen in e^+e^- scattering at energies above few MeV. In particular, lepto-hadronic counterparts of hadron jets should have been observed.

A possible resolution of these problems is provided by the loss of asymptotic freedom in lepto-hadron physics. Lepto-hadron physics would effectively exist in a rather limited energy range about one MeV.

The development of the ideas about dark matter hierarchy [**?**, K103, K42, K40] led however to a much more elegant solution of the problem.

1. TGD predicts an infinite hierarchy of various kinds of dark matters which in particular means a hierarchy of color and electro-weak physics with weak mass scales labelled by appropriate p-adic primes different from M_{89}: the simplest option is that also ordinary photons and gluons are labelled by M_{89}.
2. There are number theoretical selection rules telling which particles can interact with each other. The assignment of a collection of primes to elementary particle as characterizer of p-adic primes characterizing the particles coupling directly to it, is inspired by the notion of infinite primes [K105]. and discussed in [**?**]. Only particles characterized by integers having common prime factors can interact by the exchange of elementary bosons: the p-adic length scale of boson corresponds to a common primes.
3. Also the physics characterized by different values of $\hbar$ are dark with respect to each other as far quantum coherent gauge interactions are considered. Laser beams might well correspond to photons characterized by p-adic prime different from M_{89} and de-coherence for the beam would mean decay to ordinary photons. De-coherence interaction involves scaling down of the Compton length characterizing the size of the space-time of particle implying that particles do not anymore overlap so that macroscopic quantum coherence is lost.
4. Those dark physics which are dark relative to each other can interact only via graviton exchange. If lepto-hadrons correspond to a physics for which weak bosons correspond to a p-adic prime different from M_{89}, intermediate gauge bosons cannot have direct decays to colored excitations of leptons irrespective of whether the QCD in question is asymptotically free or not. Neither are there direct interactions between the QED:s and QCD:s in question if M_{89} characterizes also ordinary photons and gluons. These ideas are discussed and applied in detail in [**?**, K103, K42].

Skeptic reader might stop the reading after these counter arguments unless there were definite experimental evidence supporting the lepto-hadron hypothesis.

1. The production of anomalous e^+e^- pairs in heavy ion collisions (energies just above the Coulomb barrier) suggests the existence of pseudo-scalar particles decaying to e^+e^- pairs. A natural identification is as lepto-pions that is bound states of color octet excitations of e^+ and e^-.
2. The second puzzle, Karmen anomaly, is quite recent [C53]. It has been found that in charge pion decay the distribution for the number of neutrinos accompanying muon in decay $\pi \rightarrow \mu+\nu_\mu$ as a function of time seems to have a small shoulder at $t_0 \sim ms$. A possible explanation is the decay of charged pion to muon plus some new weakly interacting particle with mass of order 30 MeV [C24] : the production and decay of this particle would proceed via mixing with muon neutrino. TGD suggests the identification of this state as color singlet leptobaryon of, say type $L_B = f_{abc}L_8^aL_8^b\bar{L}_8^c$, having electro-weak quantum numbers of neutrino.
3. The third puzzle is the anomalously high decay rate of orto-positronium. [C96]. e^+e^- annihilation to virtual photon followed by the decay to real photon plus virtual lepto-pion followed by the decay of the virtual lepto-pion to real photon pair, $\pi_L\gamma\gamma$ coupling being determined by axial anomaly, provides a possible explanation of the puzzle.
4. There exists also evidence for anomalously large production of low energy e^+e^- pairs [C52, C72, C58, C141] in hadronic collisions, which might be basically due to the production of lepto-hadrons via the decay of virtual photons to colored leptons.

In this chapter a revised form of lepto-hadron hypothesis is described.

1. Sigma model realization of PCAC hypothesis allows to determine the decay widths of lepto-pion and lepto-sigma to photon pairs and e^+e^- pairs. Ortopositronium anomaly determines the value of $f(\pi_L)$ and therefore the value of lepto-pion-lepto-nucleon coupling and the decay rate of lepto-pion to two photons. Various decay widths are in accordance with the experimental data and corrections to electro-weak decay rates of neutron and muon are small.
2. One can consider several alternative interpretations for the resonances.

   Option 1: For the minimal color representation content, three lepto-pions are predicted corresponding to $8, 10, \overline{10}$ representations of the color group. If the lightest lepto-nucleons e_{ex} have masses only slightly larger than electron mass, the anomalous e^+e^- could be actually

$e^+_{ex} + e^-_{ex}$ pairs produced in the decays of lepto-pions. One could identify 1.062, 1.63 and 1.77 MeV states as the three lepto-pions corresponding to $8, 10, \overline{10}$ representations and also understand why the latter two resonances have nearly degenerate masses. Since d and s quarks have same primary condensation level and same weak quantum numbers as colored e and μ, one might argue that also colored e and μ correspond to $k = 121$. From the mass ratio of the colored e and μ, as predicted by TGD, the mass of the muonic lepto-pion should be about 1.8 MeV in the absence of topological mixing. This suggests that 1.83 MeV state corresponds to the lightest $g = 1$ lepto-pion.

Option 2: If one believes sigma model (in ordinary hadron physics the existence of sigma meson is not established and its width is certainly very large if it exists), then lepto-pions are accompanied by sigma scalars. If lepto-sigmas decay dominantly to e^+e^- pairs (this might be forced by kinematics) then one could adopt the previous scenario and could identify 1.062 state as lepto-pion and 1.63, 1.77 and 1.83 MeV states as lepto-sigmas rather than lepto-pions. The fact that muonic lepto-pion should have mass about 1.8 MeV in the absence of topological mixing, suggests that the masses of lepto-sigma and lepto-pion should be rather close to each other.

Option 3: One could also interpret the resonances as string model "satellite states" having interpretation as radial excitations of the ground state lepto-pion and lepto-sigma. This identification is not however so plausible as the genuinely TGD based identification and will not be discussed in the sequel.

3. PCAC hypothesis and sigma model leads to a general model for lepto-hadron production in the electromagnetic fields of the colliding nuclei and production rates for lepto-pion and other lepto-hadrons are closely related to the Fourier transform of the instanton density $\bar{E} \cdot \bar{B}$ of the electromagnetic field created by nuclei. The first source of anomalous e^+e^- pairs is the production of $\sigma_L \pi_L$ pairs from vacuum followed by $\sigma_L \rightarrow e^+e^-$ decay. If $e^+_{ex}e^-_{ex}$ pairs rather than genuine e^+e^- pairs are in question, the production is production of lepto-pions from vacuum followed by lepto-pion decay to lepto-nucleon pair.

   Option 1: For the production of lepto-nucleon pairs the cross section is only slightly below the experimental upper bound for the production of the anomalous e^+e^- pairs and the decay rate of lepto-pion to lepto-nucleon pair is of correct order of magnitude.

   Option 2: The rough order of magnitude estimate for the production cross section of anomalous e^+e^- pairs via $\sigma_l \pi_l$ pair creation followed by $\sigma_L \rightarrow e^+e^-$ decay, is by a factor of order $1/\sum N_c^2$ (N_c is the total number of states for a given colour representation and sum over the representations contributing to the ortopositronium anomaly appears) smaller than the reported cross section in case of 1.8 MeV resonance. The discrepancy could be due to the neglect of the large radiative corrections (the coupling $g(\pi_L \pi_L \sigma_L) = g(\sigma_L \sigma_L \sigma_L)$ is very large) and also due to the uncertainties in the value of the measured cross section.

   Given the unclear status of sigma in hadron physics, one has a temptation to conclude that anomalous e^+e^- pairs actually correspond to lepto-nucleon pairs.

4. The vision about dark matter suggests that direct couplings between leptons and lepto-hadrons are absent in which case no new effects in the direct interactions of ordinary leptons are predicted. If colored leptons couple directly to ordinary leptons, several new physics effects such as resonances in photon-photon scattering at cm energy equal to lepto-pion masses and the production of $e_{ex}\bar{e}_{ex}$ (e_{ex} is leptobaryon with quantum numbers of electron) and $e_{ex}\bar{e}$ pairs in heavy ion collisions, are possible. Lepto-pion exchange would give dominating contribution to $\nu - e$ and $\bar{\nu} - e$ scattering at low energies. Lepto-hadron jets should be observed in e^+e^- annihilation at energies above few MeV:s unless the loss of asymptotic freedom restricts lepto-hadronic physics to a very narrow energy range and perhaps to entirely non-perturbative regime of lepto-hadronic QCD.

This chapter is a revised version of the earlier chapterand still a work in progress. I apologize for the reader for possible inconvenience. The motivation for the re-writing came from the evidence for the production of τ-pions in high energy proton-antiproton collisions [C34]. Since the kinematics of these collisions differs dramatically from that for heavy ion collisions, a critical re-examination of the earlier model - which had admittedly somewhat ad hoc character- became necessary. As a consequence the earlier model simplified dramatically. As far as basic calculations are considered, the modification makes itself visible only at the level of coefficients. Even more remarkably, it turned out possible to calculate exactly the lepto-pion production amplitude under a very natural approximation, which can be also generalized so that the calculation of production amplitude can be made analytically in high accuracy and only the integration over lepto-pion momentum must be carried out numerically. As a consequence, a rough analytic estimate for the production cross section follows and turns out to be of correct order of magnitude. It must be however stressed that the cross section is highly sensitive to the value of the cutoff parameter (at least in this naive estimate) and only a precise calculation can settle the situation.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

2.2 Lepto-Hadron Hypothesis

2.2.1 Anomalous E^+E^- Pairs In Heavy Ion Collisions

Heavy ion collision experiments carried out at the Gesellschaft fur Schwerionenforschung in Darmstadt, West Germany [C87, C61, C62, C92] have yielded a rather puzzling set of results. The expectation was that in heavy ion collisions in which the combined charge of the two colliding ions exceeds 173, a composite nucleus with $Z > Z_{cr}$ would form and the probability for spontaneous positron emission would become appreciable.

Indeed, narrow peaks of widths of roughly 50-70 keV and energies about 350± 50 keV were observed in the positron spectra but it turned out that the position of the peaks seems to be a constant function of Z rather that vary as Z^{20} as expected and that peaks are generated also for Z smaller than the critical Z. The collision energies at which peaks occur lie in the neighborhood of 5.7-6 MeV/nucleon. Also it was found that positrons are accompanied by e^-- emission. Data are consistent with the assumption that some structure at rest in cm is formed and decays subsequently to e^+e^- pair.

Various theoretical explanations for these peaks have been suggested [C18, C121]. For example, lines might be created by pair conversion in the presence of heavy nuclei. In nuclear physics explanations the lines are due to some nuclear transition that occurs in the compound nucleus formed in the collision or in the fragmets formed. The Z-independence of the peaks seems however to exclude both atomic and nuclear physics explanations [C18]. Elementary particle physics explanations [C18, C121] seem to be excluded already by the fact that several peaks have been observed in the range $1.6 - 1.8\ MeV$ with widths of order $10^1 - 10^2\ keV$. These states decay to e^+e^- pairs. There is evidence for one narrow peak with width of order one keV at 1.062 Mev [C18]: this state decays to photon-photon pairs.

Thus it seems that the structures produced might be composite, perhaps resonances in e^+e^- system. The difficulty of this explanation is that conventional QED seems to offer no natural explanation for the strong force needed to explain the energy scale of the states. One idea is that the strong electromagnetic fields create a new phase of QED [C18] and that the resonances are analogous to pseudo-scalar mesons appearing as resonances in strongly interacting systems.

TGD based explanation relies on the following hypothesis motivated by Topological Geometrodynamics.

1. Ordinary leptons are not point like particles and can have colored excitations, which form color singlet bound states. A natural identification for the primary condensate level is $k = 121$ so that the mass scale is of order one MeV for the states containing lowest generation colored leptons. The fact that d and s quarks, having the same weak quantum numbers as charged leptons, have same primary condensation level, suggests that both colored electron and muon condense to the same level. The expectation that lepto-hadron physics exists in a narrow energy interval only, suggests that also colored τ should condense on the same level.

2. The states in question are lepto-hadrons, that is color confined states formed from the colored excitations of e^+ and e^-. The decay rate to lepto-nucleon pairs $e^+_{ex}e^-_{ex}$ is large and turns out to give rise to correct order of magnitude for the decay width. Hence two options emerge.

   Option 1: Lepto-nucleons e_{ex} have masses only slightly above the electron mass and since they behave like electrons, anomalous e^+e^- pairs could actually correspond to lepto-nucleon pairs created in the decays of lepto-pions. 1.062, 1.63 and 1.77 MeV states can be identified as lowest generation lepto-pions correspond to octet and two decouplets. 1.83 MeV state could be identified as the second generation lepto-pion corresponding to colored muon. The small branching fraction to gamma pairs explains why the decays of the higher mass lepto-pions to gamma pairs has not been observed. $g = 0$ lepto-pion decays to lepto-nucleon pairs can be visualized as occurring via dual diagrams obeying Zweig's rule (annihilation is not allowed inside incoming or outgoing particle states). The decay of $g = 1$ colored muon pair occurs via Zweig rule violating annihilation to two gluon intermediate state, which transforms back to virtual $g = 0$ colored electron pair decaying via dual diagram: the violation of Zweig's rule suggests that the decay rate for 1.8 MeV state is smaller than for the lighter states. Quantitive model shows that this scenario is the most plausible one.

Option 2: Lepto-sigmas, which are the scalar partners of lepto-pions predicted by sigma model, are the source of anomalous (and genuine) e^+e^- pairs. In this case 1.062 state must correspond to lepto-pion whereas higher states must be identified as lepto-sigmas. Also now new lepto-pion states decaying to gamma pairs are predicted and one could hence argue that this prediction is not consistent with what has been observed. A crucial assumption is that lepto-sigmas are light and cannot decay to other lepto-mesons. Ordinary hadronic physics suggests that this need not be the case: the hadronic decay width of the ordinary sigma, if it exists, is very large.

The program of the section is following:

1. PCAC hypothesis, successful in low energy pion physics, is generalized to the case of lepto-pion. Hypothesis allows to deduce the coupling of lepto-pion to leptons and lepto-baryons in terms of leptobaryon-lepton mixing angles. Ortopositronium anomaly allows to deduce precise value of $f(\pi_L)$ characterizing the decay rate of lepto-pion so that the crucial parameters of the model are completely fixed. The decay rates of lepto-pion to photon pair and of lepto-sigma to ordinary e^+e^- pairs are within experimental bounds and corrections to muon and beta decay rates are small. New calculable resonance contributions to photon-photon scattering at cm energy equal to lepto-pion masses are predicted.

2. If anomalous e^+e^- pairs are actually lepto-nucleon pairs, only a model for the creation of lepto-pions from vacuum is needed. In an external electromagnetic field lepto-pion develops a vacuum expectation value proportional to electromagnetic anomaly term [B22] so that the production amplitude for the lepto-pion is essentially the Fourier transform of the scalar product of the electric field of the stationary target nucleus with the magnetic field of the colliding nucleus.

3. If anomalous e^+e^- pairs are produced in the decays of lepto-sigmas, the starting point is sigma model providing a realization of PCAC hypothesis. Sigma model makes it possible to relate the production amplitude for $\sigma_L\pi_L$ pairs to the lepto-pion production amplitude: the key element of the model is the large value of the $\sigma\pi_L\pi_L$ coupling constant.

4. Lepto-hadron production amplitudes are proportional to lepto-pion production amplitude and this motivates a detailed study of lepto-pion production. Two models for lepto-pion production are developed: in classical model colliding nucleus is treated classically whereas in quantum model the colliding nucleus is described quantum mechanically. It turns out that classical model explains the peculiar production characteristics of lepto-pion but that production cross section is too small by several orders of magnitude. Quantum mechanical model predicts also diffractive effects: production cross section varies rapidly as a function of the scattering angle and for a fixed value of scattering angle there is a rapid variation with the collision velocity. The estimate for the total lepto-pion production cross section increases by several orders of magnitude due to the coherent summation of the contributions to the amplitude from different values of the impact parameter at the peak.

5. The production rate for lepto-nucleon pairs is only slightly smaller than the experimental upper bound but the e^+e- production rate predicted by sigma model approach is still by a factor of order $1/\sum N_c^2$ smaller than the reported maximum cross section. A possible explanation for this discrepancy is the huge value of the coupling $g(\pi_L,\pi_L,\sigma_L) = g(\sigma_L,\sigma_L,\sigma_L)$ implying that the diagram involving the exchange of virtual sigma can give the dominant contribution to the production cross section of $\sigma_L\pi_L$ pair.

2.2.2 Lepto-Pions And Generalized PCAC Hypothesis

One can say that the PCAC hypothesis predicts the existence of pions and a connection between the pion nucleon coupling strength and the pion decay rate to leptons. In the following we give the PCAC argument and its generalization and consider various consequences.

PCAC for ordinary pions

The PCAC argument for ordinary pions goes as follows [B27] :

1. Consider the contribution of the hadronic axial current to the matrix element describing lepton nucleon scattering (say $N+\nu \rightarrow P+e^-$) by weak interactions. The contribution in question reduces to the well-known current-current form

$$\begin{aligned} M &= \frac{G_F}{\sqrt{2}} g_A L_\alpha \langle P|A^\alpha|P\rangle \ , \\ L_\alpha &= \bar{e}\gamma_\alpha(1+\gamma_5)\nu \ , \\ \langle P|A^\alpha|P\rangle &= \bar{P}\gamma^\alpha N \ , \end{aligned} \tag{2.2.1}$$

where $G_F = \frac{\pi\alpha}{2m_W^2 sin^2(\theta_W)} \simeq 10^{-5}/m_p^2$ denotes the dimensional weak interaction coupling strength and g_A is the nucleon axial form factor: $g_A \simeq 1.253$.

2. The matrix element of the hadronic axial current is not divergenceless, due to the non-vanishing nucleon mass,

$$a_\alpha \langle P|A^\alpha|P\rangle \simeq 2m_p\bar{P}\gamma_5 N \ . \tag{2.2.2}$$

Here q^α denotes the momentum transfer vector. In order to obtain divergenceless current, one can modify the expression for the matrix element of the axial current

$$\langle P|A^\alpha|N\rangle \rightarrow \langle P|A^\alpha|N\rangle - q^\alpha 2m_p\bar{P}\gamma_5 N\frac{1}{q^2} \ . \tag{2.2.3}$$

3. The modification introduces a new term to the lepton-hadron scattering amplitude identifiable as an exchange of a massless pseudo-scalar particle

$$\delta T = \frac{G_F g_A}{\sqrt{2}} L_\alpha \frac{2m_p q^\alpha}{q^2}\bar{P}\gamma_5 N \ . \tag{2.2.4}$$

The amplitude is identifiable as the amplitude describing the exchange of the pion, which gets its mass via the breaking of chiral invariance and one obtains by the straightforward replacement $q^2 \rightarrow q^2 - m_\pi^2$ the correct form of the amplitude.

4. The nontrivial point is that the interpretations as pion exchange is indeed possible since the amplitude obtained is to a good approximation identical to that obtained from the Feynman diagram describing pion exchange, where the pion nucleon coupling constant and pion decay amplitude appear

$$T_2 = \frac{G}{\sqrt{2}} f_\pi q^\alpha L_\alpha \frac{1}{q^2-m_\pi^2} g\sqrt{2}\bar{P}\gamma_5 N \ . \tag{2.2.5}$$

The condition $\delta T \sim T_2$ gives from Goldberger-Treiman [B27]

$$g_A(\simeq 1.25) = \sqrt{2}\frac{f_\pi g}{2m_p}(\simeq 1.3) \ , \tag{2.2.6}$$

satisfied in a good accuracy experimentally.

PCAC in leptonic sector

A natural question is why not generalize the previous argument to the leptonic sector and look at what one obtains. The generalization is based on following general picture.

1. There are two levels to be considered: the level of ordinary leptons and the level of leptobaryons of, say type $f_{ABC}\nu_8^A\nu_8^B\bar{L}_{10}^C$, possessing same quantum numbers as leptons. The interaction transforming these states to each other causes in mass eigenstates mixing of leptobaryons with ordinary leptons described by mixing angles. The masses of lepton and corresponding leptobaryon could be quite near to each other and in case of electron this should be the case as it turns out.
2. A counterargument against the applications of PCAC hypothesis at level of ordinary leptons is that baryons and mesons are both bound states of quarks whereas ordinary leptons are not bound states of colored leptons. The divergence of the axial current is however completely independent of the possible internal structure of leptons and microscopic emission mechanism. Ordinary lepton cannot emit lepto-pion directly but must first transform to leptobaryon with same quantum numbers: phenomenologically this process can be described using mixing angle $sin(\theta_B)$. The emission of lepto-pion proceeds as $L \rightarrow B_L$: $B_L \rightarrow B_L + \pi_L$: $B_L \rightarrow L$, where B_L denotes leptobaryon of type structure $f_{ABC}L_8^AL_8^B\bar{L}_8^C$. The transformation amplitude $L \rightarrow B_L$ is proportional to the mixing angle $sin(\theta_L)$.

Three different PCAC type identities are assumed to hold true:

PCAC1) The vertex for the emission of lepto-pion by ordinary lepton is equivalent with the graph in which lepton L transforms to leptobaryon L^{ex} with same quantum numbers, emits lepto-pion and transforms back to ordinary lepton. The assumption relates the couplings $g(L_1, L_2)$ and $g(L_1^{ex}, L_2^{ex})$ (analogous to strong coupling) and mixing angles to each other

$$g(L_1, L_2) = g(L_1^{ex}, L_2^{ex})sin(\theta_1)sin(\theta_2) \ . \tag{2.2.7}$$

The condition implies that in electro-weak interactions ordinary leptons do not transform to their exotic counterparts.

PCAC2) The generalization of the ordinary Goldberger-Treiman argument holds true, when ordinary baryons are replaced with leptobaryons. This gives the condition expressing the coupling $f(\pi_L)$ of the lepto-pion state to axial current defined as

$$\langle vac|A_\alpha|\pi_L\rangle = ip_\alpha f(\pi_L) \ , \tag{2.2.8}$$

in terms of the masses of leptobaryons and strong coupling g.

$$f(\pi_L) = \sqrt{2}g_A\frac{(m_{ex}(1) + m_{ex}(2))sin(\theta_1)sin(\theta_2)}{g(L_1, L_2)} \ , \tag{2.2.9}$$

where g_A is parameter characterizing the deviation of weak coupling strength associated with leptobaryon from ideal value: $g_A \sim 1$ holds true in good approximation.

PCAC3) The elimination of leptonic axial anomaly from leptonic current fixes the values of $g(L_i, L_j)$.

1. The standard contribution to the scattering of leptons by weak interactions given by the expression

$$\begin{aligned} T &= \frac{G_F}{\sqrt{2}}\langle L_1|A^\alpha|L_2\rangle\langle L_3|A_\alpha|L_4\rangle \ , \\ \langle L_i|A^\alpha|L_j\rangle &= \bar{L}_i\gamma^\alpha\gamma_5L_j \ . \end{aligned} \tag{2.2.10}$$

2. The elimination of the leptonic axial anomaly

$$q_\alpha \langle L_i|A^\alpha|L_j\rangle = (m(L_i)+m(L_j))\bar{L}_i\gamma_5 L_j \ , \quad (2.2.11)$$

by modifying the axial current by the anomaly term

$$\langle L_i|A^\alpha|L_j\rangle \rightarrow \langle L_i|A^\alpha|L_j\rangle - (m(L_i)+m(L_j))\frac{q^\alpha}{q^2}\bar{L}_i\gamma_5 L_j \ , \quad (2.2.12)$$

induces a new interaction term in the scattering of ordinary leptons.

3. It is assumed that this term is equivalent with the exchange of lepto-pion. This fixes the value of the coupling constant $g(L_1, L_2)$ to

$$\begin{aligned} g(L_1,L_2) &= 2^{1/4}\sqrt{G_F}(m(L_1)+m(L_2))\xi \ , \\ \xi(charged) &= 1 \ , \\ \xi(neutral) &= cos(\theta_W) \ . \end{aligned} \quad (2.2.13)$$

Here the coefficient ξ is related to different values of masses for gauge bosons W and Z appearing in charged and neutral current interactions. An important factor 2 comes from the modification of the axial current in both matrix elements of the axial current.

Lepto-pion exchange interaction couples right and left handed leptons to each other and its strength is of the same order of magnitude as the strength of the ordinary weak interaction at energies not considerably large than the mass of the lepto-pion. At high energies this interaction is negligible and the existence of the lepto-pion predicts no corrections to the parameters of the standard model since these are determined from weak interactions at much higher energies. If lepto-pion mass is sufficiently small (as found, $m(\pi_L) < 2m_e$ is allowed by the experimental data), the interaction mediated by lepto-pion exchange can become quite strong due to the presence of the lepto-pion progator. The value of the lepton-lepto-pion coupling is $g(e,e) \equiv g \sim 5.6\cdot 10^{-6}$. It is perhaps worth noticing that the value of the coupling constant is of the same order as lepton-Higgs coupling constant and also proportional to the mass of the lepton.

PCAC identities fix the values of coupling constants apart from the values of mixing angles. If one assumes that the strong interaction mediated by lepto-pions is really strong and the coupling strength $g(L_{ex}, L_{ex})$ is of same order of magnitude as the ordinary pion nucleon coupling strength $g(\pi NN) \simeq 13.5$ one obtains an estimate for the value of the mixing angle $sin(\theta_e)$ $sin^2(\theta_e) \sim \frac{g(\pi NN)}{g(L,L)} \sim 2.4\cdot 10^{-6}$. This implies the order of magnitude $f(\pi_L) \sim 10^{-6} m_W \sim 10^2\ keV$ for $f(\pi_L)$. The order of magnitude is correct as will be found. Ortopositronium decay rate anomaly $\Delta\Gamma/\Gamma \sim 10^{-3}$ and the assumption $m_{ex} \geq 1.3\ MeV$ (so that $e_{ex}\bar{e}$ decay is not possible) gives the upper bound $sin(\theta_e) \leq x\cdot\sqrt{N_c}\cdot 10^{-4}$, where the value of $x \sim 1$ depends on the number of the lepto-pion type states and on the precise value of the Op anomaly.

2.2.3 Lepto-Pion Decays And PCAC Hypothesis

The PCAC argument makes it possible to predict the lepto-pion coupling and decay rates of the lepto-pion to various channels. Actually the orders of magnitude for the decay rates of the lepto-sigma and other lepto-mesons can be deduced also. The comparison with the experimental data is made difficult by the uncertainty of the identifications. The lightest candidate has mass 1.062 MeV and decay width of order 1 keV [C18]: only photon photon decay has been observed for this state. The next lepto-meson candidates are in the mass range $1.6-1.8\ MeV$. Perhaps the best status is possessed by "Darmstadtium" with mass 1.8 MeV. For these states decays to final states identified as e^+e^- pairs dominate: if indeed e^+e^- pairs, these states probably correspond to the decay products of lepto-sigma. Another possibility is that pairs are actually lepto-nucleon pairs with the mass of the lepto-nucleon only slightly larger than electron mass. Hadron physics experience suggests that the decay widths of the lepto-hadrons (lepto-pion forming a possible exception) should be about 1-10 per cent of particle mass as in hadron physics. The upper bounds for the widths are indeed in the range $50-70\ keV$ [C18].

$\Gamma(\pi_L \rightarrow \gamma\gamma)$

As in the case of the ordinary pion, anomaly considerations give the following approximate expression for the decay rate of the lepto-pion to two-photon final states [B22])

$$\Gamma(\pi_L \rightarrow \gamma\gamma) = \frac{N_c^2 \alpha^2 m^3(\pi_L)}{64 f(\pi_L)^2 \pi^3} . \tag{2.2.14}$$

$N_c = 8, 10$ is the number of the colored lepton states coming from the axial anomaly loop. For $m(\pi_L) = 1.062\ MeV$ and $f(\pi_L) = N_c \cdot 7.9\ keV$ implied by the ortopositronium decay rate anomaly $\Delta\Gamma/\Gamma = 10^{-3}$ one has $\Gamma(\gamma\gamma) = .52\ keV$, which is consistent with the experimental estimate of order 1 keV [C18].

In fact, several lepto-pion states could exist (4 at least corresponding to the resonances at 1.062, 1.63, 1.77 and 1.83 MeV). Since all these lepto-pion states contribute to Op decay rate, the actual value of $f(\pi_L)$ assumed to scale as $m(\pi_L)$, is actually larger in this case: it turns out that $f(\pi_L)$ for the lightest lepto-pion increases to $f(\pi_L)(lightest) = N_c \cdot 15\ keV$ and gives $\Gamma(\gamma\gamma) \simeq .13\ keV$ in case of the lightest lepto-pion if lepto-pions are assumed to correspond the resonances. Note that the order of magnitude for $f(\pi_L)$ is same as deduced from the assumption that lepto-hadronic counterpart of $g(\pi NN)$ equals to the ordinary $g(\pi NN)$. The increase of the ortopositronium anomaly by a factor of, say 4, implies corresponding decrease in $f(\pi_L)^2$. The value of $f(\pi_L)$ is also sensitive to the precise value of the mass of the lightest lepto-pion.

Lepto-pion-lepton coupling

The value of the lepto-pion-lepton coupling can be used to predict the decay rate of lepto-pion to leptons. One obtains for the decay rate $\pi_L^0 \rightarrow e^+e^-$ the estimate

$$\begin{aligned}
\Gamma(\pi_L \rightarrow e^+e^-) &= 4\frac{g(e,e)^2\pi}{2(2\pi)^2}(1-4x^2)m(\pi_L) \\
&= 16Gm_e^2 cos^2(\theta_W)\frac{\sqrt{2}}{4\pi}(1-4x^2)m(\pi_L) \ , \\
x &= \frac{m_e}{m(\pi_L)} \ .
\end{aligned} \tag{2.2.15}$$

for the decay rate of the lepto-pion: for lepto-pion mass $m(\pi_L) \simeq 1.062\ MeV$ one obtains for the decay rate the estimate $\Gamma \sim 1/(1.3 \cdot 10^{-8}\ sec)$: the low decay rate is partly due to the phase space suppression and implies that e^+e^- decay products cannot be observed in the measurement volume. The low decay rate is in accordance with the identification of the lepto-pion as the $m = 1.062\ MeV$ lepto-pion candidate. In sigma model lepto-pion and lepto-sigma have identical lifetimes and for lepto-sigma mass of order 1.8 MeV one obtains $\Gamma(\sigma_L \rightarrow e^+e^-) \simeq 1/(8.2 \cdot 10^{-10}\ sec)$: the prediction is larger than the lower limit $\sim 1/(10^{-9}\ sec)$ for the decay rate implied by the requirement that σ_L decays inside the measurement volume. The estimates of the lifetime obtained from heavy ion collisions [C78] give the estimate $\tau \geq 10^{-10}\ sec$. The large value of the lifetime is in accordance with the limits for the lifetime obtained from Babbha scattering [C75], which indicate that the lifetime must be longer than 10^{-12} sec.

For lepto-meson candidates with mass above 1.6 MeV no experimental evidence for other decay modes than $X \rightarrow e^+e^-$ has been found and the empirical upper limit for $\gamma\gamma/e^+e^-$ branching ratio [C65] is $\Gamma(\gamma\gamma)/\Gamma(e^+e^-) \leq 10^{-3}$. If the identification of the decay products as e^+e^- pairs is correct then the only possible conclusion is that these states cannot correspond to lepto-pion since lepto-pion should decay dominantly into photon photon pairs. Situation changes if pairs of lepton-ucleons $e_{ex}\overline{e}_{ex}$ of type $e_{ex} = e_8\nu_8\overline{\nu}_8$ pair are in question.

I realized that this conclusion might be questioned for more than decade after writing the above text as I developed a model for CDF anomaly suggesting the existence of τ-pions. Since colored leptons are color octets, anomalous magnetic moment type coupling of form $\overline{L}Tr(F^{\mu\nu}\Sigma_{\mu\nu}L_8)$ (the trace is over the Lie-algebra generators of $SU(3)$ and $F^{\mu\nu}$ denotes color gauge field) between ordinary lepton, colored lepton and lepto-gluon is possible. The exchange of a virtual lepto-gluon allows lepto-pion to decay by lepto-strong interactions to electron-positron pairs. The decay rate is limited by the kinematics for the lightest state very near to the final state mass and might make decay rate to in this case very small. If the rate for the decay to electron-positron pair is comparable to that for the decay to two photons the production rate for electron-positron pairs could be of the same order of magnitude as lepto-pion production rate. The anomalous magnetic moment of electron however poses strong limitations on this coupling and it might be that the coupling is too small. This coupling could however induce the mixing of e_{ex} with e.

$\Gamma(\pi_L \rightarrow e + \bar{\nu_e})$

The expression for the decay rate $\pi_L \rightarrow e + \bar{\nu_e}$ reads as

$$\begin{aligned}\Gamma(\pi_L^- \rightarrow e\nu_e) &= 8Gm_e^2\frac{(1-x^2)^2}{2(1+x^2)}\frac{\sqrt{2}}{(2\pi)^5}m(\pi_L) \ , \\ &= \frac{4}{cos^2(\theta_W)}\frac{(1-x^2)}{(1+x^2)(1-4x^2)}\Gamma(\pi_L^0 \rightarrow e^+e^-) \ , \end{aligned} \quad (2.2.16)$$

and gives $\Gamma(\pi_L^- \rightarrow e\nu_e) \simeq 1/(3.6\cdot 10^{-10}\ sec)$ for $m(\pi_L) = 1.062\ MeV$.

$\Gamma(\pi_L/\sigma_L \rightarrow e_{ex}\bar{e}_{ex})$ **and** $\Gamma(\pi_L/\sigma_L \rightarrow e_{ex}\bar{e})$

Sigma model predicts lepto-pion and lepto-sigma to have same coupling to lepto-nucleon e_{ex} pair so that in the sequel only lepto-pion decay rates are considered. One must consider also the possibility that lepto-pion decay products are either $e_{ex}\bar{e}_{ex}$ or $e_{ex}\bar{e}$ pairs with e_{ex} having mass of near the mass of electron so that it could be misidentified as electron. If the mass of lepto-nucleon e_{ex} with quantum numbers of electron is smaller than $m(\pi_L)/2$ it can be produced in lepto-pion annihilation. One must also assume $m(e_{ex}) > m_e$: otherwise electrons would spontaneously decay to lepto-nucleons via photon emission. The production rate to lepto-nucleon pair can be written as

$$\begin{aligned}\Gamma(\pi_L \rightarrow e_{ex}^+e_{ex}^-) &= \frac{1}{sin^4(\theta_e)}\frac{(1-4y^2)}{(1-4x^2)}\Gamma(\pi_L \rightarrow e^+e^-) \ , \\ y &= \frac{m(e_{ex})}{m(\pi_L)} \ . \end{aligned} \quad (2.2.17)$$

If $e - e_{ex}$ mass difference is sufficiently small the kinematic suppression does not differ significantly from that for e^+e^- pair. The limits from Babbha scattering give no bounds on the rate of $\pi_L \rightarrow e_{ex}^+e_{ex}^-$ decay. The decay rate $\Gamma \sim 10^{20}/sec$ implied by $sin(\theta_e) \sim 10^{-4}$ implies decay width of order .1 MeV: the order of magnitude is the naïvely expected one and means that the decay to $e_{ex}^+e_{ex}^-$ pairs dominates over the decay to gamma pairs except in the case of the lightest lepto-pion state for which the decay is kinematically forbidden.

The decay rate of the lepto-pion to $\bar{e}e_{ex}$ pair has sensible order of magnitude: for $sin(\theta_e) = 1.2\cdot 10^{-3}$, $m_{\sigma_L} = 1.8\ MeV$ and $m_{e_{ex}} = 1.3\ MeV$ one has $\Gamma \simeq 60\ eV$ allowed by the experimental limits. This decay is kinematically possible only provided the mass of e_{ex} is in below $1.3\ MeV$. These decays should dominate by a factor $1/sin^2(\theta_e)$ over e^+e^- decays if kinematically allowed.

A signature of these events, if identified erratically as electron positron pairs, is the non-vanishing value of the energy difference in the cm frame of the pair: $E(e^-) - E(e^+) \simeq (m^2(e_{ex}) - m_e^2)/2E > 160\ keV$ for $E = 1.8\ MeV$. If the decay $e_{ex} \rightarrow e + \gamma$ takes place before the detection the energy asymmetry changes its sign. Energy asymmetry [C85] increasing with the rest energy of the decaying object has indeed been observed: the proposed interpretation has been that electron forms a bound state with the second nucleus so that its energy is lowered. Also a deviation from the momentum distribution implied by the decay of neutral particle to e^+e^- pair (momenta are opposite in the rest frame) results from the emission of photon. This kind of deviation has also been observed [C85]: the proposed explanation is that third object is involved in the decay. A possible alternative explanation for the asymmetries is the production mechanism ($\sigma_L\pi_L$ pairs instead of single particle states).

$\Gamma(e_{ex} \to e + \gamma)$

The decay to electron and photon would be a unique signature of e_{ex}. The general feature of of fermion family mixing is that mixing takes place in charged currents. In present case mixing is of different type so that $e_{ex} \to e + \gamma$ might be allowed. If this is not the case then the decay takes place as weak decay via the emission of virtual W boson: $e_{ex} \to e + \nu_e + \bar{\nu}_e$ and is very slow due to the presence of mixing angle and kinematical suppression. The energy of the emitted photon is $E_\gamma = (m_{ex}^2 - m_e^2)/2m_e$. The decay rate $\Gamma(e_{ex} \to e + \gamma)$ is given by

$$\begin{aligned} \Gamma(e_{ex} \to e + \gamma) &= \alpha_{em} sin^2(\theta_e) X m_e \ , \\ X &= \frac{(m_1 - m_e)^3 (m_1 + m_e) m_e}{(m_1^2 + m_e^2)^2 m_1} \ . \end{aligned} \tag{2.2.18}$$

For $m(e_{ex}) = 1.3\ MeV$ the decay of order $1/(1.4 \cdot 10^{-12}\ sec)$ for $sin(\theta_e) = 1.2 \cdot 10^{-3}$ so that lepto-nucleons would decay to electrons in the measurement volume. In the experiments positrons are identified via pair annihilation and since pair annihilation rate for $\bar{e}_{ex}$ is by a factor $sin^2(\theta_e)$ slower than for e^+ the particles identified as positrons must indeed be positrons. For sufficiently small mass difference $m(e_{ex}) - m_e$ the particles identified as electron could actually be e_{ex}. The decay of e_{ex} to electron plus photon before its detection seems however more reasonable alternative since it could explain the observed energy asymmetry [C85].

Some implications

The results have several implications as far as the decays of on mass shell states are considered:

1. For $m(e_{ex}) > 1.3\ MeV$ the only kinematically possible decay mode is the decay to e^+e^- pair. Production mechanism might explain the asymmetries [C85]. The decay rate of on mass shell π_L and σ_L (or $\eta_L, \rho_L, ..$) is above the lower limit allowed by the detection in the measurement volume.
2. If the mass of e_{ex} is larger than .9 MeV but smaller than 1.3 MeV $e_{ex}\bar{e}$ decays dominate over e^+e^- decays. The decay $e_{ex} \to e + \gamma$ before detection could explain the observed energy asymmetry.
3. It will be found that the direct production of $e_{ex}\bar{e}$ pairs is also possible in the heavy ion collision but the rate is much smaller due to the smaller phase space volume in two-particle case. The annihilation rate of $\bar{e}_{ex}$ in matter is by a factor $sin^2(\theta_e)$ smaller than the annihilation rate of positron. This provides a unique signature of e_{ex} if e^+ annihilation rate in matter is larger than the decay rate of $\bar{e}_{ex}$. In lead the lifetime of positron is $\tau \sim 10^{-10}\ sec$ and indeed larger that e_{ex} lifetime.

Karmen anomaly

A brief comment on the Karmen anomaly [C53] observed in the decays of π^+ is in order. The anomaly suggests the existence [C24] of new weakly interacting neutral particle x, which mixes with muon neutrino. Since $g = 1$ neutrino corresponds to charmed quark in hadron physics context having $k = 103$ rather than $k = 107$ as primary condensation level, a natural guess for its primary condensation level is $k = 113$, which would mean that the mass scale would be of order muon mass: the particle candidate indeed has mass of order 30 MeV. One class of solutions to laboratory constraints, which might evade also cosmological and astrophysical constraints, corresponds to object x mixing with muon type neutrino and decaying radiatively to $\gamma + \nu_\mu$ via the emission of virtual W boson. The value of the mixing parameter $U(\mu, x)$ describing $\nu_{mu} - x$ mixing satisfies $|U_{\mu,x}|^4 \simeq .8 \cdot 10^{-10}$.

The following naïve PCAC argument gives order of magnitude estimate for $|U(\mu, x)| \sim sin(\theta_\mu)$. The value of $g(\mu, \mu)$ is by a factor $m(\mu)/m_e$ larger than $g(e, e)$. If the lepto-hadronic couplings $g(\mu_{ex}, \mu_{ex})$ and $g(e_{ex}, e_{ex})$ are of same order of magnitude then one has $sin(\theta_\mu) \leq .02$ (3 lepto-pion states and Op anomaly equal to $Op = 5 \cdot 10^{-3}$): the lower bound is 6.5 times larger than the value .003 deduced in [C24]. The actual value could be considerably smaller since e_{ex} mass could be larger than 1.3 MeV by a factor of order 10.

2.2.4 Lepto-Pions And Weak Decays

The couplings of lepto-meson to electro-weak gauge bosons can be estimated using PCAC and CVC hypothesis [B22]. The effective $m_{\pi_L} - W$ vertex is the matrix element of electro-weak axial current between vacuum and charged lepto-meson state and can be deduced using same arguments as in the case of ordinary charged pion

$$\langle 0|J_A^\alpha|\pi_L^-\rangle = Km(\pi_l)p^\alpha \ , \tag{2.2.19}$$

where K is some numerical factor and p^α denotes the momentum of lepto-pion. For neutral lepto-pion the same argument gives vanishing coupling to photon by the conservation of vector current. This has the important consequence that lepto-pion cannot be observed as resonance in e^+e^- annihilation in single photon channel. In two photon channel lepto-pion should appear as resonance. The effective interaction Lagrangian is the "instanton" density of electromagnetic field giving additional contribution to the divergence of the axial current and was used to derive a model for lepto-pion production in heavy ion collisions.

Lepto-hadrons and lepton decays

The lifetime of charged lepto-pion is from PCAC estimates larger than 10^{-10} seconds by the previous PCAC estimates. Therefore lepto-pions are practically stable particles and can appear in the final states of particle reactions. In particular, lepto-pion atoms are possible and by Bose statistics have the peculiar property that ground state can contain many lepto-pions.

Lepton decays $L \to \nu_\mu + H_L$, $L = e, \mu, \tau$ via emission of virtual W are kinematically allowed and an anomalous resonance peak in the neutrino energy spectrum at energy

$$E(\nu_L) = \frac{m(L)}{2} - \frac{m_H^2}{2m(L)} \ , \tag{2.2.20}$$

provides a unique test for the lepto-hadron hypothesis. If lepto-pion is too light electrons would decay to charged lepto-pions and neutrinos unless the condition $m(\pi_L) > m_e$ holds true.

The existence of a new decay channel for muon is an obvious danger to the lepto-hadron scenario: large changes in muon decay rate are not allowed.

Consider first the decay $\mu \to \nu_\mu + \pi_L$ where π_L is on mass shell lepto-pion. Lepto-pion has energy $\sim m(\mu)/2$ in muon rest system and is highly relativistic so that in the muon rest system the lifetime of lepto-pion is of order $\frac{m(\mu)}{2m(\pi_L)}\tau(\pi_L)$ and the average length traveled by lepto-pion before decay is of order 10^8 meters! This means that lepto-pion can be treated as stable particle. The presence of a new decay channel changes the lifetime of muon although the rate for events using $e\nu_e$ pair as signature is not changed. The effective $H_L - W$ vertex was deduced above. The rate for the decay via lepto-pion emission and its ratio to ordinary rate for muon decay are given by

$$\begin{aligned}\Gamma(\mu \to \nu_\mu + H_L) &= \frac{G^2K^2}{2^5\pi}m^4(\mu)m^2(H_L)(1-\frac{m^2(H_L)}{m^2(\mu)})\frac{(m^2(\mu)-m^2(H_L))}{(m^2(\mu)+m^2(H_L))} \ ,\\ \frac{\Gamma(\mu \to \nu_\mu + H_L)}{\Gamma(\mu \to \nu_\mu + e + \bar{\nu}_e)} &= 6\cdot(2\pi^4)K^2\frac{m^2(H_L)}{m^2(\mu)}\frac{(m^2(\mu)-m^2(H_L))}{(m^2(\mu)+m^2(H_L))} \ ,\end{aligned} \tag{2.2.21}$$

and is of order $.93K^2$ in case of lepto-pion. As far as the determination of G_F or equivalently m_W^2 from muon decay rate is considered the situation seems to be good since the change introduced to G_F is of order $\Delta G_F/G_F \simeq 0.93K^2$ so that K must be considerably smaller than one. For the physical value of K: $K \leq 10^{-2}$ the contribution to the muon decay rate is negligible.

Lepto-hadrons can appear also as virtual particles in the decay amplitude $\mu \to \nu_\mu + e\nu_e$ and this changes the value of muon decay rate. The correction is however extremely small since the decay vertex of intermediate off mass shell lepto-pion is proportional to its decay rate.

Lepto-pions and beta decay

If lepto-pions are allowed as final state particles lepto-pion emission provides a new channel $n \rightarrow p + \pi_L$ for beta decay of nuclei since the invariant mass of virtual W boson varies within the range $(m_e = 0.511\ MeV, m_n - m_p = 1.293 MeV$. The resonance peak for $m(\pi_L) \simeq 1\ MeV$ is extremely sharp due to the long lifetime of the charged lepto-pion. The energy of the lepto-pion at resonance is

$$E(\pi_L) = (m_n - m_p)\frac{(m_n + m_p)}{2m_n} + \frac{m(\pi_L)^2}{2m_n} \simeq m_n - m_p \ . \tag{2.2.22}$$

Together with long lifetime this lepto-pions escape the detector volume without decaying (the exact knowledge of the energy of charged lepto-pion might make possible its direct detection).

The contribution of lepto-pion to neutron decay rate is not negligible. Decay amplitude is proportional to superposition of divergences of axial and vector currents between proton and neutron states.

$$M = \frac{G}{\sqrt{2}} K m(\pi_L)(q^\alpha V_\alpha + q^\alpha A_\alpha) \ . \tag{2.2.23}$$

For exactly conserved vector current the contribution of vector current vanishes identically. The matrix element of the divergence of axial vector current at small momentum transfer (approximately zero) is in good approximation given by

$$\begin{aligned} \langle p | q^\alpha A_\alpha | n \rangle &= g_A(m_p + m_n)\bar{u}_p \gamma_5 u_n \ , \\ g_A &\simeq 1.253 \ . \end{aligned} \tag{2.2.24}$$

Straightforward calculation shows that the ratio for the decay rate via lepto-pion emission and ordinary beta decay rate is in good approximation given by

$$\begin{aligned} \frac{\Gamma(n \rightarrow p + \pi_L)}{\Gamma(n \rightarrow p + e + \bar{\nu}_e)} &= \frac{30\pi^2 g_A^2 K^2}{0.47 \cdot (1 + 3g_A^2)} \frac{m_{\pi_L}^2 (\Delta^2 - m_{\pi_L}^2)^2}{\Delta^6} \ , \\ \Delta &= m(n) - m(p) \ . \end{aligned} \tag{2.2.25}$$

Lepto-pion contribution is smaller than ordinary contribution if the condition

$$K < \left[\frac{.47 \cdot (1 + 3g_A^2)}{30\pi^2 g_A^2} \frac{\Delta^6}{(\Delta^2 - m_{\pi_L}^2)^2 m_{\pi_L}^2} \right]^{1/2} \simeq .28 \ , \tag{2.2.26}$$

is satisfied. The upper bound $K \leq 10^{-2}$ coming from the lepto-pion decay width and Op anomaly implies that the contribution of the lepto-pion to beta decay rate is very small.

2.2.5 Ortopositronium Puzzle And Lepto-Pion In Photon Photon Scattering

The decay rate of ortopositronium (Op) has been found to be slightly larger than the rate predicted by QED [C96, C49]: the discrepancy is of order $\Delta\Gamma/\Gamma \sim 10^{-3}$. For parapositronium no anomaly has been observed. Most of the proposed explanations [C49] are based on the decay mode $Op \rightarrow X + \gamma$, where X is some exotic particle. The experimental limits on the branching ratio $\Gamma(Op \rightarrow X + \gamma)$ are below the required value of order 10^{-3}. This explanation is excluded also by the standard cosmology [C49].

Lepto-pion hypothesis suggests an obvious solution of the Op-puzzle. The increase in annihilation rate is due to the additional contribution to $Op \rightarrow 3\gamma$ decay coming from the decay $Op \rightarrow \gamma_V$ (V denotes "virtual") followed by the decay $\gamma_V \rightarrow \gamma + \pi_L^V$ followed by the decay $\pi_L^V \rightarrow \gamma + \gamma$ of the virtual lepto-pion to two photon state. $\gamma\gamma\pi_L$ vertices are induced by the axial current anomaly $\propto E\cdot B$. Also a modification of parapositronium decay rate is predicted. The first contribution comes from the decay $Op \rightarrow \pi_L^V \rightarrow \gamma+\gamma$ but the contribution is very small due the smallness of the coupling $g(e,e)$. The second contribution obtained from ortopositronium contribution by replacing one outgoing photon with a loop photon is also small. Since the production of a real lepto-pion is impossible, the mechanism is consistent with the experimental constraints.

The modification to the Op annihilation amplitude comes in a good approximation from the interference term between the ordinary e^+e^- annihilation amplitude F_{st} and lepto-pion induced annihilation amplitude F_{new}:

$$\Delta\Gamma \quad \propto \quad 2Re(F_{st}\bar{F}_{new}) \ , \qquad (2.2.27)$$

and rough order of magnitude estimate suggests $\Delta\Gamma/\Gamma \sim K^2/e^2 = \alpha^2/4\pi \sim 10^{-3}$. It turns out that the sign and the order of magnitude of the new contribution are correct for $f(\pi_L)\sim 2\ keV$ deduced also from the anomalous e^+e^- production rate.

The new contribution to $e^+e^- \rightarrow 3\gamma$ decay amplitude is most easily derivable using for lepto-pion-photon interaction the effective action

$$\begin{aligned} L_1 &= K\pi_L F\wedge F \ , \\ K &= \frac{\alpha_{em}N_c}{8\pi f(\pi_L)} \ , \end{aligned} \qquad (2.2.28)$$

where F is quantized electromagnetic field. The calculation of the lepto-pion contribution proceeds in manner described in [B22], where the expression for the standard contribution and an elegant method for treating the average over e^+e^- spin triplet states and sum over photon polarizations, can be found. The contribution to the decay rate can be written as

$$\begin{aligned} \frac{\Delta\Gamma}{\Gamma} &\simeq K_1 I_0 \ , \\ K_1 &= \frac{3\alpha N_c^2}{(\pi^2-9)2^9(2\pi)^3}(\frac{m_e}{f(\pi_L)})^2 \ , \\ I_0 &= \int_0^1\int_{-1}^{umax}\frac{f}{v+f-1-x^2}v^2(2(f-v)u+2-v-f)dvdu \ , \\ f &\equiv f(v,u) = 1-\frac{v}{2}-\sqrt{(1-\frac{v}{2})^2-\frac{1-v}{1-u}} \ , \\ u &= \bar{n}_1\cdot\bar{n}_2 \ , \ \bar{n}_i = \frac{\bar{k}_i}{\omega_i} \ , \ umax = \frac{(\frac{v}{2})^2}{(1-\frac{v}{2})^2} \ , \\ v &= \frac{\omega_3}{m_e} \ , \ x = \frac{m_{\pi_L}}{2m_e} \ . \end{aligned} \qquad (2.2.29)$$

ω_i and $\bar{k}_i$ denote the energies of photons, u denotes the cosine of the angle between first and second photon and v is the energy of the third photon using electron mass as unit. The condition $\Delta\Gamma/\Gamma = 10^{-3}$ gives for the parameter $f(\pi_L)$ the value $f(\pi_L)(1.062\ MeV)\simeq N_c\cdot 7.9\ keV$. If there are several lepto-pion states, they contribute to the decay anomaly additively. If the four known resonances correspond directly to lepto-pions decaying to lepto-nucleon pairs and $f(\pi_L)$ is assumed to scale as $N_c m_{\pi_L}$, one obtains $f(\pi_L)(1.062\ MeV)\simeq N_c\cdot 14.7\ keV$. From the PCAC relation one obtains for $sin(\theta_e)$ the upper bound $sin(\theta_e)\leq x\cdot\sqrt{N_c}10^{-4}$ assuming $m_{ex}\geq 1.3\ MeV$ (so that $e_{ex}\bar{e}$ decay is not possible), where $x=1.2$ for single lepto-pion state and $x=1.36$ for four lepto-pion states identified as the observed resonances.

Lepto-pion photon interaction implies also a new contribution to photon-photon scattering. Just at the threshold $E = m_{\pi_L}/2$ the creation of lepto-pion in photon photon scattering is possible and the appearance of lepto-pion as virtual particle gives resonance type behaviour to photon photon scattering near $s = m_{\pi_L}^2$. The total photon-photon cross section in zero decay width approximation is given by

N	$Op/10^{-3}$	$f(\pi_L)/(N_c keV)$	$sin(\theta_e)(m_{ex}/1.3\ MeV)^{1/2}$	$\Gamma(\pi_L)/keV$
1	1	7.9	$1.2\cdot 10^{-4}\sqrt{N_c}$	.51
3	1	14.7	$1.7\cdot 10^{-4}\sqrt{N_c}$	.13
3	5	6.5	$3.6\cdot 10^{-4}\sqrt{N_c}$	.73

Table 2.1: The dependence of various quantities on the number of lepto-pion type states and Op anomaly, whose value is varied assuming the proportionality $f(\pi_L) \propto N_c m_{\pi_L}$. N_c refers to the number of lepto-pion states in given representation and Op denotes lepto-pion anomaly.

$$\sigma = \frac{\alpha^4 N_c^2}{2^{14}(2\pi)^6}\frac{E^6}{f_{\pi_L}^4(E^2-\frac{m_{\pi_L}^2}{4})^2} \ . \tag{2.2.30}$$

2.2.6 Spontaneous Vacuum Expectation Of Lepto-Pion Field As Source Of Lepto-Pions

The basic assumption in the model of lepto-pion and lepto-hadron production is the spontaneous generation of lepto-pion vacuum expectation value in strong nonorthogonal electric and magnetic fields. This assumption is in fact very natural in TGD [1].

1. The well known relation [B22] expressing pion field as a sum of the divergence of axial vector current and anomaly term generalizes to the case of lepto-pion

$$\pi_L = \frac{1}{f(\pi_L)m^2(\pi_L)}(\nabla\cdot j^A + \frac{\alpha_{em}N_c}{2\pi}E\cdot B) \ . \tag{2.2.31}$$

   In the case of lepto-pion case the value of $f(\pi_L)$ has been already deduced from PCAC argument. Anomaly term gives rise to pion decay to two photons so that one obtains an estimate for the lifetime of the lepto-pion.

   This relation is taken as the basis for the model describing also the production of lepto-pion in external electromagnetic field. The idea is that the presence of external electromagnetic field gives rise to a vacuum expectation value of lepto-pion field. Vacuum expectation is obtained by assuming that the vacuum expectation value of axial vector current vanishes.

$$\begin{aligned}\langle vac \mid \pi \mid vac\rangle &= KE\cdot B \ , \\ K &= \frac{\alpha_{em}N_c}{2\pi f(\pi_L)m^2(\pi_L)} \ .\end{aligned} \tag{2.2.32}$$

   Some comments concerning this hypothesis are in order here:

   (a) The basic hypothesis making possible to avoid large parity breaking effects in atomic and molecular physics is that p-adic condensation levels with length scale $L(n) < 10^{-6}\ m$ are purely electromagnetic in the sense that nuclei feed their Z^0 charges on condensate levels with $L(n) \geq 10^{-6}\ m$. The absence of Z^0 charges does not however exclude the possibility of the classical Z^0 fields induced by the nonorthogonality of the ordinary electric and magnetic fields (if Z^0 fields vanish E and B are orthogonal in TGD.

   (b) The non-vanishing vacuum expectation value of the lepto-pion field implies parity breaking in atomic length scales. This is understandable from basic principles of TGD since classical Z^0 field has parity breaking axial coupling to electrons and protons. The non-vanishing classical lepto-pion field is in fact more or less equivalent with the presence of classical Z^0 field.

[1] "Instanton density" generates coherent state of lepto-pions just like classical em current generates coherent state of photons

2. The amplitude for the production of lepto-pion with four momentum $p = (p_0, \bar{p})$ in an external electromagnetic field can be deduced by writing lepto-pion field as sum of classical and quantum parts: $\pi_L = \pi_L(class) + \pi_L(quant)$ and by decomposing the mass term into interaction term plus c-number term and standard mass term:

$$\begin{aligned} \frac{m^2(\pi_L)\pi_L^2}{2} &= L_{int} + L_0 \ , \\ L_0 &= \frac{m^2(\pi_L)}{2}(\pi_L^2(class) + \pi_L^2(quant)) \ , \\ L_{int} &= m^2(\pi_L)\pi_L(class)\pi_L(quant) \ . \end{aligned} \quad (2.2.33)$$

Interaction Lagrangian corresponds to L_{int} linear in lepto-pion oscillator operators. Using standard LSZ reduction formula and normalization conventions of [B22] one obtains for the probability amplitude for creating lepto-pion of momentum p from vacuum the expression

$$\begin{aligned} A(p) &\equiv \langle a(p)\pi_L\rangle = (2\pi)^3 m^2(\pi_L)\int f_p(x)\langle vac \mid \pi \mid vac\rangle d^4x \ , \\ f_p &= e^{ip\cdot x} \ . \end{aligned} \quad (2.2.34)$$

The probability for the production of lepto-pion in phase space volume element $d3p$ is obtained by multiplying with the density of states factor $d^3n = V\frac{d^3p}{(2\pi)^3}$:

$$\begin{aligned} dP &= A|U|^2 V d^3p \ , \\ A &= (\frac{\alpha_{em}N_c^2 m^2(\pi_L)}{2\pi f(\pi_L)})^2 \ , \\ U &= \int e^{ip\cdot x} E\cdot B d^4x \ . \end{aligned} \quad (2.2.35)$$

The first conclusion that one can draw is that nonstatic electromagnetic fields are required for lepto-pion creation since in static fields energy conservation forces lepto-pion to have zero energy and thus prohibits real lepto-pion production. In particular, the spontaneous creation lepto-pion in static Coulombic and magnetic dipole fields of nucleus is impossible.

2.2.7 Sigma Model And Creation Of Lepto-Hadrons In Electromagnetic Fields

Why sigma model approach?

For several reasons it is necessary to generalize the model for lepto-pion production to a model for lepto-hadron production.

1. Sigma model approach is necessary if one assumes that anomalous e^+e^- pairs are genuine e^+e^- pairs rather lepto-nucleon pairs produced in the decays of lepto-sigmas.
2. A model for the production of lepto-hadrons is obtained from an effective action describing the strong and electromagnetic interactions between lepto-hadrons. The simplest model is sigma model describing the interaction between lepto-nucleons, lepto-pion and a hypothetical scalar particle σ_L [B22]. This model realizes lepto-pion field as a divergence of the axial current and gives the standard relation between $f(\pi_L), g$ and m_{ex}. All couplings of the model are related to the masses of e_{ex}, π_L and σ_L. The generation of lepto-pion vacuum expectation value in the proposed manner takes place via triangle anomaly diagrams in the external electromagnetic field.
3. If needed the model can be generalized to contain terms describing also other lepto-hadrons. The generalized model should contain also vector bosons ρ_L and ω_L as well as pseudo-scalars η_L and η_L' and radial excitations of π_L and σ_L. An open question is whether also η and η' generate vacuum expectation value proportional to $E\cdot B$. Actually all these states appear as 3-fold degenerate for the minimal color representation content of the theory.

4. The following observations are useful for what follows.

   (a) Ortopositronium decay width anomaly gives the estimate $f(\pi_L) \sim N_c \cdot 7.9\ keV$ and from this one can deduce an upper bound for lepto-pion production cross section in an external electromagnetic field. The calculation of lepto-pion production cross section shows that lepto-pion production cross section is somewhat smaller than the upper bound for the observed anomalous e^+e^- production cross section, even when one tunes the values of the various parameters. This is consistent with the idea that lepto-nucleon pairs, with lepto-nucleon mass being only slightly larger than electron mass, are in question.

   (b) Also the direct production of the lepto-nucleon pairs via the interaction term $gcos(\theta_e)\bar{e}_{ex}\gamma_5 e_{ex}\pi_L(cl)$ is possible but gives rise to continuum mass squared spectrum rather than resonant structures. The direct production of the pairs via the interaction term $gsin(\theta_e)\bar{e}\gamma_5 e_{ex}\pi_L(cl)$ from is much slower process than the production via the meson decays and does not give rise to resonant structures since Also the production via the $\bar{e}e_{ex}$ decay of virtual lepto-pion created from classical field is slow process since it involves $sin^2(\theta_e)$.

   (c) e^+e^- production can also proceed also via the creation of many particle states. The simplest candidates are $V_L + \pi_L$ states created via $\partial_\alpha \pi_L V^\alpha \pi_L(class)$ term in action and $\sigma_L + \pi_L$ states created via the the $k\sigma_L\pi_L\pi_L(class)$ term in the sigma model action. The production cross section via the decays of vector mesons is certainly very small since the production vertex involves the inner product of vector boson 3 momentum with its polarization vector and the situation is non-relativistic.

   (d) If the strong decay of σ_L to lepto-mesons is kinematically forbidden (this is not suggested by the experience with the ordinary hadron physics), the production rate for σ_L meson is large since the coupling k turns out to be given by $k = (m^2_{\sigma_L} - m^2_{\pi_L})/2f(\pi_L)$ and is anomalously large for the value of $f(\pi_L) \geq 7.9 \cdot N_c\ keV$ derived from ortopositronium anomaly: $k \sim 336m(\pi_L)/N_c$ for $f(\pi_L) \sim N_c \cdot 7.9\ keV$. The resulting additional factor in the production cross section compensates the reduction factor coming from two-particle phase space volume. Despite this the estimate for the production cross section of anomalous e^+e^- pairs is roughly by a factor $1/N_c^2$ smaller than the maximum experimental cross section. The radiative corrections are huge and should give the dominant contribution to the cross section. It is however questionable very the assumed small lepto-hadronic decay width and mass of σ_L is consistent with the extremely strong interactions of σ_L.

Simplest sigma model

A detailed description of the sigma model can be found in [B22] and it suffices to outline only the crucial features here.

1. The action of lepto-hadronic sigma model reads as

$$
\begin{aligned}
L &= L_S + c\sigma_L \ , \\
L_S &= \bar{\psi}_L(i\gamma^k\partial_k + g(\sigma_L + i\pi_L\cdot\tau\gamma_5))\psi_L + \frac{1}{2}((\partial\pi_L)^2 + (\partial\sigma_L)^2) \\
&- \frac{\mu^2}{2}(\sigma_L^2 + \pi_L^2) - \frac{\lambda}{4}(\sigma_L^2 + \pi_L^2)^2 \ . \qquad (2.2.36)
\end{aligned}
$$

   π_L is isospin triplet and σ_L isospin singlet. ψ_L is isospin doublet with electro-weak quantum numbers of electron and neutrino (e_{ex} and ν_{ex}). The model allows $so(4)$ symmetry. Vector current is conserved but for $c \neq 0$ axial current generates divergence, which is proportional to pion field: $\partial^\alpha A_\alpha = -c\pi_L$.

2. The presence of the linear term implies that σ_L field generates vacuum expectation value $\langle 0|\sigma_L|0\rangle = v$. When the action is written in terms of new quantum field $\sigma'_L = \sigma_L - v$ one has

$$
\begin{aligned}
L &= \bar{\psi}_L(i\gamma^k\partial_k + m + g(\sigma'_L + i\pi_L\cdot\tau\gamma_5))\psi_L + \frac{1}{2}((\partial\pi_L)^2 + (\partial\sigma'_L)^2) \\
&- \frac{1}{2}m^2_{\sigma_L}(\sigma'_L)^2 - \frac{m^2_{\pi_L}}{2}\pi_L^2 \\
&- \lambda v\sigma'_L((\sigma'_L)^2 + \pi_L^2) - \frac{\lambda}{4}((\sigma'_L)^2 + \pi_L^2)^2 \ ,
\end{aligned} \tag{2.2.37}
$$

The masses are given by

$$
\begin{aligned}
m^2_{\pi_L} &= \mu^2 + \lambda v^2 \ , \\
m^2_{\sigma_L} &= \mu^2 + 3\lambda v^2 \ , \\
m &= -gv \ .
\end{aligned} \tag{2.2.38}
$$

These formulas relate the parameters μ, v, g to lepto-hadrons masses.

3. The requirement that σ'_L has vanishing vacuum expectation implies in Born approximation

$$
c - \mu^2 v - \lambda v^3 = 0 \ , \tag{2.2.39}
$$

which implies

$$
\begin{aligned}
f(\pi_L) &= -v = -\frac{c}{m^2(\pi_L)} \ , \\
m_{ex} &= gf(\pi_L) \ .
\end{aligned} \tag{2.2.40}
$$

Note that e_{ex} and ν_{ex} are predicted to have identical masses in this approximation. The value of the strong coupling constant g of lepto-hadronic physics is indeed strong from $m_{ex} > m_e$ and $f(\pi_L) < N_c \cdot 10$ keV.

4. A new feature is the generation of the lepto-pion vacuum expectation value in an external electromagnetic field (of course, this is possible for the ordinary pion field, too!). The vacuum expectation is generated via the triangle anomaly diagram in a way identical to the generation of a non-vanishing photon-photon decay amplitude and is proportional to the instanton density of the electromagnetic field. By redefining the pion field as a sum $\pi_L = \pi_L(cl) + \pi'_L$ one obtains effective action describing the creation of the lepto-hadrons in strong electromagnetic fields.

5. As far as the production of $\sigma_L\pi_L$ pairs is considered, the interaction term $\lambda v\sigma'_L\pi_L^2$ is especially interesting since it leads to the creation of $\sigma_L\pi_L$ pairs via the interaction term $k\lambda v\sigma'_L\pi_L(qu)\pi_L(cl)$.
The coefficient of this term can be expressed in terms of the lepto-meson masses and $f(\pi_L)$:

$$
\begin{aligned}
k &\equiv 2\lambda v = \frac{m^2_{\sigma_L} - m^2_{\pi_L}}{2f(\pi_L)} = xm_{\pi_L} \ , \\
x &= \frac{1}{2}(\frac{m^2_{\sigma_L}}{m^2_{\pi_L}} - 1)\frac{m_{\pi_L}}{f(\pi_L)} \ .
\end{aligned} \tag{2.2.41}
$$

The large value of the coupling deriving from $f(\pi_L) = N_c \cdot 7.9\ keV)$ compensates the reduction of the production rate coming from the smallness of two-particle phase space volume as compared with single particle-phase space volume but fails to produce large enough production cross section. The large value of $g(\sigma_L, \sigma_L, \sigma_L) = g(\sigma_L, \pi_L, \pi_L)$ however implies that the radiative contribution to the production cross section coming from the emission of a virtual sigma in the production vertex is much larger than the lowest order production cross section and with a rather small value of the relative $\sigma_L - \pi_L$ mass difference correct order of magnitude of cross section should be possible.

2.2.8 Classical Model For Lepto-Pion Production

The nice feature of both quantum and classical model is that the production amplitudes associated with all lepto-hadron production reactions in external electromagnetic field are proportional to the lepto-pion production amplitude and apart from phase space volume factors production cross sections are expected to be given by lepto-pion production cross section. Therefore it makes sense to construct a detailed model for lepto-pion production despite the fact that lepto-pion decays probably contribute only a very small fraction to the observed e^+e^- pairs.

General considerations

Angular momentum barrier makes the production of lepto-mesons with orbital angular momentum $L > 0$ improbable. Therefore the observed resonances are expected to be $L = 0$ pseudo-scalar states. Lepto-pion production has two signatures which any realistic model should reproduce.

1. Data are consistent with the assumption that states are produced at rest in cm frame.
2. The production probability has a peak in a narrow region of velocities of colliding nucleus around the velocity needed to overcome Coulomb barrier in head on collision. The relative width of the velocity peak is of order $\Delta\beta/\beta \simeq \cdot 10^{-2}$ [C62]. In Th-Th system [J13] two peaks at projectile energies 5.70 MeV and 5.75 MeV per nucleon have been observed. This suggests that some kind of diffraction mechanism based on the finite size of nuclei is at work.
   In this section a model treating nuclei as point like charges and nucleus-nucleus collision purely classically is developed. This model yields qualitative predictions in agreement with the signature 1) but fails to reproduce the possible diffraction behavior although one can develop argument for understanding the behavior above Coulomb wall.

The general expression for the amplitude for creation of lepto-pion in external electric and magnetic fields has been derived in Appendix. Let us now specialize to the case of heavy ion collision. We consider the situation, where the scattering angle of the colliding nucleus is measured. Treating the collision completely classically we can assume that collision occurs with a well defined value of the impact parameter in a fixed scattering plane. The coordinates are chosen so that target nucleus is at rest at the origin of the coordinates and colliding nucleus moves in z-direction in y=0 plane with velocity β. The scattering angle of the scattered nucleus is denoted by α, the velocity of the lepto- pion by v and the direction angles of lepto-pion velocity by (θ, ϕ).

The minimum value of the impact parameter for the Coulomb collision of point like charges is given by the expression

$$\begin{aligned} b &= \frac{b_0 cot(\alpha/2)}{2} \ , \\ b_0 &= \frac{2Z_1Z_2\alpha_{em}}{M_R\beta^2} \ , \end{aligned} \tag{2.2.42}$$

where b_0 is the expression for the distance of the closest approach in head on collision. M_R denotes the reduced mass of the nucleus-nucleus system.

To estimate the amplitude for lepto-pion production the following simplifying assumptions are made.

1. Nuclei can be treated as point like charges. This assumption is well motivated, when the impact parameter of the collision is larger than the critical impact parameter given by the sum of radii of the colliding nuclei:

   $$b_{cr} = R_1 + R_2 \ . \tag{2.2.43}$$

   For scattering angles that are sufficiently large the values of the impact parameter do not satisfy the above condition in the region of the velocity peak. p-Adic considerations lead to the conclusion that nuclear condensation level corresponds to prime $p \sim 2^k$, $k = 113$ (k is prime). This suggest that nuclear radius should be replaced by the size $L(113)$ of the p-adic convergence cube associated with nucleus (see the chapter "TGD and Nuclear Physics": $L(113) \sim 1.7 \cdot 10^{-14}\ m$ implies that cutoff radius is $b_{cr} \sim 2L(113) \sim 3.4 \cdot 10^{-14}\ m$.

2. Since the velocities are non-relativistic (about $0.12c$) one can treat the motion of the nuclei non-relativistically and the non-retarded electromagnetic fields associated with the exactly known classical orbits can be used. The use of classical orbit doesn't take into account recoil effect caused by lepto-pion production. Since the mass ratio of lepto-pion and the reduced mass of heavy nucleus system is of order 10^{-5} the recoil effect is however negligible.
3. The model simplifies considerably, when the orbit is idealized with a straight line with impact parameter determined from the condition expressing scattering angle in terms of the impact parameter. This approximation is certainly well founded for large values of impact parameter. For small values of impact parameter the situation is quite different and an interesting problem is whether the contributions of long range radiation fields created by accelerating nuclei in head-on collision could give large contribution to lepto-pion production rate. On the line connecting the nuclei the electric part of the radiation field created by first nucleus is indeed parallel to the magnetic part of the radiation field created by second nucleus. In this approximation the instanton density in the rest frame of the target nucleus is just the scalar product of the Coulombic electric field E of the target nucleus and of the magnetic field B of the colliding nucleus obtained by boosting it from the Coulomb field of nucleus at rest.

Expression of the classical cross section

First some kinematical notations. lepto-pion four-momentum in the rest system of target nucleus is given by the following expression

$$
\begin{aligned}
p &= (p_0,\bar{p}) = m\gamma_1(1, vsin(\theta)cos(\phi), vsin(\theta)sin(\phi), vcos(\theta)) \ , \\
\gamma_1 &= 1/(1-v^2)^{1/2} \ .
\end{aligned}
\tag{2.2.44}
$$

The velocity and Lorentz boost factor of the projectile nucleus are denoted by β and $\gamma = 1/\sqrt{1-\beta^2}$.

The double differential cross section in the classical model can be written as

$$
\begin{aligned}
d\sigma &= dP2\pi bdb \ , \\
dP &= K|A(b,p)|^2 d^3n \ , per d^3n = V\frac{d^3p}{(2\pi)^3} \ , \\
K &= (Z_1Z_2)^2(\alpha_{em})^4 \times N_c^2(\frac{m(\pi_L}{f(\pi_L)})^2\frac{1}{2\pi^{13}} \ , \\
A(b,p) &= N_0\frac{4\pi}{Z_1Z_2\alpha_{em}} \times U(b,p) \ , \\
U(b,p) &= \int e^{ip\cdot x}E\cdot Bd^4x \ , \\
N_0 &= \frac{(2\pi)^7}{i} \ .
\end{aligned}
\tag{2.2.45}
$$

where b denotes impact parameter. The formula generalizes the classical formula for the cross section of Coulomb scattering. In the calculation of the total cross section one must introduce some cutoff radii and the presence of the volume factor V brings in the cutoff volume explicitly (particle in the box description for lepto-pions). Obviously the cutoff length must be longer than lepto-pion Compton length. Normalization factor N_0 has been introduced in order to extract out large powers of 2π.

From this one obtains differential cross section as

$$
\begin{aligned}
d\sigma &= P2\pi bdb \ , \\
P &= \int K|A(b,p)|^2V\frac{d^3p}{(2\pi)^3} \ , \ .
\end{aligned}
\tag{2.2.46}
$$

The first objection is the need to explicitly introduce the reaction volume: this obviously breaks manifest Lorentz invariance. The cross section was estimated in the earlier version of the model and turned to be too small by several orders of magnitude. This inspired the idea that constructive interference for the production amplitudes for different values of impact parameter could increase the cross section.

2.2.9 Quantum Model For Lepto-Pion Production

There are good reasons for considering the quantum model. First, the lepto-pion production cross section is by several orders of magnitude too small in classical model. Secondly, in Th-Th collisions there are indications about the presence of two velocity peaks with separation $\delta\beta/\beta \sim 10^{-2}$ [C62] and this suggests that quantum mechanical diffraction effects might be in question. These effects could come from the upper and/or lower length scale cutoff and from the de-localization of the wave function of incoming nucleus.

The question is what quantum model means. The most natural thing is to start from Coulomb scattering and multiply Coulomb scattering amplitude for a given impact parameter value b with the amplitude for lepto-pion production. This because the classical differential cross section given by $2\pi bdb$ in Coulomb scattering equals to the quantum cross section. One might however argue that on basis of $S = 1+T$ decomposition of S-matrix the lowest order contribution to lepto-pion production in quantum situation corresponds to the absence of any scattering. The lepto-pion production amplitude is indeed non-vanishing also for the free motion of nuclei. The resolution of what looks like a paradox could come from many-sheeted space-time concept (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book): if no scattering occurs, the space-time sheets representing colliding nuclei do not touch and all and there is no interference of em fields so that there is no lepto-pion production. It turns however that lowest order contribution indeed corresponds to the absence of scattering in the model that works.

Two possible approaches

One can imagine two approaches to the construction of the model for production amplitude in quantum case.

The first approach is based on eikonal approximation [B26]. Eikonal approximation applies at high energy limit when the scattering angle is small and one can approximate the orbit of the projectile with a straight orbit.

The expression for the scattering amplitude in eikonal approximation reads as

$$\begin{aligned} f(\theta,\phi) &= \frac{k}{2\pi i}\int d^2b exp(-ik\cdot b)exp(i\xi(b))-1) \ , \\ \xi(b) &= \frac{-m}{k\hbar^2}\int_{z=-\infty}^{z=\infty} dzV(z,b) \ , \end{aligned}$$
$$\frac{d\sigma}{d\Omega} = |f^2| \ . \tag{2.2.47}$$

as one expands the exponential in lowest in spherically symmetric potential order one obtains the

$$f(\theta,\phi) \simeq -\frac{m}{2\pi\hbar^2}\int J_0(k_Tb)\xi(b)bdb \ . \tag{2.2.48}$$

The challenge is to find whether it is possible to generalize this expression so that it applies to the production of lepto-pions.

1. The simplest guess is that one should multiply the eikonal amplitude with the dimensionless amplitude $A(b)$:

$$\begin{aligned} f(\theta,\phi) &\rightarrow f(\theta,\phi,p) = \frac{k}{2\pi i}\int d^2b exp(-ik\cdot b)exp(i\xi(b))-1)A(b,p) \\ &\simeq -\frac{m}{2\pi\hbar^2}\int J_0(k_Tb)\xi(b)A(b,p)bdb \ . \end{aligned} \tag{2.2.49}$$

2. Amplitude squared must give differential cross section for lepto-pion production and scattering

$$\begin{aligned} d\sigma &= |f(\theta,\phi,p)|^2 d\Omega d^3n \ , \\ d^3n &= Vd^3p \ . \end{aligned} \tag{2.2.50}$$

This requires an explicit introduction of a volume factor V via a spatial cutoff. This cutoff is necessary for the coordinate z in the case of Coulomb potential, and would have interpretation in terms of a finite spatio-temporal volume in which the space-time sheets of the colliding particles are in contact and fields interfere.

3. There are several objections against this approach. The loss of a manifest relativistic invariance in the density of states factor for lepto-pion does not look nice. One must keep count about the scattering of the projectile which means a considerable complication from the point of view of numerical calculations. In classical picture for orbits the scattering angle in principle is fixed once impact parameter is known so that the introduction of scattering angles does not look logical.

Second approach starts from the classical picture in which each impact parameter corresponds to a definite scattering angle so that the resulting amplitude describes lepto-pion production amplitude and says nothing about the scattering of the projectile. This approach is more in spirit with TGD since classical physics is exact part of quantum TGD and classical orbit is absolutely real from the point of view of lepto-pion production amplitude.

1. The counterpart of the eikonal exponent has interpretation as the exponent of classical action associated with the Coulomb interaction

$$S(b) = \int_\gamma Vds \tag{2.2.51}$$

along the orbit γ of the particle, which can be taken also as a real classical orbit but will be approximated with rectilinear orbit in sequel.

2. The first guess for the production amplitude is

$$\begin{aligned} f(p) &= \int d^2bexp(-i\Delta k(b)\cdot b)exp[\frac{i}{\hbar}S(b)]A(b,p) \\ &= \int J_0(k_T(b)b)(1+\frac{i}{\hbar}\int_{z=-a}^{z=a} dzV(z,b)+..)A(b,p) \ . \end{aligned} \tag{2.2.52}$$

Δk is the change of the momentum in the classical scattering and in the scattering plane. The cutoff $|z|\leq a$ in the longitudinal direction corresponds to a finite embedding space volume inside which the space-time sheets of target and projectile are in contact.

3. The production amplitude is non-trivial even if the interaction potential vanishes being given by

$$f(p) = \int d^2bexp(-ik\cdot b))A(b,p) = 2\pi int J_0(k_T(b)b)\times A(b,p)bdb \ . \tag{2.2.53}$$

This formula can be seen as a generalization of quantum formula in the sense that incoherent integral over production probabilities at various values of b is replaced by an integral over production amplitude over b so that interference effects become possible.

4. This result could be seen as a problem. On basis of $S=1+iT$ decomposition corresponding to free motion and genuine interaction, one could argue that since the exponent of action corresponds to S, $A(p,b)$ vanishes when the space-time sheets are not in contact. The improved guess for the amplitude is

$$
\begin{aligned}
f(p) &= \int d^2bexp(-ik\cdot b)exp(\frac{i}{\hbar}S(b))A(b,p) \\
&= \int J_0(k_T(b)b)(\frac{i}{\hbar}\int_{z=-a}^{z=a} V(z,b)+..)A(b,p) \quad .
\end{aligned} \tag{2.2.54}
$$

This would mean that there would be no classical limit when coherence is assumed to be lost. At this stage one must keep mind open for both options.

5. The dimension of $f(p)$ is $L^2/\hbar$

$$
d\sigma = |f(p)|^2\frac{d^3p}{2E_p(2\pi)^3} \quad . \tag{2.2.55}
$$

has correct dimension. This model will be considered in sequel. The earlier work in was however based on the first option.

Production amplitude

The Fourier transform of $E\cdot B$ can be expressed as a convolution of Fourier transforms of E and B and the resulting expression for the amplitude reduces by residue calculus (see APPENDIX) to the following general form

$$
\begin{aligned}
A(b,p) &\equiv N_0\times\frac{4\pi}{Z_1Z_2\alpha_{em}}\times U(b,p) = 2\pi i(CUT_1+CUT_2) \quad , \\
N_0 &= \frac{(2\pi)^7}{i} \quad .
\end{aligned} \tag{2.2.56}
$$

where nuclear charges are such that Coulomb potential is $1/r$. The motivation for the strange looking notation is to extract all powers of 2π so that the resulting amplitudes contain only factors of order unity.

The contribution of the first cut for $\phi\in[0,\pi/2]$ is given by the expression

$$
\begin{aligned}
CUT_1 &= D_1\times\int_0^{\pi/2} exp(-\frac{b}{b_0}cos(\psi))A_1d\psi \quad , \\
D_1 &= -\frac{1}{2}\frac{sin(\phi)}{sin(\theta)} \quad , \quad b_0=\frac{\hbar}{m}\frac{\beta\gamma}{\gamma_1} \quad , \\
A_1 &= \frac{A+iBcos(\psi)}{cos^2(\psi)+2iCcos(\psi)+D} \quad , \\
A &= sin(\theta)cos(\phi) \quad , \quad B=K \quad , \\
C &= K\frac{cos(\phi)}{sin(\theta)} \quad , \quad D=-sin^2(\phi)-\frac{K^2}{sin^2(\theta)} \quad , \\
K &= \beta\gamma(1-\frac{v_{cm}}{\beta}cos(\theta)) \quad , \quad v_{cm}=\frac{2v}{1+v^2} \quad .
\end{aligned} \tag{2.2.57}
$$

The definitions of the various kinematical variables are given in previous formulas. The notation is tailored to express the facts that A_1 is rational function of $cos(\psi)$ and that integrand depends exponentially on the impact parameter.

The expression for CUT_2 reads as

$$
\begin{aligned}
CUT_2 &= D_2 \times \int_0^{\pi/2} exp(i\frac{b}{b_1}cos(\psi))A_2 d\psi \ , \\
D_2 &= -\frac{sin(\frac{\phi}{2})}{usin(\theta)} \times exp(-\frac{b}{b_2}) \ , \\
b_1 &= \frac{\hbar}{m}\frac{\beta}{\gamma_1} \ , \ b_2 = \frac{\hbar}{mb}\frac{1}{\gamma_1 \times sin(\theta)cos(\phi)} \\
A_2 &= \frac{Acos(\psi)+B}{cos^2(\psi)+Ccos(\psi)+D} \ , \\
A &= sin(\theta)cos(\phi)u \ , \ B = \frac{w}{v_{cm}} + \frac{v}{\beta}sin^2(\theta)[sin^2(\phi)-cos^2(\phi)] \ , \\
C &= 2i\frac{\beta w}{uv_{cm}}\frac{cos(\phi)}{sin(\theta)} \ , \ D = -\frac{1}{u^2}(\frac{sin^2(\phi)}{\gamma^2} + \beta^2(v^2 sin^2(\theta) - \frac{2vw}{v_{cm}})cos^2(\phi)) \\
&+ \frac{w^2}{v_{cm}^2 u^2 sin^2(\theta)} + 2i\frac{\beta v}{u}sin(\theta)cos(\phi) \ , \\
u &= 1-\beta vcos(\theta) \ , \ w = 1-\frac{v_{cm}}{\beta}cos(\theta) \ . \qquad (2.2.58)
\end{aligned}
$$

(2.2.59)

The denominator X_2 has no poles and the contribution of the second cut is therefore always finite. Again the expression is tailored to make clear the functional dependence of the integrand on $cos(\psi)$ and on impact parameter. Besides this the exponential damping makes in non-relativistic situation the integrand small everywhere expect in the vicinity of $cos(\Psi)=0$ and for small values of the impact parameter.

Using the symmetries

$$
\begin{aligned}
U(b,p_x,-p_y) &= -U(b,p_x,p_y) \ , \\
U(b,-p_x,-p_y) &= \bar{U}(b,p_x,p_y) \ , \qquad (2.2.60)
\end{aligned}
$$

of the amplitude one can calculate the amplitude for other values of ϕ.

CUT_1 gives the singular contribution to the amplitude. The reason is that the factor X_1 appearing in denominator of cut term vanishes, when the conditions

$$
\begin{aligned}
cos(\theta) &= \frac{\beta}{v_{cm}} \ , \\
sin(\phi) &= cos(\psi) \ , \qquad (2.2.61)
\end{aligned}
$$

are satisfied. In forward direction this condition tells that z- component of the lepto-pion momentum in velocity center of mass coordinate system vanishes. In laboratory this condition means that the lepto-pion moves in certain cone defined by the value of its velocity. The condition is possible to satisfy only above the threshold $v_{cm} \geq \beta$.
For $K=0$ the integral reduces to the form

$$
CUT_1 = \frac{1}{2}cos(\phi)sin(\phi)\lim_{\varepsilon\rightarrow 0}\frac{\int_0^{\pi/2} exp(-\frac{cos(\psi)}{sin(\phi_0)})d\psi}{(sin^2(\phi)-cos^2\psi+i\varepsilon)} \ . \qquad (2.2.62)
$$

One can estimate the singular part of the integral by replacing the exponent term with its value at the pole. The integral contains two parts: the first part is principal value integral and second part can be regarded as integral over a small semicircle going around the pole of integrand in upper half plane. The remaining integrations can be performed using elementary calculus and one obtains for the singular cut contribution the approximate expression

$$
\begin{aligned}
CUT_1 &\simeq e^{-(b/a)(sin(\phi)/sin(\phi_0))}(\frac{ln(X)}{2}+\frac{i\pi}{2}) \ , \\
X &= \frac{((1+s)^{1/2}+(1-s)^{1/2})}{((1+s)^{1/2}-(1-s)^{1/2})} \ , \\
s &= sin(\phi) \ , \\
sin(\phi_0) &= \frac{\beta\gamma}{\gamma_1 m(\pi_L)a} \ .
\end{aligned} \tag{2.2.63}
$$

The principal value contribution to the amplitude diverges logarithmically for $\phi = 0$ and dominates over "pole" contribution for small values of ϕ. For finite values of impact parameter the amplitude decreases exponentially as a function of ϕ.

If the singular term appearing in CUT_1 indeed gives the dominant contribution to the lepto-pion production one can make some conclusions concerning the properties of the production amplitude. For given lepto-pion cm velocity v_{cm} the production associated with the singular peak is predicted to occur mainly in the cone $cos(\theta) = \beta/v_{cm}$: in forward direction this corresponds to the vanishing of the z-component of the lepto-pion momentum in velocity center of mass frame. Since the values of $sin(\theta)$ are of order .1 the transversal momentum is small and production occurs almost at rest in cm frame as observed. In addition, the singular production cross section is concentrated in the production plane ($\phi = 0$) due to the exponential dependence of the singular production amplitude on the angle ϕ and impact parameter and the presence of the logarithmic singularity. The observed lepto-pion velocities are in the range $\Delta v/v \simeq 0.2$ [C62] and this corresponds to the angular width $\Delta\theta \simeq 34$ degrees.

Differential cross section in the quantum model

There are two options to consider depending on whether one uses $exp(iS)$ or $exp(iS) - 1$ to define the production amplitude.

1. For the $exp(iS)$ option the expression for the differential cross section reads in the lowest order as

$$
\begin{aligned}
d\sigma &= K|f_B|^2\frac{d^3p}{2E_p} \ , \\
f_B &\simeq i\int exp(-i\Delta k\cdot r)(CUT_1+CUT_2)bdbdzd\phi \ , \\
K &= (Z_1Z_2)^2\alpha_{em}^4N_c^2(\frac{m(\pi_L)}{f(\pi_L)})^2\frac{1}{(2\pi)^{15}} \ .
\end{aligned} \tag{2.2.64}
$$

   Here Δk is the momentum exchange in Coulomb scattering and a vector in the scattering plane so that the above described formula is obtained for the linear orbits.

2. For the $exp(iS) - 1$ option the differential production cross section for lepto-pion is in the lowest non-trivial approximation for the exponent of action S given by the expression

$$
\begin{aligned}
d\sigma &= K|f_B|^2\frac{d^3p}{2E_p} \ , \\
f_B &\simeq \int exp(-i\Delta k\cdot r)V(z,b)(CUT_1+CUT_2)bdbdzd\phi \ , \\
V(z,b) &= \frac{1}{r} \ , \\
K &= (Z_1Z_2)^4\alpha_{em}^6N_c^2(\frac{m(\pi_L)}{f(\pi_L)})^2\frac{1}{(2\pi)^{15}} \ .
\end{aligned} \tag{2.2.65}
$$

   Effectively the Coulomb potential is replaced with the product of the Coulomb potential and lepto-pion production amplitude $A(b,p)$. Since α_{em} is assumed to correspond to relate to its standard value by a scaling $\hbar_0/\hbar$ factor.

3. Coulomb potential brings in an additional $(Z_1Z_2\alpha_{em})^2$ factor to the differential cross section, which in the case of heavy ion scattering increases the contribution to the cross section by a factor of order 3×10^3 but reduces it by a factor of order 5×10^{-5} in the case of proton-antiproton scattering. The increase of $\hbar$ expected to be forced by the requirement that perturbation theory is not lost however reduces the contribution from higher orders in V. It should be possible to distinguish between the two options on basis of these differences.

The scattering amplitude can be reduced to a simpler form by using the defining integral representation

$$J_0(x) = \frac{1}{2\pi}\int_0^{2\pi} exp(-ixsin(\phi))d\phi$$

of Bessel functions.

1. For $exp(iS)$ option this gives

$$\begin{aligned}
f_B &= 2\pi i\int J_0(\Delta kb)(CUT_1+CUT_2)bdb \ , \\
\Delta k &= 2ksin(\frac{\alpha}{2}) \ , \ k = M_R\beta \ , \\
M_R &\simeq A_Rm_p \ , \quad A_R = \frac{A_1A_2}{A_1+A_2} \ , \qquad (2.2.66)
\end{aligned}$$

where the length scale cutoffs in various integrations are not written explicitly. The value of α can be deduced once the value of impact parameter is known in the case of the classical Coulomb scattering.

2. For $exp(iS)-1$ option one has

$$\begin{aligned}
f_B &= 2\pi i\int F(b)J_0(\Delta kb)(CUT_1+CUT_2)bdb \ , \\
F(b\geq b_{cr}) &= 2\int dz\frac{1}{\sqrt{z^2+b^2}} = ln(\frac{\sqrt{a^2-b^2}+a}{b}) \ , \\
. & \qquad (2.2.67)
\end{aligned}$$

Note that the factors K appearing in the different cross section are different in these to cases.

Calculation of the lepto-pion production amplitude in the quantum model

The details related to the calculation of the production amplitude can be found in appendix and it suffices to describe only the general treatment here. The production amplitude of the quantum model contains integrations over the impact parameter and angle parameter ψ associated with the cut. The integrands appearing in the definition of the contributions CUT_1 and CUT_2 to the scattering amplitude have simple exponential dependence on impact parameter. The function F appearing in the definition of the scattering amplitude is a rather slow varying function as compared to the Bessel function, which allows trigonometric approximation and for small values of scattering angle equals to its value at origin. This motivates the division of the impact parameter range into pieces so that F can approximated with its mean value inside each piece so that integration over cutoff parameters can be performed exactly inside each piece.

In Appendix the explicit expansion in power series with respect to impact parameter is derived by assuming $J_0(k_Tb)\simeq 1$ and $F(b) = F = constant$. These formulas can be easily generalized by assuming a piecewise constancy of these two functions. This means that the only the integration over the lepto-pion phase space must be carried out numerically.

CUT_1 becomes also singular at $cos(\theta) = \beta/v_{cm}$, $cos(\psi) = \sin(\phi)$. The singular contribution of the production amplitude can be extracted by putting $cos(\psi) = sin(\phi)$ in the arguments of the exponent functions appearing in the amplitude so that one obtains a rational function of $cos(\psi)$ and $sin(\psi)$ integrable analytically. The remaining nonsingular contribution can be integrated numerically.

Formula for the production cross section

In the case of heavy ion collisions the rectilinear motion is not an excellent approximation since the anomalous events are observed near Coulomb wall and $\beta \simeq .1$ holds true. Despite this this can be taken as a first approximation.

The expression for the differential cross section for lepto-pion production in heavy ion collisions is given by

$$d\sigma = KF^2 |\int (CUT_1 + CUT_2) bdb|^2 \frac{d^3p}{2E} \ , \tag{2.2.68}$$

This expression and also the expressions of the integrals of CUT_1 and CUT_2 are calculated explicitly as powers series of the impact parameter in the Appendix.

1. For $exp(iS)$ option one has

$$\begin{aligned} K &= (Z_1Z_2)^2 \alpha_{em}^4 N_c^2 [\frac{m(\pi_L)}{f(\pi_L)}]^2 \frac{1}{(2\pi)^{13}} \ , \\ F &= 1 \ . \end{aligned} \tag{2.2.69}$$

2. For $exp(iS) - 1$ option one has

$$\begin{aligned} K &= (Z_1Z_2)^4 \alpha_{em}^6 N_c^2 [\frac{m(\pi_L)}{f(\pi_L)}]^2 \frac{1}{(2\pi)^{13}} \ , \\ F &= 2\langle\langle ln(\frac{\sqrt{a^2-b^2}+a}{b})\rangle\rangle \ . \end{aligned} \tag{2.2.70}$$

In the approximation that F is constant the two lowest order predictions are related by a scaling factor

$$R = (Z_1Z_2\alpha_{em})^2 F^2 \ . \tag{2.2.71}$$

It is interesting to get a rough order of magnitude feeling about the situation assuming that the contributions of CUT_1 and CUT_2 are of order unity. For $Z_1 = Z_2 = 92$ and $m(\pi_L)/f(\pi_L) \simeq 1.5$ -as in the case of ordinary pion- one obtains following results. It must be emphasized that these estimates are extremely sensitive to the over all scaling of f_B and to the choice of the cutoff parameter a and cannot be taken too seriously.

1. From $\beta \simeq .1$ one has $b_0 \simeq .1/m(\pi_L)$. One can argue that the impact parameter cutoff $a = xb_0$ should satisfy $a \geq 1/m_{\pi_L}$ so that $x \geq 10$ should hold true.
2. For $expi(S) - 1$ option one has $K = 4.7 \times 10^{-6}$. From the classical model the allowed phase space volume is of order $\frac{1}{3}\Delta v^3 \sim 10^{-4}$. By using $a = m(\pi_L)$ as a cutoff and $m(\pi_L) \simeq 2m_e$ one obtains $\sigma \sim 4$ μb, which is of same order of magnitude as the experimental estimate 5 μb.
3. For $exp(iS)$ option one has $K = 1.2 \times 10^{-9}$ and the estimate for cross section is 1.1 nb for $a = 1/m(\pi_L)$. A correct order of magnitude is obtained by assuming $a = 5.5/m(\pi_L)$ and that a^4 scaling holds true. At larger values of impact parameter a^2 scaling sets on and would require $a \sim 30/m(\pi_L)$ which would correspond to .36 A and to atomic length scale. It is not possible to distinguish between the two options.
4. The singular contribution near to production plane at the cone $v_{cm}cos(\theta) = \beta$ is expected to enhance the total cross section. The strong sensitivity of the cross section to the choice of the cutoff parameter allows to reproduce the experimental findings easily and it would be important to establish strong bounds on the value of the impact parameter.

Dominating contribution to production cross section and diffractive effects

Consider now the behavior of the dominating singular contribution to the production amplitude at the cone $cos(\theta) = \beta/v_{cm}$ depending on b via the exponent factor. This amplitude factorizes into a product

$$\begin{aligned}
f_{B,sing} &= K_0 a^2 B(\Delta k) A_{sing}(b,p) \ , \\
B(\Delta k) &= \int F(ax) J_0(\Delta k a x) exp(-\frac{sin(\phi)}{sin(\phi_0)} x) x dx \ , \\
&\sim \sqrt{\frac{2}{\pi \Delta k a}} \int F(ax) cos(\Delta k a x - \frac{\pi}{4}) exp(-\frac{sin(\phi)}{sin(\phi_0)} x) \sqrt{x} dx \ , \\
x &= \frac{b}{a} \ .
\end{aligned} \tag{2.2.72}$$

The factor $A_{sing}(b,p) \equiv (4\pi/(Z_1Z_2\alpha_{em})U_{sing}(b,p)$ is the analytically calculable singular and dominating part of the lepto-pion production amplitude (see appendix) with the exponential factor excluded. The factor B is responsible for diffractive effects. The contribution of the peak to the total production cross section is of same order of magnitude as the classical production cross section.

At the peak $\phi \sim 0$ the contribution the exponent of the production amplitude is constant at this limit one obtains product of the Fourier transform of Coulomb potential with cutoffs with the production amplitude. One can calculate the Fourier transform of the Coulomb potential analytically to obtain

$$\begin{aligned}
f_{B,sing} &\simeq 4\pi K_0 \frac{(cos(\Delta k a) - cos(\Delta k b_{cr}))}{\Delta k^2} CUT_1 \\
\Delta k &= 2\beta sin(\frac{\alpha}{2}) \ .
\end{aligned} \tag{2.2.73}$$

One obtains oscillatory behavior as a function of the collision velocity in fixed angle scattering and the period of oscillation depends on scattering angle and varies in wide limits.

The relationship between scattering angle α and impact parameter in Coulomb scattering translates the impact parameter cutoffs to the scattering angle cutoffs

$$\begin{aligned}
a &= \frac{Z_1Z_2\alpha_{em}}{M_R\beta^2} cot(\alpha(min)/2) \ , \\
b_{cr} &= \frac{Z_1Z_2\alpha_{em}}{M_R\beta^2} cot(\alpha(max)/2) \ .
\end{aligned} \tag{2.2.74}$$

This gives for the argument $\Delta k b$ of the Bessel function at lower and upper cutoffs the approximate expressions

$$\begin{aligned}
\Delta k a &\simeq \frac{2Z_1Z_2\alpha_{em}}{\beta} \sim \frac{124}{\beta} \ , \\
\Delta k b_{cr} &\simeq x_0 \frac{2Z_1Z_2\alpha_{em}}{\beta} \sim \frac{124 x_0}{\beta} \ .
\end{aligned} \tag{2.2.75}$$

The numerical values are for $Z_1 = Z_2 = 92$ (U-U collision). What is remarkable that the argument $\Delta k a$ at upper momentum cutoff does not depend at all on the value of the cutoff length. The resulting oscillation at minimum scattering angle is more rapid than allowed by the width of the observed peak: $\Delta\beta/\beta \sim 3 \cdot 10^{-3}$ instead of $\Delta\beta/\beta \sim 10^{-2}$: of course, the measured value need not correspond to minimum scattering angle. The oscillation associated with the lower cutoff comes from $cos(2M_R b_{cr} \beta sin(\alpha/2))$ and is slow for small scattering angles $\alpha < 1/A_R \sim 10^{-2}$. For $\alpha(max)$ the oscillation is rapid: $\delta\beta/\beta \sim 10^{-3}$.

In the total production cross section integrated over all scattering angles (or finite angular range) diffractive effects disappear. This might explain why the peak has not been observed in some experiments [C62].

Cutoff length scales

Consider next the constraints on the upper cutoff length scale.

1. The production amplitude turns out to decrease exponentially as a function of impact parameter b unless lepto-pion is produced in scattering plane. The contribution of lepto-pions produced in scattering plane however gives divergent contribution to the total cross section integrated over all impact parameter values and upper cutoff length scale a is necessary. If one considers scattering with scattering angle between specified limits this is of course not a problem of classical model.
2. Upper cutoff length scale must be longer than the Compton length of lepto-pion.
3. Upper cutoff length scale a should be certainly smaller than the interatomic distance. For partially ionized atoms a more stringent upper bound for a is the size r of atom defined as the distance above which atom looks essentially neutral: a rough extrapolation from hydrogen atom gives $r \sim a_0/Z^{1/3} \sim 1.5 \cdot 10^{-11}\ m$ (a_0 is Bohr radius of hydrogen atom). Therefore cutoff scale would be between Bohr radius $a_0/Z \sim .5 \cdot 10^{-12}\ m$ and r. In the recent case however atoms are completely ionized so that cutoff length scale can be longer. It turns out that 10 A reproduces the empirical estimate for the cross section correctly.

Numerical estimate for the electro-pion production cross section

The numerical estimate for the electro-pion production cross section (see **Fig. 2.1**) is carried out for thorium with ($Z = 90, A = 232$). The value of the collision velocity of the incoming nucleus in the rest frame of the second nucleus is taken as $\beta = .1$. From the width $\delta v/v = .2$ of velocity distribution in the same frame the upper bound $\gamma \leq 1 + \delta$, $\delta \simeq 2 \times 10^{-3}$ for the Lorentz boost factor of electro-pion in cm system is deduced. The cutoff is necessary because energy conservation is not coded to the structure of the model.

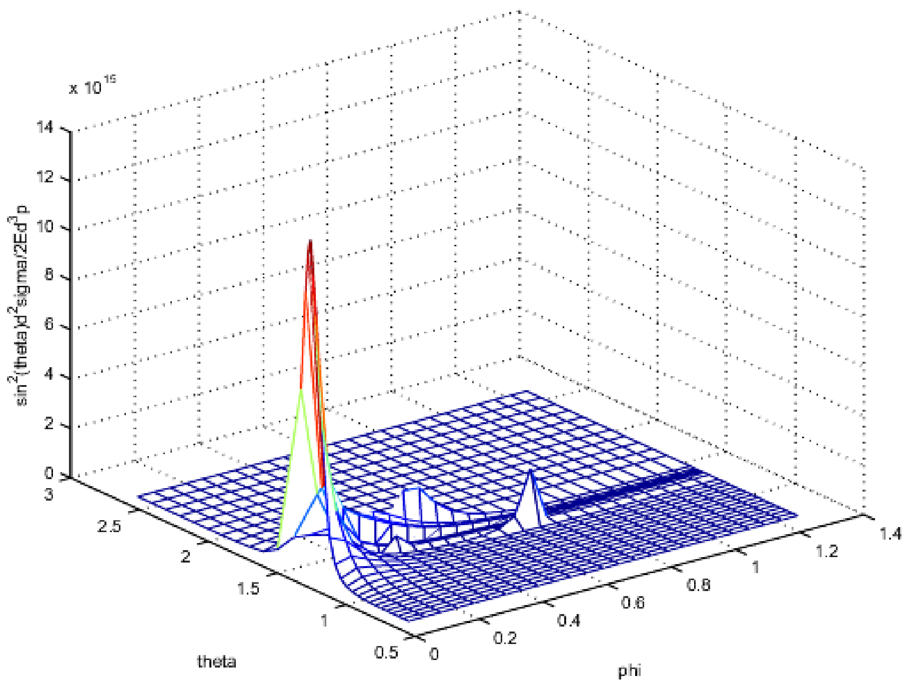

Figure 2.1: Differential cross section $sin^2(\theta) \times \frac{d^2\sigma}{2Ed^3p}$ for τ-pion production for $\gamma_1 = 1.0319 \times 10^3$ in the rest system of antiproton for $\delta = 1.5$. $m(\pi_\tau)$ defines the unit of energy and nb is the unit for cross section. The ranges of θ and ϕ are $(0, \pi)$ and $(0, \pi/2)$.

As expected, the singular contribution from the cone $v_{cm}cos(\theta) = \beta$, $v_{cm} = 2v/(1+v^2)$ gives the dominating contribution to the cross section. This contribution is proportional to the value of b_{max}^2 at the limit $\phi = 0$. Cutoff radius is taken to be $b_{max} = 150 \times \gamma_{cm}\hbar/m(\pi_e) = 1.04$ A. The numerical estimate for the cross section using the parameter values listed comes out as $\sigma = 5.6$ μb to be compared with the rough experimental estimate of about 5 μb. The interpretation would be that the space-time sheet associated with colliding nuclei during the collision has this transversal size in cm system. At this space-time sheet the electric and magnetic fields of the nuclei interfere.

From this one can cautiously conclude that lepto-pion model is consistent with both electro-pion production and τ-pion production in proton antiproton collisions. One can of course criticize the large value of impact parameter and a good justification for 1 Angstrom should be found. One could also worry about the singular character of the amplitude making the integration of total cross section somewhat risky business using the rather meager numerical facilities available. The rigorous method to calculate the contribution near the singularity relies on stepwise halving of the increment $\Delta\theta$ as one approaches the singularity. The calculation gives essentially the same result as that with constant value of $\Delta\theta$. Hence it seems that one can trust on the result of calculation.

Figure 2. gives the differential production cross section for $\gamma_1 = 1.0319$. Obviously the differential cross section is strongly concentrated at the cone due to singularity of the production amplitude for fixed b.

The important conclusion is that the same model can reproduce the value of production cross section for both electro-pions explaining the old electron-positron anomaly of heavy ion collisions and τ-pions explaining the CDF anomaly of proton-antiproton collisions at cm energy $\sqrt{s} = 1.96$ TeV (to be discussed later) with essentially same and rather reasonable assumptions (do not however forget the large maximal value of the impact parameter!).

In the case of electro-pions one must notice that depending on situation the final states are gamma pairs for the electron-pion with mass very nearly equal to electron mass. In the case of neutral tau-pion the strong decay to three p-adically scaled down versions of τ-pion proceeds faster or at least rate comparable to that for the decay to gamma pair. For higher mass variants of electro-pion for which there is evidence (for instance, one with mass 1.6 MeV) the final states are dominated by electron-positron pairs. This is true if the primary decay products are electro-baryons of form (say) $e_{ex} = e_8\nu_8\nu_{c,8}$ resulting via electro-strong decays instead of electrons and having slightly larger mass than electron. Otherwise the decay to gamma pair would dominate also the decays of higher mass states. A small magnetic moment type coupling between e, e_{ex} and electro-gluon field made possible by the color octet character of colored leptons induces the mixing of e and e_{ex} so that e_{ex} can transform to e by the emission of photon. The anomalous magnetic moment of electron poses restrictions on the color magnetic coupling.

$e_{ex}^+e_{ex}^-$ pairs from lepto-pions or e^+e^- pairs from lepto-sigmas?

If one assumes that anomalous e^+e^- pairs correspond to lepto-nucleon pairs, then lepto-pion production cross section gives a direct estimate for the production rate of e^+e^- pairs. The results of the table 3 show that in case of 1.8 MeV state, the predicted cross section is roughly by a factor 5 smaller than the experimental upper bound for the cross section. Since this lepto-pion state is rather massive, positron decay width allows smaller $f(\pi_L)$ in this case and the production cross section could be larger than the estimate used by the $1/f(\pi_L)^2$ proportionality of the cross section. Both the simplicity and predictive power of this option and the satisfactory agreement with the experimental data suggest that this option provides the most plausible explanation of the anomalous e^+e^- pairs.

Table 2.

If one assumes that anomalous e^+e^- pairs result from the decays of lepto-sigmas, the value of e^+e^- production cross section can be estimated as follows. e^+e^- pairs are produced from via the creation of $\sigma_L\pi_L$ pairs from vacuum and subsequent decay σ_L to e^+e^- pairs. The estimate for (or rather for the upper bound of) $\pi_L\sigma_L$ production cross section is obtained as

N	$Op/10^{-3}$	$\Gamma(\pi_L)/keV$	$\sigma(\pi_L)/\mu b$	$\sigma(\pi_L)/\mu b$
			$a = .01$	$a = .1$
1	1	.51	.13	1.4
3	1	.13	.04	.41
3	5	.73	.19	2.1

Table 2.2: Table summarizes lepto-pion lifetime and the upper bounds for lepto-pion (and lepto-nucleon pair) production cross sections for the lightest lepto-pion. N refers to the number of lepto-pion states and $Op = \Delta\Gamma/\Gamma$ refers to ortopositronium decay anomaly. The values of upper cutoff length a are in units of 10^{-10} m.

$$\begin{aligned}
\sigma(e^+e^-) &\simeq X\sigma(\pi_L) \ , \\
X &= \frac{V_2}{V_1}(\frac{km_{\sigma_L}}{m_{\pi_L}^2})^2 \ , \\
\frac{V_2}{V_1} &= V_{rel} = \frac{v_{12}^3}{3(2\pi)^2} \sim 1.1 \cdot 10^{-5} \ , \\
\frac{k}{m_{pi_L}} &= \frac{(m_\sigma^2 - m_{\pi_L}^2)}{2m_{\pi_L} f(\pi_L)} \ .
\end{aligned} \tag{2.2.76}$$

Here V_2/V_1 of two-particle and single particle phase space volumes. V_2 is in good approximation the product $V_1(cm)V_1(rel)$ of single particle phase space volumes associated with cm coordinate and relative coordinate and one has $V_2/V_1 \sim V_{rel} = \frac{v_{12}^3}{3(2\pi)^2)} \simeq 1.1 \cdot 10^{-5}$ if the maximum value of the relative velocity is $v_{12} \sim .1$.

Situation is partially saved by the anomalously large value of $\sigma_L\pi_L\pi_L$ coupling constant k appearing in the production vertex $k\sigma_L\pi_L\pi_L(class)$. Production cross section is very sensitive to the value of $f(\pi_L)$ and Op anomaly $\Delta\Gamma/\Gamma = 5 \cdot 10^{-3}$ gives upper bound 2 $\mu b/N_c^2$ for $a = 10^{-11}$ m, which is considerably smaller than the experimental upper bound 5 μb. The huge value of the $g(\pi_L, \pi_L, \sigma_L)$ and $g(\sigma_L, \sigma_L, \sigma_L)$, however implies that radiative corrections to the cross section given by σ exchange are much larger than the lowest order contribution to the cross section! If this is the case then lepto-sigma option might survive but perturbative approach probably would not make sense. On the other hand, one could argue that sigma model action should be regarded as an effective action giving only tree diagrams so that radiative corrections cannot save the situation. There are also purely physical counter arguments against lepto-sigma option: hadronic physics experience suggests that the mass of lepto-sigma is much larger than lepto-pion mass so that lepto-sigma becomes very wide resonance decaying strongly and having negligibly small branching ratio to e^+e^- pairs.

It must be emphasized that the estimates are very rough (the replacement of the integral over the angle α with rough upper bound, estimate for the phase space volume, the values of cutoff radii, the neglect of the velocity dependence of the production cross section, the estimate for the minimum scattering angle, ...). Also the measured production cross section is subject to considerable uncertainties (even the issue whether or not anomalous pairs are produced is not yet completely settled!).

Summary

The usefulness of the modelling lepto-pion production is that the knowledge of lepto-pion production rate makes it possible to estimate also the production rates for other lepto-hadrons and even for many particle states consisting of lepto-hadrons using some effective action describing the strong interactions between lepto-hadrons. One can consider two basic models for lepto-pion production. The models contain no free parameters unless one regards cutoff length scales as such. Classical model predicts the singular production characteristics of lepto-pion. Quantum model predicts several velocity peaks at fixed scattering angle and the distance between the peaks of the production cross section depends sensitively on the value of the scattering angle. Production cross section depends sensitively on the value of the scattering angle for a fixed collision velocity. In both models the reduction of the lepto-pion production rate above Coulomb wall could be understood as a threshold effect: for the collisions with impact parameter smaller than two times nuclear radius, the production amplitude becomes very small since $E \cdot B$ is more or less random for these collisions in the interaction region. The effect is visible for fixed sufficiently large scattering angle only. The value of the anomalous e^+e^- production cross section is of nearly the observed order of magnitude provided that e^+e^- pairs are actually lepto-nucleon pairs originating from the decays of the lepto-pions. Alternative mechanism, in which anomalous pairs originate from the creation of $\sigma_L\pi_L$ pairs from vacuum followed by the decay $\sigma_L \to e^+e^-$ gives too small production cross section by a factor of order $1/N_c^2$ in lowest order calculation. This alternative works only provided that radiative corrections give the dominant contribution to the production rate of $\pi_L\sigma_L$ pairs as is the case if $\pi_L\sigma_L$ mass difference is of order ten per cent. The existence of at least three colored leptons and family replication provide the most plausible explanation the appearance of several peaks.

The proposed models are certainly over idealizations: in particular the approximation that nuclear motion is free motion fails for those values of the impact parameter, which are most important in the classical model. To improve the models one should calculate the Fourier transform of $E \cdot B$ using the fields of nuclei for classical orbits in Coulomb field rather than free motion. The second improvement is related to the more precise modelling of the situation at length scales below b_{cr}, where nuclei do not behave like point like charges. A peculiar feature of the model from the point of view of standard physics is the appearance of the classical electromagnetic fields associated with the classical orbits of the colliding nuclei in the definition of the quantum model. This is in spirit with Quantum TGD: Quantum TGD associates a unique space-time surface (classical history) to a given 3-surface (counterpart of quantum state).

2.3 Further Developments

This section represents further developments of lepto-hadron model which have emerged during years after the first version of the model published in International Journal of Theoretical Physics.

2.3.1 How To Observe Leptonic Color?

The most obvious argument against lepto-hadrons is that their production via the decay of virtual photons to lepto-mesons has not been observed in hadronic collisions. The argument is wrong. Anomalously large production of low energy e^+e^- pairs [C52, C72, C58, C141] in hadronic collisions has been actually observed. The most natural source for photons and e^+e^- pairs are lepto-hadrons. There are two possibilities for the basic production mechanism.

1. Colored leptons result directly from the decay of hadronic gluons. Internal consistency excludes this alternative.

2. Colored leptons result from the decay of virtual photons. This hypothesis is in accordance with the general idea that the QCD: s associated with different condensate levels of p-adic topological condensate do not communicate. More precisely, in TGD framework leptons and quarks correspond to different chiralities of WCW spinor s: this implies that baryon and lepton numbers are conserved exactly and therefore the stability of proton. In particular, leptons and quarks correspond to different Kac Moody representations: important difference as compared with typical unified theory, where leptons and quarks share common multiplets of the unifying group. The special feature of TGD is that there are several gluons since it is possible to associate to each Kac-Moody representation gluons, which are "irreducible" in the sense that they couple only to a single Kac Moody representation. It is clear that if the physical gluons are "irreducible" the world separates into different Kac Moody representations having their own color interactions and communicating only via electro-weak and gravitational interactions. In particular, no strong interactions between leptons and hadrons occur. Since colored lepton corresponds to colored ground state of Kac-Moody representations the gluonic color coupling between ordinary lepton and colored lepton vanishes.

If this picture is correct then lepto-hadrons are produced only via the ordinary electro-weak interactions: at higher energies via the decay of virtual photon to colored lepton pair and at low energies via the emission of lepto-pion by photon. Consider next various ways to observe the effects of lepton color.

1. Resonance structure in the photon-photon scattering and energy near lepto-pion mass is a unique signature of lepto-pion.
2. The production of lepto-mesons in strong classical electromagetic fields (of nuclei, for example) is one possibility. There are several important constraints for the production of lepto-pions in this kind of situation.

   i) The scalar product $E \cdot B$ must be large. Faraway from the source region this scalar product tends to vanish: consider only Coulomb field.

   ii) The region, where $E \cdot B$ has considerable size cannot be too small as compared with lepto-pion de Broglie wavelength (large when compared with the size of nuclei for example). If this condition doesn't hold true the plane wave appearing in Fourier amplitude is essentially constant spatially and since the fields are approximately static the Fourier component of $E \cdot B$ is expressible as a spatial divergence, which reduces to a surface integral over a surface faraway from the source region. Resulting amplitude is small since fields in faraway region have essentially vanishing $E \cdot B$.

   iii) If fields are exactly static, then energy conservation prohibits lepto-hadron production.
3. Also the production of $e^+_{ex}e^-_{ex}$ and $e^+e^-_{ex}$ pairs in nuclear electromagnetic fields with non-vanishing $E \cdot B$ is possible either directly or as decay products of lepto-pions. In the direct production, the predicted cross section is small due to the presence of two-particle phase space factor. One signature of e^-_{ex} is emission line accompanying the decay $e^-_{ex} \rightarrow e^- + \gamma$. The collisions of nuclei in highly ionized (perhaps astrophysical) plasmas provide a possible source of leptobaryons.
4. The interaction of quantized em field with classical electromagnetic fields is one experimental arrangement to come into mind. The simplest arrangement consisting of linearly polarized photons with energy near lepto-pion mass plus constant classical em field does not however work. The direct production of $\pi_L - \gamma$ pairs in rapidly varying classical electromagnetic field with frequency near lepto-pion mass is perhaps a more realistic possibility. An interesting possibility is that violent collisions inside astrophysical objects could lead to gamma ray bursts via the production of pions and lepto-pions in rapidly varying classical E and B fields.
5. In the collisions of hadrons, virtual photon produced in collision can decay to lepto-hadrons, which in turn produce lepto-pions decaying to leptonucleon pairs. As already noticed, anomalous production of low energy e^+e^- pairs (actually leptonucleon pairs!) [C52] in hadronic collisions has been observed.
6. $e - \nu_e$ and $e - \bar{\nu}_e$ scattering at energies below one MeV provide a unique signature of lepto-pion. In $e - \bar{\nu}_e$ scattering π_L appears as resonance.
7. If leptonic color coupling strength has sufficiently small value in the energy range at which lepto-hadronic QCD exists, e^+e^- annihilation at energies above few MeV should produce colored pairs and lepto-hadronic counterparts of the hadron jets should be observed. The fact that nothing like this has been observed, suggests that lepto-hadronic coupling constant evolution does not allow the perturbative QCD phase.

2.3.2 New Experimental Evidence

After writing this chapter astrophysical support for the notion of lepto-pions has appeared. There is also experimental evidence for the existence of colored muons

Could lepto-hadrons correspond to dark matter?

The proposed identification of cosmic strings (in TGD sense) as the ultimate source of both visible and dark matter discussed in [K31] does not exclude the possibility that a considerable portion of topologically condensed cosmic strings have decayed to some light particles. In particular, this could be the situation in the galactic nuclei.

The idea that lepto-hadrons might have something to do with the dark matter has popped up now and then during the last decade but for some reason I have not taken it seriously. Situation changed towards the end of the year 2003. There exist now detailed maps of the dark matter in the center of galaxy and it has been found that the density of dark matter correlates strongly with the intensity of monochromatic photons with energy equal to the rest mass of electron [E15].

The only explanation for the radiation is that some yet unidentified particle of mass very nearly equal to $2m_e$ decays to an electron positron pair. Electron and positron are almost at rest and this implies a high rate for the annihilation to a pair of gamma rays. A natural identification for the particle in question would be as a lepto-pion (or rather, electro-pion). By their low mass lepto-pions, just like ordinary pions, would be produced in high abundance, in lepto-hadronic strong reactions and therefore the intensity of the monochromatic photons resulting in their decays would serve as a measure for the density of the lepto-hadronic matter. Also the presence of lepto-pionic condensates can be considered.

These findings force to take seriously the identification of the dark matter as lepto-hadrons. This is however not the only possibility. The TGD based model for tetra-neutrons discussed in [K103] is based on the hypothesis that mesons made of scaled down versions of quarks corresponding to Mersenne prime M_{127} (ordinary quarks correspond to $k = 107$) and having masses around one MeV could correspond to the color electric flux tubes binding the neutrons to form a tetra-neutron. The same force would be also relevant for the understanding of alpha particles.

There are also good theoretical arguments for why lepto-hadrons should be dark matter in the sense of having a non-standard value of Planck constant.

1. Since particles with different Planck constant correspond to different pages of the book like structure defining the generalization of the embedding space, the decays of intermediate gauge bosons to colored excitations of leptons would not occur and would thus not contribute to their decay widths.
2. In the case of electro-pions the large value of the coupling parameter $Z_1Z_2\alpha_{em} > 1$ combined with the hypothesis that a phase transition increasing Planck constant occurs as perturbative QFT like description fails would predict that electro-pions represent dark matter. Indeed, the power series expansion of the $exp(iS)$ term might well fail to converge in this case since S is proportional to Z_1Z_2. For τ-pion production one has $Z_1 = -Z_2 = 1$ and in this case one can consider also the possibility that τ-pions are not dark in the sense of having large Planck constant. Contrary to the original expectations darkness does not affect the lowest order prediction for the production cross section of lepto-pion.

The proposed identification raises several questions.

1. Why the ratio of the lepto-hadronic mass density to the mass density of the ordinary hadrons would be so high, of order 7? Could an entire hierarchy of asymptotically non-free QCDs be responsible for the dark matter so that lepto-hadrons would explain only a small portion of the dark matter?
2. Under what conditions one can regard lepto-hadronic matter as a dark matter? Could short life-times of lepto-hadrons make them effectively dark matter in the sense that there would be no stable enough atom like structures consisting of say charged leptobaryons bound electromagnetically to the ordinary nuclei or electrons? But what would be the mechanism producing lepto-hadrons in this case (nuclear collisions produce lepto-pions only under very special conditions)?
3. What would be the role of the many-sheeted space-time: could lepto-hadrons and atomic nuclei reside at different space-time sheets so that leptobaryons could be long-lived? Could dark matter quite generally correspond to the matter at different space-time sheets and thus serve as a direct signature of the many-sheeted space-time topology?

Lightnings and lepto-pions

The latest discovery of Fermi space-telescope [C29] is the finding of.511 MeV gamma rays in the spectrum of photons associated with lightnings. It was discovered already years ago that lightnings are accompanied by X-rays [C128] and even gamma rays [C125]. For instance, the strong electric fields created by a positively charged region of cloud could accelerate electron from both downwards and upwards to this region. The problem is that atmosphere is not empty and dissipation would restrict the energies to be much lower than gamma ray energies which are in MeV range. Note that the temperatures in lightning are about 3×10^4 K and correspond to electron energy of 2.6 eV which is by a factor 10^5 smaller than electron mass and gamma ray energy scale!

Situation changes if dissipation is absent so that the electrons are accelerated without any energy losses. This is the case if the electrons reside in large $\hbar$ quantum phase at magnetic flux tubes so that dissipative losses are small and electrons can reach relativistic energies. This is the explanation that I provided years ago for the [K40].

Fermi however observed also something completely new. There is also a peaking of gamma rays around energy .511 MeV. The decay of electro-pion is an obvious explanation for this peaking. If electro-pions are there, collisions of highly energetic particles lasting for time of about $\tau \sim \hbar/\text{MeV}$ are expected. The natural candidates for the colliding charged particles are electrons. The center of mass system -the system in which total momentum of colliding electron pair vanishes- should be in a good approximation at rest with respect to Fermi space telescope. Otherwise the energy of gamma rays would be higher or lower than .511 MeV.

The only possibility that I can imagine is that the second electron comes from below and second from above the positively charged region of the thunder cloud. Both arrive as dark electrons with a large value of $\hbar$ and are accelerated to relativistic energies since dissipation is very small. They could collide as dark electrons (the more probable option as will be found below) or suffer a phase transition transforming them to ordinary electrons before the collision. Electro-pion coherent state is created in the strong $E \cdot B$ created for a a period of time of order $\tau \sim \hbar_0/\text{MeV}$. This state annihilates rapidly to pairs of gamma rays which are ordinary or transform to ordinary ones depending on whether electrons where dark or not.

What the phase transition of dark electrons to ordinary electrons means, needs some explaining. The generalized embedding space is obtained by gluing almost copies of 8-D embedding space $M^4 \times CP_2$ along their common back to get a book like structure. Particles at different pages of the book are dark with respect to each other in the sense that they have no local interactions. This is enough to explain what is actually known about dark matter. Particles at different pages can however interact via classical fields and photon exchange (for instance). The phase transition of electron from dark to visible form preceding the collision of dark electrons would simply mean the leakage from large $\hbar$ page to the "visible" page with ordinary value of Planck constant.

Alert reader might be ready to ask the obvious question. Why not to test the hypothesis in laboratory? It should not be too difficult to allow two electrons to collide with a relativistic energy and find whether gamma pairs with energy.511 MeV are produced in rest system. Maybe gamma ray pairs have been missed for some reason? If not (the probable option), then colored electrons and lepto-pions are always dark. This would explain why the colored leptons do not contribute to the decay widths of weak gauge bosons which pose very strong constraints for the existence of light exotic particles.

Lightnings, dark matter, and lepto-pion hypothesis again

Lightnings have been found to involve phenomena difficult to understand in the framework of standard physics. Very high energy photons, even gamma rays and electrons and positrons with energies in gamma energy range, have been observed.

I learned recently about even more mysterious looking discovery (see `http://tinyurl.com/jucwhod`. Physicist Joseph Dwyer from University of New Hampshire and lightning scientists from the University of California at Santa Cruz and Florida Tech describe this discovery in a paper to be published in the Journal of Plasma Physics. In August 2009, Dwyer and colleagues were aboard a National Center for Atmospheric Research Gulfstream V when it inadvertently flew into the extremely violent thunderstorm—and, it turned out, through a large cloud of positrons, the antimatter opposite of electrons, that should not have been there. One would have expected that positrons would have been produced by annihilation of highly energetic gamma rays with energy aboe .5 MeV but no gamma rays were detected.

This looks rather mysterious from standard physics point of view. There are also earlier strange discoveries

1. Lightning strikes release powerful X-ray bursts [C128] (see "Lightning strikes release powerful X-ray bursts" at `tinyurl.com/zqc7r7z`).

2. Also high energy gamma rays and electrons accompany lighnings [C125] (see "Earth creates powerful gamma-ray flashes" at `http://tinyurl.com/juy8uj8`). The problem is that electrons should lose their energy while traversing through the atmosphere so that energies in even X ray range would be impossible.
3. The third strange discovery was made with Fermi telescope [C29] (see "Antimatter from lightning flashes the Fermi space telescope" at `http://tinyurl.com/p2z3n9p`): gamma rays with energies .511 MeV (electron mass) accompany lightnings as if something with mass of 2 electron masses would decay to gamma pairs.

Could TGD explain these findings.

1. A possible explanation for the finding of Fermi telescope is that in the strong magnetic field of colliding very high energy colliding electrons assignable to the dark magnetic flux tubes of Earth particles that I call electropions suggested by TGD are created [K115] (see `http://tinyurl.com/zvk3umn`). Also evidence for mu-pions and tau-pions exists. They would have mass rather precisely 2 times the mass of electron and would be bound states of color excited electron and positron. Evidence for this kind of states was found already at seventies in heavy ion collisions around Coulomb wall producing electron positron pairs at total energy of 2 times electron mass but since they do not fit at all to the standard physics picture (too large decay width for weak bosons would be predicted) they have been put under the rug, so to say. The paradox is solved if these particles are dark in TGD sense.
2. If the annihilations of electropions give rise to dark electron-positron pairs and dark gamma rays, which then transform to ordinary particles, one could understand the absence of gamma rays in the situation described by Dwyer *et al* in terms of too slow transformation to ordinary particles. For instance, the strong electric fields created by a positively charged region of cloud could accelerate electron from both downwards and upwards to this region and lepto-pions would be generated in the strong magnetic fields generating strong electromagnetic instanton density $E \cdot B$ generating lepto-pion coherent state. If only positrons are observed, the absence of electrons could be due to different direction of accelerate motion for electrons. Since electrons are observed at the surface of Earth, this would suggest that electron positron pairs are created below the airplane.
3. But how it is possible to observe gamma rays and ultrahigh energy electrons at the surface of Earth? The problem is that atmosphere is not empty and dissipation would restrict the energies to be much lower than gamma ray energies which are in MeV range. Note that the temperatures in lightning are about 3×10^4 K and correspond to electron energy of 2.6 eV which is by a factor 10^5 smaller than electron mass and gamma ray energy scale! And how the electrons with energies above MeV range are created in thunder cloud? For years ago I proposed a model for high energy gamma rays and electrons associated with lightnings in terms of dark matter identified as $h_{eff} = n \times h$ phases. This model could provide answer to these questions.

First some background is needed.

1. I ended up to $h_{eff} = n \times h$ hypothesis [K43, ?] from the observations of Blackman and other pioneers of bio-electromagnetism [J7] about quantal effects of ELF em fields to vertebrate brain, which he explained in terms of cyclotron frequencies of Ca^+ ion in endoneous magnetic field $B_{end} = 0.2$ Gauss (2/5:th of the nominal value $B_E = .5$ Gauss of the Earth's magnetic field). Cyclotron energy $E = h \times f$ is however extremely low, much below the thermal energy in physiological temperature so that no quantal effects should be possible. This inspited the hypothesis $h_{eff} = n \times h$ scaling up the energy.
2. Nottale [E9] introduced originally the notion of gravitational Planck constant $\hbar_{gr} = GMm/v_0$ to explain the orbital radii of planets in solar system as Bohr orbits. The velocity parameter v_0 is different for inner and outer planets and quite recently I proposed v_0 is in constant ratio to the rotation velocity of the large mass M. The interpretation in TGD framework is that the magnetic flux tubes mediate gravitational interaction between M and m and the value of Planck constant is h_{gr} at them. The proposal $h_{eff} = h_{gr}$ at flux tubes is very natural sharpening of the original hypothesis [?, K80]. The predictions of the model do not depend on whether m is taken to be the mass of the planet or any elementary particle associated with

it and the gravitational Compton length $\lambda_{gr} = GMc/v_0$ does not depend on the mass of the particle as is proportional to the Schwartschild radius $2GM$ of Sun.

3. This hypothesis can be generalized to apply also to Earth (see `http://tinyurl.com/ht4pwy7`). For the strength $B_{gal} \sim 1$ nT for galactic magnetic field assumed to mediate Earth's gravitational interaction cyclotron frequency 10 Hz in alpha band is mapped to cyclotron frequency scale of 72 minutes. Scaled EEG range corresponds to cyclotron periods varying up to 12 hours for B_{gal}. For $M = M_E$ and B_{gal} the cyclotron energy corresponds to about 1 eV at the lower end of visible photon energies.

4. What about the interpretation of ordinary EEG in terms of cyclotron frequencies assuming that the corresponding energies are in visible and UV range corresponding to the variation of B_{end}?

   M_E is certainly too large to give a spectrum of cyclotron energies in this range suggested by Blackman to explain the findings about quantal effects of ELF radiation on brain not possible in standard quantum theory because the energy is much below the thermal threshold. $M_D \simeq .5 \times 10^{-4} M_E$ would be needed. I have proposed that M_D corresponds to a mass assignable to a spherical layer at distance of Moon's orbital radius and there are independent pieces of evidence for the existence of this layer. Ordinary intuition about gravitatio however suggests that the flux tubes with this value of h_{gr} must be outside the Moon's orbital radius.

   The most attractive solution of the problem emerged from the observation that the "inner inner" core of Earth having radius about 300 km has mass of order $M_D = 10^{-4} M_E$ if the density in this region is the average density of Earth. Probably M_D is somewhat larger meaning that actual estimate is higher, and even $M_D = 2 \times 10^{-4} M_E$ giving 4 times higher cyclotron energy scale - bio-photon energies include visible and UV range so that this might well make sense.

   B_{end} would represent the lower bound for the value range of the magnetic field varying at least by 7 octaves would give the highest UV energies around 124 eV. The transformation of dark photons to ordinary photons would yield biophotons with energies in visible and UV range. Also B_{gal} would have some variation range.

5. This has a connection to quantum biology and neuroscience. The proposal is that dark cyclotron photons with energies in visible and UV range associated with flux tubes of magnetic field of appropriate strength serve as a communication tool making biological body (BB) to communicate sensory data to magnetic body (MB) and allow BB to control BB. The recent model involves

Consider now the model for how electrons and gamma rays accompanying lightnings can travel to the surface of Earth without dissipating their energies and how the collisions of electrons with gamma ray energies generating electropions are possible.

1. What happens if one replaces M_D with M_E meaning that also Earth's gravitons would reside at the flux tubes of B_{end}? The energies get scale up by a factor $M_E/M_1 = 2 \times 10^4$ and this scales up the 1-100 eV range .02-2 MeV so that also gamma ray energies would be obtained.

2. The earlier proposal was that electrons and gamma rays associated with lightning arrive to the surface of Earth along dark magnetic flux tubes so that by macroscopic quantum coherence in scale of λ_{gr} they do not dissipate their energy.

Experimental evidence for colored muons

Also μ and τ should possess colored excitations. About fifteen years after this prediction was made. Direct experimental evidence for these states finally emerges (the year I am adding this comment is 2007) [C107, C108]. The mass of the new particle, which is either scalar or pseudo-scalar, is 214.4 MeV whereas muon mass is 105.6 MeV. The mass is about 1.5 per cent higher than two times muon mass. The proposed interpretation is as a light Higgs. I do not immediately resonate with this interpretation although p-adically scaled up variants of also Higgs bosons live happily in the fractal Universe of TGD. The most natural TGD inspired interpretation is as a pion like bound state of colored excitations of muon completely analogous to lepto-pion (or rather, electro-pion).

Scaled up variants of QCD appear also in nuclear string model [K103, L4], [L4], where scaled variant of QCD for exotic quarks in p-adic length scale of electron is responsible for the binding of ^4He nuclei to nuclear strings. One cannot exclude the possibility that the fermion and anti-fermion at the ends of color flux tubes connecting nucleons are actually colored leptons although the working hypothesis is that they are exotic quark and anti-quark. One can of course also turn around the argument: could it be that lepto-pions are "leptonuclei", that is bound states of ordinary leptons bound by color flux tubes for a QCD in length scale considerably shorter than the p-adic length scale of lepton.

2.3.3 Evidence For τ-Hadrons

The evidence for τ-leptons came in somewhat funny but very pleasant manner. During my friday morning blog walk, the day next to my birthday October 30, I found that Peter Woit had told in his blog about a possible discovery of a new long-lived particle by CDF experiment [C132] emphasizing how revolutionary finding is if it is real. There is a detailed paper [C34] with title *Study of multi-muon events produced in p-pbar collisions at* $\sqrt(s) = 1.96\ TeV$ by CDF collaboration added to the ArXiv October 29 - the eve of my birthday. I got even second gift posted to arXiv the very same day and reporting an anomalously high abundance of positrons in cosmic ray radiation [C126]. Both of these article give support for basic predictions of TGD differentiating between TGD and standard model and its generalizations.

The first gift

A brief summary of Peter Woit about the finding gives good idea about what is involved.

The article originates in studies designed to determine the b-bbar cross-section by looking for events, where a b-bbar pair is produced, each component of the pair decaying into a muon. The b-quark lifetime is of order a picosecond, so b-quarks travel a millimeter or so before decaying. The tracks from these decays can be reconstructed using the inner silicon detectors surrounding the beam-pipe, which has a radius of 1.5 cm. They can be characterized by their impact parameter, the closest distance between the extrapolated track and the primary interaction vertex, in the plane transverse to the beam.

If one looks at events where the b-quark vertices are directly reconstructed, fitting a secondary vertex, the cross-section for b-bbar production comes out about as expected. On the other hand, if one just tries to identify b-quarks by their semi-leptonic decays, one gets a value for the b-bbar cross-section that is too large by a factor of two. In the second case, presumably there is some background being misidentified as b-bbar production.

The new result is based on a study of this background using a sample of events containing two muons, varying the tightness of the requirements on observed tracks in the layers of the silicon detector. The background being searched for should appear as the requirements are loosened. It turns out that such events seem to contain an anomalous component with unexpected properties that disagree with those of the known possible sources of background. The number of these anomalous events is large (tens of thousands), so this cannot just be a statistical fluctuation.

One of the anomalous properties of these events is that they contain tracks with large impact parameters, of order a centimeter rather than the hundreds of microns characteristic of b-quark decays. Fitting this tail by an exponential, one gets what one would expect to see from the decay of a new, unknown particle with a lifetime of about 20 picoseconds. These events have further unusual properties, including an anomalously high number of additional muons in small angular cones about the primary ones.

The lifetime is estimated to be considerably longer than b quark life time and below the lifetime 89.5 ps of $K_{0,s}$ mesons. The fit to the tail of "ghost" muons gives the estimate of 20 picoseconds.

The second gift

In October 29 also another remarkable paper [C126] had appeared in arXiv. It was titled *Observation of an anomalous positron abundance in the cosmic radiation.* PAMELA collaboration finds an excess of cosmic ray positron at energies 10 $\rightarrow$ 50 GeV. PAMELA anomaly is discussed in Resonaances blog [C7]. ATIC collaboration in turn sees an excess of electrons and positrons going all the way up to energies of order 500-800 GeV [C99].

Also Peter Woit refers to these cosmic ray anomalies and also to the article *LHC Signals for a SuperUnified Theory of Dark Matter* by Nima Arkadi-Hamed and Neal Weiner [C20], where a model of dark matter inspired by these anomalies is proposed together with a prediction of lepton jets with invariant masses with mass scale of order GeV. The model assumes a new gauge interaction for dark matter particles with Higgs and gauge boson masses around GeV. The prediction is that LHC should detect "lepton jets" with smaller angular separations and GeV scale invariant masses.

Explanation of the CDF anomaly

Consider first the CDF anomaly. TGD predicts a fractal hierarchy of QCD type physics. In particular, colored excitations of leptons are predicted to exist. Neutral lepto-pions would have mass only slightly above two times the charged lepton mass. Also charged lepto-pions are predicts and their masses depend on what is the p-adic mass scale of neutrino and it is not clear whether it is much longer than that for charge colored lepton as in the case of ordinary leptons.

1. There exists a considerable evidence for colored electrons as already found. The anomalous production of electron positron pairs discovered in heavy ion collisions can be understood in terms of decays of electro-pions produced in the strong non-orthogonal electric and magnetic fields created in these collisions. The action determining the production rate would be proportional to the product of the lepto-pion field and highly unique "instanton" action for electromagnetic field determined by anomaly arguments so that the model is highly predictive.
2. Also the.511 MeV emission line [C60, C94] from the galactic center can be understood in terms of decays of neutral electro-pions to photon pairs. Electro-pions would reside at magnetic flux tubes of strong galactic magnetic fields. It is also possible that these particles are dark in TGD sense.
3. There is also evidence for colored excitations of muon and muo-pion [C107, C108]. Muo-pions could be produced by the same mechanism as electro-pions in high energy collisions of charged particles when strong non-orthogonal magnetic and electric fields are generated.

Also τ-hadrons are possible and CDF anomaly can be understood in terms of a production of higher energy τ-hadrons as the following argument demonstrates.

1. τ-QCD at high energies would produce "lepton jets" just as ordinary QCD. In particular, muon pairs with invariant energy below $2m(\tau) \sim 3.6$ GeV would be produced by the decays of neutral τ-pions. The production of monochromatic gamma ray pairs is predicted to dominate the decays. Note that the space-time sheet associated with both ordinary hadrons and τ lepton correspond to the p-adic prime $M_{107} = 2^{107} - 1$.
2. The model for the production of electro-pions in heavy ion collisions suggests that the production of τ-pions could take place in higher energy collisions of protons generating very strong non-orthogonal magnetic and electric fields. This This would reduce the model to the quantum model for electro-pion production.
3. One can imagine several options for the detailed production mechanism.
   (a) The decay of *virtual* τ-pions created in these fields to pairs of leptobaryons generates lepton jets. Since colored leptons correspond to color octets, leptobaryons could correspond to states of form LLL or $L\overline{L}L$.
   (b) The option inspired by a blog discussion with Ervin Goldfein is that a coherent state of τ-pions is created first and is then heated to QCD plasma like state producing the lepton jets like in QCD. The linear coupling to $E \cdot B$ defined by em fields of colliding nucleons would be analogous to the coupling of harmonic oscillator to constant force and generate the coherent state.
   (c) The option inspired by CDF model [C64] is that a p-adically scaled up variant of *on mass shell* neutral τ-pion having $k = 103$ and 4 times larger mass than $k = 107$ τ-pion is produced and decays to three $k = 105$ τ-pions with $k = 105$ neutral τ-pion in turn decaying to three $k = 107$ τ-pions.
4. The basic characteristics of the anomalous muon pair prediction seems to fit with what one would expect from a jet generating a cascade of τ-pions. Muons with both charges would be

produced democratically from neutral τ-pions; the number of muons would be anomalously high; and the invariant masses of muon pairs would be below 3.6 GeV for neutral τ-pions and below 1.8 GeV for charged τ-pions if colored neutrinos are light.

5. The lifetime of 20 ps can be assigned with charged τ-pion decaying weakly only into muon and neutrino. This provides a killer test for the hypothesis. In absence of CKM mixing for colored neutrinos, the decay rate to lepton and its antineutrino is given by

$$\Gamma(\pi_\tau \rightarrow L + \overline{\nu}_L) = \frac{G^2 m(L)^2 f^2(\pi)(m(\pi_\tau)^2 - m(L)^2)^2}{4\pi m^3(\pi_\tau)} . \tag{2.3.1}$$

The parameter $f(\pi_\tau)$ characterizing the coupling of pion to the axial current can be written as $f(\pi_\tau) = r(\pi_\tau)m(\pi_\tau)$. For ordinary pion one has $f(\pi) = 93$ MeV and $r(\pi) = .67$. The decay rate for charged τ-pion is obtained by simple scaling giving

$$\begin{aligned} \Gamma(\pi_\tau \rightarrow L + \overline{\nu}_L) &= 8x^2u^2y^3(1-z^2)\frac{1}{cos^2(\theta_c)}\Gamma(\pi \rightarrow \mu + \overline{\nu_\mu}) \ , \\ x &= \frac{m(L)}{m(\mu)} \ , \ y = \frac{m(\tau)}{m(\pi)} \ , \ z = \frac{m(L)}{2m(\tau)} \ , \ u = \frac{r(\pi_\tau)}{r(\pi)} \ . \end{aligned} \tag{2.3.2}$$

If the p-adic mass scale of the colored neutrino is same as for ordinary neutrinos, the mass of charged lepto-pion is in good approximation equal to the mass of τ and the decay rates to τ and electron are for the lack of phase space much slower than to muons so that muons are produced preferentially.

6. For $m(\tau) = 1.8$ GeV and $m(\pi) = .14$ GeV and the same value for f_π as for ordinary pion the lifetime is obtained by scaling from the lifetime of charged pion about 2.6×10^{-8} s. The prediction is 3.31×10^{-12} s to be compared with the experimental estimate about 20×10^{-12} s. $r(\pi_\tau) = .41 r_\pi$ gives a correct prediction. Hence the explanation in terms of τ-pions seems to be rather convincing unless one is willing to believe in really nasty miracles.

7. Neutral τ-pion would decay dominantly to monochromatic pairs of gamma rays. The decay rate is dictated by the product of τ-pion field and "instanton" action, essentially the inner product of electric and magnetic fields and reducing to total divergence of instanton current locally. The rate is given by

$$\begin{aligned} \Gamma(\pi_\tau \rightarrow \gamma + \gamma) &= \frac{\alpha_{em}^2 m^3(\pi_\tau)}{64\pi^3 f(\pi_\tau)^2} = 2x^{-2}y \times \Gamma(\pi \rightarrow \gamma + \gamma) \ , \\ x &= \frac{f(\pi_\tau)}{m(\pi_\tau)} \ , \ y = \frac{m(\tau)}{m(\pi)} \ .\Gamma(\pi \rightarrow \gamma + \gamma) = 7.37 \ eV \ . \end{aligned} \tag{2.3.3}$$

The predicted lifetime is 1.17×10^{-17} seconds.

8. Second decay channel is to lepton pairs, with muon pair production dominating for kinematical reasons. The invariant mass of the pairs is 3.6 GeV of no other particles are produced. Whether the mass of colored neutrino is essentially the same as that of charged lepton or corresponds to the same p-adic scale as the mass of the ordinary neutrino remains an open question. If colored neutrino is light, the invariant mass of muon-neutrino pair is below 1.78 GeV.

PAMELA and ATIC anomalies

TGD predicts also a hierarchy of hadron physics assignable to Mersenne primes. The mass scale of M_{89} hadron physics is by a factor 512 higher than that of ordinary hadron physics. Therefore a very rough estimate for the nucleons of this physics is 512 GeV. This suggest that the decays of M_{89} hadrons are responsible for the anomalous positrons and electrons up to energies 500-800

GeV reported by ATIC collaboration. An equally naïve scaling for the mass of pion predicts that M_{89} pion has mass 72 GeV. This could relate to the anomalous cosmic ray positrons in the energy interval 10-50 GeV reported by PAMELA collaboration. Be as it may, the prediction is that M_{89} hadron physics exists and could make itself visible in LHC.

The surprising finding is that positron fraction (the ratio of flux of positrons to the sum of electron and positron fluxes) increases above 10 GeV. If positrons emerge from secondary production during the propagation of cosmic ray-nuclei, this ratio should decrease if only standard physics is be involved with the collisions. This is taken as evidence for the production of electron-positron pairs, possibly in the decays of dark matter particles.

Leptohadron hypothesis predicts that in high energy collisions of charged nuclei with charged particles of matter it is possible to produce also charged electro-pions, which decay to electrons or positrons depending on their charge and produce the electronic counterparts of the jets discovered in CDF. This proposal - and more generally lepto-hadron hypothesis - could be tested by trying to find whether also electronic jets can be found in proton-proton collisions. They should be present at considerably lower energies than muon jets. I decided to check whether I have said something about this earlier and found that I have noticed years ago that there is evidence for the production of anomalous electron-positron pairs in hadronic reactions [C52, C72, C58, C141]: some of it dates back to seventies.

The first guess is that the center of mass energy at which the jet formation begins to make itself visible is in a constant ratio to the mass of charged lepton. From CDF data this ratio satisfies $\sqrt{s}/m_\tau = x < 10^3$. For electro-pions the threshold energy would be around $10^{-3}x \times .5$ GeV and for muo-pions around $10^{-3}x \times 100$ GeV.

Comparison of TGD model with the model of CDF collaboration

Few days after the experimental a theoretical paper by CDF collaboration proposing a phenomenological model for the CDF anomaly appeared in the arXiv [C64], and it is interesting to compare the model with TGD based model (or rather, one of them corresponding to the third option mentioned above).

The paper proposes that three new particles are involved. The masses for the particles - christened h_3, h_2, and h_1 - are assumed to be 3.6 GeV, 7.3 GeV, and 15 GeV. h_1 is assumed to be pair produced and decay to h_2 pair decaying to h_3 pair decaying to a τ pair.

h_3 is assumed to have mass 3.6 GeV and life-time of 20×10^{-12} seconds. The mass is same as the TGD based prediction for neutral τ-pion mass, whose lifetime however equals to 1.12×10^{-17} seconds ($\gamma + \gamma$ decay dominates). The correct prediction for the lifetime provides a strong support for the identification of long-lived state as charged τ-pion with mass near τ mass so that the decay to μ and its antineutrino dominates. Hence the model is not consistent with lepto-hadronic model.

p-Adic length scale hypothesis predicts that allowed mass scales come as powers of $\sqrt{2}$ and these masses indeed come in good approximation as powers of 2. Several p-adic scales appear in low energy hadron physics for quarks and this replaces Gell-Mann formula for low-lying hadron masses. Therefore one can ask whether the proposed masses correspond to neutral tau-pion with $p = M_k = 2^k - 1$, $k = 107$, and its p-adically scaled up variants with $p \simeq 2^k$, $k = 105$, and $k = 103$ (also prime). The prediction for masses would be 3.6 GeV, 7.2 GeV, 14.4 GeV.

This co-incidence cannot of course be taken too seriously since the powers of two in CDF model have a rather mundane origin: they follow from the assumed production mechanism producing 8 τ-leptons from h_1. One can however spend some time by looking whether it could be realized somehow allowing p-adically scaled up variants of τ-pion.

1. The proposed model for the production of muon jets is based on production of k=103 neutral τ-pion (or several of them) having 4 times larger mass than k=107 τ-pion in strong EB background of the colliding proton and antiproton and decaying via weak boson and gluon exchanges to k=105 and k=107 τ-pions. The simplest decays are parity breaking $1 \rightarrow 2$ decays and must involve exchange of virtual W or Z boson. Three-pion coupling λ with dimensions of mass determines the decay rates for neutral τ-pions appearing in the cascade. For the four-pion decay the coupling is dimensionless. Rates are proportional to phase space-volumes, which are rather small by kinetic reasons and also reduced by weak coupling.

2. For a neutral initial state the first step could be one of the following ones:

$$\begin{aligned}
\pi_\tau^0(103) &\rightarrow \pi_\tau^+(105)+\pi_\tau^-(105) \\
\pi_\tau^0(103) &\rightarrow \pi_\tau^0(105)+\pi_\tau^0(105) \\
\pi_\tau^0(103) &\rightarrow 2\gamma \\
\pi_\tau^0(103) &\rightarrow \pi_\tau^+(105)+\pi_\tau^-(107)+\pi_\tau^0(107)
\end{aligned}$$

In the last decay permutations of the final state charges are possible. Since the last reaction is parity conserving and governed by strong interactions it dominates. This step is not kinematically possible if masses are obtained by exact scaling and if $m(\pi_\tau^0) < m(pi_\tau^\pm)$ holds true as for ordinary pion. p-Adic mass formulas do not however predict exact scaling. In the case that reaction is not kinematically possible, it must be replaced with a reaction in which one final state pion is virtual.

3. At the second step charged pion would decay to two pions

$$\pi_\tau^\pm(105) \rightarrow \pi_\tau^0(107)+\pi_\tau^\pm(107) \ ,$$

Neutral pion could decay to two gammas or to two pions

$$\pi_\tau^0(105) \rightarrow 2\gamma \ or \ \pi_\tau^+(107)+\pi_\tau^-(107) \ or \ \pi_\tau^0(107)+\pi_\tau^0(107) \ .,$$

Here second charged pion also can be virtual and decay weakly, and the weak decays of the $\pi_\tau^\pm(105)$ with mass $2m(\tau)$ to lepton pairs. The rates for these are obtained from previous formulas by scaling. For neutral pion the deay to two gammas dominates now.

4. The last step would involve the decays of both charged and neutral $\pi_\tau(107)$. The signature of the mechanism would be anomalous γ pairs with invariant masses $2^k \times m(\tau)$, $k=1,2,3$ coming from the decays of neutral τ-pions.

The total cross section for producing single lepto-pion can be estimated by using the quantum model for lepto-pion production. Production amplitude is essentially Coulomb scattering amplitude for a given value of the impact parameter b for colliding proton and anti-proton multiplied by the amplitude $U(b,p)$ for producing on mass shell $k=103$ lepto-pion with given four-momentum in the fields E and B and given essentially by the Fourier transform of $E\cdot B$. The replacement of the motion with free motion should be a good approximation.

UV and IR cutoffs for the impact parameter appear in the model and are identifiable as appropriate p-adic length scales. UV cutoff could correspond to the Compton size of nucleon ($k=107$) and IR cutoff to the size of the space-time sheets representing topologically quantized electromagnetic fields of colliding nucleons (perhaps $k=113$ corresponding to nuclear p-adic length scale and size for color magnetic body of constituent quarks or $k=127$ for the magnetic body of current quarks with mass scale of order MeV). If one has $\hbar/\hbar_0 = 2^7$ one could also guess that the IR cutoff corresponds to the size of dark em space-time sheet equal to $2^7L(113)=L(127)$ (or $2^7L(127)=L(141)$), which corresponds to electron's p-adic length scale. These are of course rough guesses.

Quantitatively the jet-likeness of muons means that the additional muons are contained in the cone $\theta < 36.8$ degrees around the initial muon direction. If the decay of $\pi_\tau^0(k)$ can occur to on mass shell $\pi_\tau^0(k+2)$, $k=103,105$, it is possible to understand jets as a consequence of the decay kinematics forcing the pions resulting as decay products to be almost at rest.

1. Suppose that the decays to three pions can take place as on mass shell decays so that pions are very nearly at rest. The distribution of decay products $\mu\overline{\nu}$ in the decays of $\pi^\pm(105)$ is spherically symmetric in the rest frame and the energy and momentum of the muon are given by

$$[E,p] = [m(\tau)+\frac{m^2(\mu)}{4m(\tau)}, m(\tau)-\frac{m^2(\mu)}{4m(\tau)}] \ .$$

The boost factor $\gamma = 1/\sqrt{1-v^2}$ to the rest system of muon is $\gamma = \frac{m(\tau)}{m(\mu)} + \frac{m(\mu)}{4m(\tau})) \sim 18$.

2. The momentum distribution for μ^+ coming from π_τ^+ is spherically symmetric in the rest system of π^+. In the rest system of μ^- the momentum distribution is non-vanishing only for when the angle θ between the direction of velocity of μ^- is below a maximum value of given by $tan(\theta_{max}) = 1$ corresponding to a situation in which the momentum μ^+ is orthogonal to the momentum of μ^- (the maximum transverse momentum equals to $m(\mu)v\gamma$ and longitudinal momentum becomes $m(\mu)v\gamma$ in the boost). This angle corresponds to 45 degrees and is not too far from 36.8 degrees.

3. At the next step the energy of muons resulting in the decays of $\pi^\pm(103)$

$$[E,p] = [\frac{m(\tau)}{2} + \frac{m^2(\mu)}{2m(\tau)}, \frac{m(\tau)}{2} - \frac{m^2(\mu)}{2m(\tau)}] \ ,$$

   and the boost factor is $\gamma_1 = \frac{m(\tau)}{2m(\mu)} + \frac{m(\mu)}{2m(\tau)} \sim 9$. θ_{max} satisfies the condition $tan(\theta_{max}) = \gamma_1 v_1/\gamma v \simeq 1/2$ giving $\theta_{max} \simeq 26.6$ degrees.

If on mass shell decays are not allowed the situation changes since either of the charged pions is off mass shell. In order to obtain similar result the virtual should occur dominantly via states near to on mass shell pion. Since four-pion coupling is just constant, this option does not seem to be realized.

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If on mass shell decays are not possible, the situation changes since either of the charged pions is off mass shell. In order to obtain similar result the virtual should occur dominantly via states near to on mass shell pion. Since four-pion coupling is just constant, this option does not seem to be realized.

Numerical estimate for the production cross section

The numerical estimate of the cross section involves some delicacies. The model has purely physical cutoffs which must be formulated in a precise manner.

1. Since energy conservation is not coded into the model, some assumption about the maximal τ-pion energy in cm system expressed as a fraction ϵ of proton's center of mass energy is necessary. Maximal fraction corresponds to the condition $m(\pi_\tau) \leq m(\pi_\tau)\gamma_1 \leq \epsilon m_p \gamma_{cm}$ in cm system giving $[m(\pi_\tau)/(m_p\gamma_{cm}) \leq \epsilon \leq 1$. γ_{cm} can be deduced from the center of mass energy of proton as $\gamma_{cm} = \sqrt{s}2m_p$, $\sqrt{s} = 1.96$ TeV. This gives $1.6 \times 10^{-2} < \epsilon < 1$ in a reasonable approximation. It is convenient to parameterize ϵ as

$$\epsilon = (1+\delta) \times \frac{m(\pi_\tau)}{m_p} \times \frac{1}{\gamma_{cm}} \quad .$$

   The coordinate system in which the calculations are carried out is taken to be the rest system of (say) antiproton so that one must perform a Lorentz boost to obtain upper and lower limits for the velocity of τ-pion in this system. In this system the range of γ_1 is fixed by the maximal cm velocity fixed by ϵ and the upper/lower limit of γ_1 corresponds to a direction parallel/opposite to the velocity of proton.

2. By Lorentz invariance the value of the impact parameter cutoff b_{max} should be expressible in terms τ-pion Compton length and the center of mass energy of the colliding proton and the assumption is that $b_{max} = \gamma_{cm} \times \hbar/m(\pi_\tau)$, where it is assumed $m(\pi_\tau) = 8m(\tau)$. The production cross section does not depend much on the precise choice of the impact parameter cutoff b_{max} unless it is un-physically large in which case b_{max}^2 proportionality is predicted.

The numerical estimate for the production cross section involves some delicacies.

1. The power series expansion of the integral of CUT_1 using partial fraction representation does not converge since that roots $c_\pm$ are very large in the entire integration region. Instead the approximation $A_1 \simeq iBcos(\psi)/D$ simplifying considerably the calculations can be used. Also the value of b_1L is rather small and one can use stationary phase approximation for CUT_2. It turns out that the contribution of CUT_2 is negligible as compared to that of CUT_1.

2. Since the situation is singular for $\theta = 0$ and $\phi = 0$ and $\phi = \pi/2$ (by symmetry it is enough to calculate the cross section only for this kinematical region), cutoffs

$$\theta \in [\epsilon_1, (1-\epsilon_1)] \times \pi \quad , \quad \phi \in [\epsilon_1, (1-\epsilon_1)] \times \pi/2 \quad , \quad \epsilon_1 = 10^{-3} \quad .$$

   The result of the calculation is not very sensitive to the value of the cutoff.

3. Since the available numerical environment was rather primitive (MATLAB in personal computer), the requirement of a reasonable calculation time restricted the number of intervals in the discretization for the three kinematical variables γ, θ, ϕ to be below $N_{max} = 80$. The result of calculation did not depend appreciably on the number of intervals above $N = 40$ for γ_1 integral and for θ and ϕ integrals even $N = 10$ gave a good estimate.

The calculations were carried for the $exp(iS)$ option since in good approximation the estimate for $exp(iS) - 1$ model is obtained by a simple scaling. $exp(iS)$ model produces a correct order of magnitude for the cross section whereas $exp(iS) - 1$ variant predicts a cross section, which is by several orders of magnitude smaller by downwards α_{em}^2 scaling. As I asked Tommaso Dorigo for an estimate for the production cross section in his first blog posting [C147], he mentioned that authors refer to a production cross section is 100 nb which looks to me suspiciously large (too large by three orders of magnitude), when compared with the production rate of muon pairs from b-bbar. $\delta = 1.5$ which corresponds to τ-pion energy 36 GeV gives the estimate $\sigma = 351$ nb. The energy is suspiciously high.

In fact, in the recent blog posting of Tommaso Dorigo [C148] a value of order.1 nb for the production cross section was mentioned. Electro-pions in heavy ion collisions are produced almost at rest and one has $\Delta v/v \simeq .2$ giving $\delta = \Delta E/m(\pi) \simeq 2 \times 10^{-3}$. If one believes in fractal scaling, this should be at least the order of magnitude also in the case of τ-pion. This would give the estimate $\sigma = 1$ nb. For $\delta = \Delta E/m(\pi) \simeq 10^{-3}$ a cross section $\sigma = .16$ nb would result.

One must of course take the estimate cautiously but there are reasons to hope that large systematic errors are not present anymore. In any case, the model can explain also the order of magnitude of the production cross section under reasonable assumptions about cutoffs (see **Fig. 2.2**).

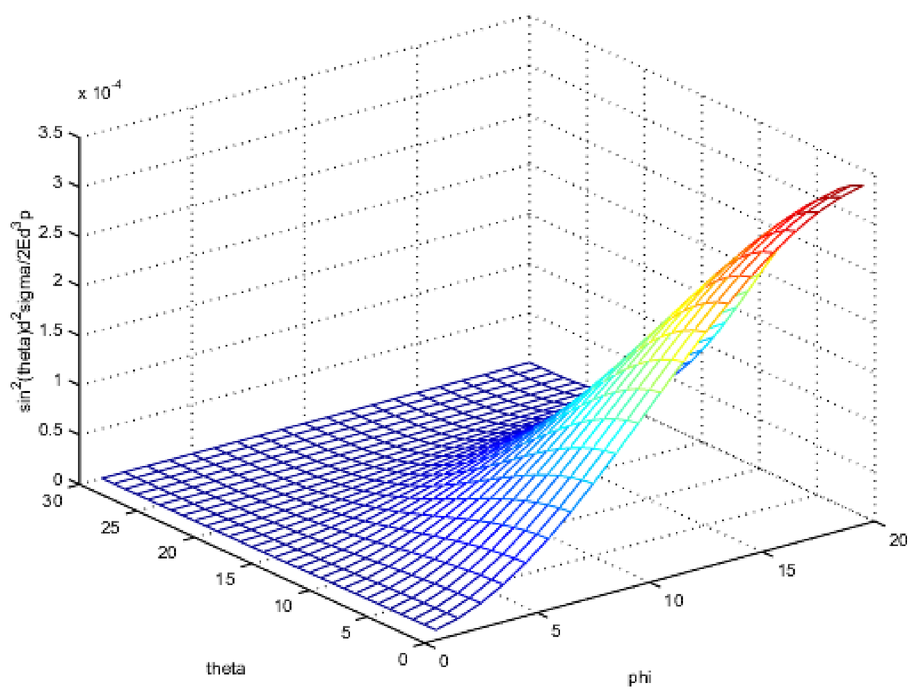

Figure 2.2: Differential cross section $sin^2(\theta) \times \frac{d^2\sigma}{2Ed^3p}$ for τ-pion production for $\gamma_1 = 1.090 \times 10^3$ in the rest system of antiproton for $\delta = 1.5$. $m(\pi_\tau)$ defines the unit of energy and nb is the unit for cross section. The ranges of θ and ϕ are $(0, \pi)$ and $(0, \pi/2)$.

Does the production of lepto-pions involve a phase transition increasing Planck constant?

The critical argument of Tommaso Dorigo in his blog inspired an attempt to formulate more precisely the hypothesis $\sqrt{s}/m_\tau > x < 10^3$. This led to the realization that a phase transition increasing Planck constant might happen in the production process as also the model for the production of electro-pions requires.

Suppose that the instanton coupling gives rise to *virtual* neutral lepto-pions which ultimately produce the jets (this is first of the three models that one can imagine). E and B could be associated with the colliding proton and antiproton or quarks.

1. The amplitude for lepto-pion production is essentially Fourier transform of $E \cdot B$, where E and B are the non-orthogonal electric and magnetic fields of the colliding charges. At the level of scales one has $\tau \sim \hbar/E$, where τ is the time during which $E \cdot B$ is large enough during collision and E is the energy scale of the virtual lepto-pion giving rise to the jet.

2. In order to have jets one must have $m(\pi_\tau) << E$. If the scaling law $E \propto \sqrt{s}$ hold true, one indeed has $\sqrt{s}/m(\pi_\tau) > x < 10^3$.

3. If proton and antiproton would move freely, τ would be of the order of the time for proton to move through a distance, which is 2 times the Lorentz contracted radius of proton: $\tau_{free} = 2 \times \sqrt{1 - v^2} R_p/v = 2\hbar/E_p$. This would give for the energy scale of virtual τ-pion the estimate $E = \hbar/\tau_{free} = \sqrt{s}/4$. $x = 4$ is certainly quite too small value. Actually $\tau > \tau_{free}$ holds true but one can argue that without new physics the time for the preservation of $E \cdot B$ cannot be by a factor of order 2^8 longer than for free collision.

4. For a colliding quark pair one would have $\tau_{free} = 4\hbar/\sqrt{s_{pair}(s)}$, where $\sqrt{s_{pair}(s)}$ would be the typical invariant energy of the pair which is exponentially smaller than $\sqrt{s}$. Somewhat paradoxically from classical physics point of view, the time scale would be much longer for the collision of quarks than that for proton and antiproton.

The possible new physics relates to the possibility that lepto-pions are dark matter in the sense that they have Planck constant larger than the standard value.

1. Suppose that the produced lepto-pions have Planck constant larger than its standard value $\hbar_0$. Originally the idea was that larger value of $\hbar$ would scale up the production cross section. It turned out that this is not the case. For $exp(iS)$ option the lowest order contribution is not affected by the scaling of $\hbar$ and for $exp(iS)-1$ option the lowest order contribution scales down as $1/\hbar^2$. The improved formulation of the model however led to a correct order of magnitude estimates for the production cross section.
2. Assume that a phase transition increasing Planck constant occurs during the collision. Hence τ is scaled up by a factor $y=\hbar/\hbar_0$. The inverse of the lepto-pion mass scale is a natural candidate for the scaled up dark time scale. $\tau(\hbar_0)\sim\tau_{free}$, one obtains $y\sim\sqrt{s_{min}}/4m(\pi_\tau)\leq 2^8$ giving for proton-antiproton option the first guess $\sqrt{s}/m(\pi_\tau)>x<2^{10}$. If the value of y does not depend on the type of lepto-pion, the proposed estimates for muo- and electro-pion follow.
3. If the fields E and B are associated with colliding quarks, only colliding quark pairs with $\sqrt{s_{pair}(s)}>(>)m(\pi_\tau)$ contribute giving $y_q(s)=\sqrt{s_{pair}(s)/s}\times y$.

If the τ-pions produced in the magnetic field are on-mass shell τ-pions with $k=113$, the value of $\hbar$ would satisfy $\hbar/\hbar_0<2^5$ and $\sqrt{s}/m(\pi_\tau)>x<2^7$.

Tau-pions again but now as dark matter candidate in galactic center

The standard view about dark matter is that it has only gravitational interactions with ordinary matter so that high densities of dark matter are required to detect its signatures. On the average the density of dark matter is about 80 per cent of ordinary matter. Clearly, Milky Way's center is an excellent place for detecting the signatures of dark matter. The annihilation of pairs of dark matter particles to gamma rays is one possible signature and one could study the anomalous features of gamma ray spectrum from the galactic center (a region with radius about 100 light years).

Europe's INTEGRAL satellite launched in 2002 indeed found bright gamma ray radiations coming from the center of galaxy with energy of.511 MeV, which is slightly above electron mass (see the references below). The official interpretation is that the gammas are produced in the annihilations of particles of positrons and electrons in turn created in dark matter annihilations. TGD suggests much simpler mechanism. Gamma rays would be produced in the decay of what I call electro-pions having mass which is slightly larger than $m=2m_e$.

The news of the day [C135] was that the data from Fermi Gamma Ray telescope give analyzed by Dan Hooper and Lisa Goodenough [C110] gives evidence for a dark matter candidate with mass between 7.3-9.2 GeV decaying predominantly into a pair of τ leptons. The estimate for the mass region is roughly 4 times τ mass. What puts bells ringing that a mass of a charged lepton appears again!

1. Explanation in TGD framework

The new finding fits nicely to a bigger story based on TGD.

1. TGD predicts that both quarks and leptons should have colored excitations devoted to the lepto-hadron model). In the case of leptons lowest excitations are color octets. In the case of electro-pion this hypothesis finds support from the anomalous production of electron positron pairs in heavy ion collisions discovered already at seventies but forgotten for long ago since the existence of light particle at this mass scale simply was in total complete with standard model and what was known about the decay widths of intermediate gauge bosons. Also ortopositronium decay width anomaly -forgotten also-has explanation in terms of lepto-pion hypothesis [C96, C49].
2. The colored leptons would be dark in TGD sense, which means that they live in dark sector of the "world of classical worlds" (WCW) meaning that they have no direct interactions (common vertices of Feynman diagrams) with ordinary matter. They simply live at different space-time sheets. A phase transition which is geometrically a leakage between dark sector and ordinary sector are possible and make possible interactions between ordinary and dark matter

based on exchanged particles suffering this phase transition. Therefore the decay widths of intermediate gauge bosons do not kill the model. TGD based model of dark matter in terms of hierarchy of values of Planck constants coming as multiples of its smallest possible value (the simplest option) need not to be postulated separately and can be regarded as a prediction of quantum TGD reflecting directly the vacuum degeneracy and extreme non-linearity of Kähler action (Maxwell action for induced CP_2 Kähler form).

3. CDF anomaly which created a lot of discussion in blogs for two years ago can be understood in terms of taupion. Taupion and its p-adically scaled up versions with masses about $2^k m_\tau$, $k = 1, 2, 3$ and $m_\tau \simeq 1.8$ GeV explains the findings reported by CDF in TGD framework. The masses of taupions would be 3.6 GeV, 7.2 GeV, and 14.2 GeV in good approximation and come as octaves of the mass of tau-lepton pair.

2. Predictions

The mass estimate for the dark matter particle suggests by Fermi Gamma Ray telescope corresponds to $k = 2$ octave for taupion and the predict mass is about 7.2 GeV which at the lower boundary of the range 7.3-9.2 GeV. Also dark matter particles decaying to tau pairs and having masses 3.6 GeV and 14.2 GeV should be found.

Also muo-pion should exist there and should have mass slightly above $2m_\mu = 210.4$ MeV so that a gamma rays peak slightly above the energy $m_\mu = 105.2$ MeV should be discovered. Also octaves of this mass can be imagined. There is also evidence also for the existence of muo-pion [C107, C108].

LHC should provide excellent opportunities to test tau-pion and muo-pion hypothesis. Electro-pion was discovered in heavy ion collisions and also at LHC they study have heavy ion collisions but at much higher energies generating the required very strong non-orthogonal electric and magnetic fields for which the "instanton density" defined as the inner product of electric and magnetic fields is large and rapidly varying. As an optimist I hope that muo-pion and tau-pion could be discovered despite the fact that their decay signatures are very different from those for ordinary particles and despite that fact that at these energies one must know precisely what one is trying to find in order to disentangle it from the enormous background.

3. Also DAMA, CoGeNT, and PAMELA give indications for tau-pion

Note that also DAMA experiment [C38] suggests the existence of dark matter particle in this mass range but it is not clear whether it can have anything to do with tau-pion state. One could of course imagine that dark tau-pions are created in the collisions of highly energetic cosmic rays with the nuclei of atmosphere. Also Coherent Germanium Neutrino Technology (CoGeNT) experiment [C36] has released data that are best explained in terms of a dark matter particle with mass in the range 7-11 GeV.

The decay of tau-pions produce lepton pairs, mostly tau but also muons and electrons. The subsequent decays of tau-leptons to muons and electrons produce also electrons and positrons. This relates interestingly to the positron excess reported by PAMELA collaboration [C126] at the same time as CDF anomaly was reported. The anomaly started at positron energy about 3.6 GeV, which is one just one half of 7. 2 GeV for tau-pion mass! What was remarkable that no antiproton excess predicted by standard dark matter candidates was observed. Therefore the interpretation as decay products of tau-pions seems to make sense!

Could it have been otherwise?

To sum up, the probability that a correct prediction for the lifetime of the new particle using only known lepton masses and standard formulas for weak decay rates follows by accident is extremely low. Throwing billion times coin and getting the same result every time might be something comparable to this. Therefore my sincere hope is that colleagues would be finally mature to take TGD seriously. If TGD based explanation of the anomalous production of electron positron pairs in heavy ion collisions would have been taken seriously for fifteen years ago, particle physics might look quite different now.

2.3.4 Dark Matter Puzzle

Sean Carroll has explained in Cosmic Variance (http://tinyurl.com/c2r2cv) the latest rather puzzling situation in dark matter searches. Some experiments support the existence of dark matter particles with mass of about 7 GeV, some experiments exclude them. The following arguments show that TGD based explanation might allow to understand the discrepancy.

How to detect dark matter and what's the problem?

Consider first the general idea behind the attempts to detect dark matter particles and how one ends up with the puzzling situation.

1. Galactic nucleus serves as a source of dark matter particles and these one should be able to detect. There is an intense cosmic ray flux of ordinary particles from galactic center which must be eliminated so that only dark matter particles interacting very weakly with matter remain in the flux. The elimination is achieved by going sufficiently deep underground so that ordinary cosmic rays are shielded but extremely weakly interacting dark matter particles remain in the flux. After this one can in the ideal situation record only the events in which dark matter particles scatter from nuclei provided one eliminates events such as neutrino scattering.
2. DAMA experiment does not detect dark matter events as such but annual variations in the rate of events which can include besides dark matter events and other kind of events. DAMA finds an annual variation interpreted as dark matter signal since other sources of events are not expected to have this kind of variation [C37]. Also CoGENT has reported the annual variation with 2.8 sigma confidence level [C136]. The mass of the dark matter particle should be around 7 GeV rather than hundreds of GeVs as required by many models. An unidentified noise with annual variation having nothing to do with dark matter could of course be present and this is the weakness of this approach.
3. For a few weeks ago we learned that XENON100 experiment detects no dark matter [C42] (http://tinyurl.com/y9t3gxxu). Also CDMS has reported a negative result [C35]. According to Sean Carroll, the detection strategy used by XENON100 is different from that of DAMA: individual dark matter scatterings on nuclei are detected. This is a very significant difference which might explain the discrepancy since the theory laden prejudices about what dark matter particle scattering can look like, could eliminate the particles causing the annual variations. For instance, these prejudices are quite different for the habitants of the main stream Universe and TGD Universe.

TGD based explanation of the DAMA events and related anomalies

I have commented earlier the possible interpretation of DAMA events in terms of tau-pions (http://tinyurl.com/ycgkvuy9). The spirit is highly speculative.

1. Tau-pions would be identifiable as the particles claimed by Fermi Gamma Ray telescope with mass around 7 GeV and decaying into tau pairs so that one could cope with several independent observations instead of only single one.
2. Recall that the CDF anomaly gave for two and half years ago support for tau-pions whereas earlier anomalies dating back to seventies give support for electro-pions and mu-pions. The existence of these particles is purely TGD based phenomenon and due to the different view about the origin of color quantum numbers. In TGD colored states would be partial waves in CP_2 and spin like quantum numbers in standard theories so that leptons would not have colored excitations.
3. Tau-pions are of course highly unstable and would not come from the galactic center. Instead, they would be created in cosmic ray events at the surface of Earth and if they can penetrate the shielding eliminating ordinary cosmic rays they could produce events responsible for the annual variation caused by that for the cosmic ray flux from galactic center.

Can one regard tau-pion as dark matter in some sense? Or must one do so? The answer is affirmative to both questions on both theoretical and experimental grounds.

1. The existence of colored variants of leptons is excluded in standard physics by intermediate gauge boson decay widths. They could however appear as states with non-standard value of Planck constant and therefore not appearing in same vertices with ordinary gauge bosons so that they would not contribute to the decay widths of weak bosons. In this minimal sense they would be dark and this is what is required in order to understand what we know about dark matter.

   Of course, all particles can in principle appear in states with non-standard value of Planck constant so that tau-pion would be one special instance of dark matter. For instance, in living matter the role of dark variants of electrons and possibly also other stable particles would be decisive. To put it bluntly: in mainstream approach dark matter is identified as some exotic particle with ad hoc properties whereas in TGD framework dark matter is outcome of a generalization of quantum theory itself.

2. DAMA experiment requires that the tau-pions behave like dark matter: otherwise they would never reach the strongly shielded detector. The interaction with the nuclei of detector would be preceded by a transformation to a particle-tau-pion or something else- with ordinary value of Planck constant.

TGD based explanation for the dark matter puzzle

The criteria used in experiments to eliminate events which definitely are not dark matter events - according to the prevailing wisdom of course - dictates to high degree what interactions of tau pions with solid matter detector are used as a signature of dark matter event. It could well be that the criteria used in XENON100 do not allow the scatterings of tau-pions with nuclei. This is indeed the case. The clue comes from the comments of Jester in Resonaances (see `http://tinyurl.com/yd3vs7x5`). From a comment of Jester one learns that CoGENT - and also DAMA utilizing the same detections strategy - “does not cut on ionization fraction”. Therefore, if dark matter mimics electron recoils (as Jester says) or if dark matter produced in the collisions of cosmic rays with the nuclei of the atmosphere decays to charged particles one can understand the discrepancy.

The TGD based model [K115] explaining the more than two years old CDF anomaly [C34, C71] indeed explains also the discrepancy between XENON100 and CDMS on one hand and DAMA and CoGENT on the other hand. The TGD based model for the CDF anomaly can be found in [K115].

1. To explain the observations of CDF [C34, C71] one had to assume that tau-pions and therefore also color excited tau-leptons inside them appear as several p-adically scaled up variants so that one would have several octaves of the ground state of tau-pion with masses in good approximation equal to 3.6 GeV (two times the tau-lepton mass), 7.2 GeV, 14.4 GeV. The 14.4 GeV tau-pion was assumed to decay in a cascade like manner via lepto-strong interactions to lighter tau-pions- both charged and neutral- which eventually decayed to ordinary charged leptons and neutrinos.
2. Also other decay modes -say the decay of neutral tau-pions to gamma pair and to a pair of ordinary leptons- are possible but the corresponding rates are much slower than the decay rates for cascade like decay via multi-tau-pion states proceeding via lepto-strong interactions.
3. Just this cascade would take place also now after the collision of the incoming cosmic ray with the nucleus of atmosphere. The mechanism producing the neutral tau-pions -perhaps a coherent state of them- would degenerate in the collision of charged cosmic ray with nucleus generating strong non-orthogonal electric and magnetic fields and the production amplitude would be essentially the Fourier transform of the “instanton density” $E \cdot B$. The decays of 14 GeV neutral tau-pions would produce 7 GeV charged tau-pions, which would scatter from the protons of nuclei and generate the events excluded by XENON100 but not by DAMA and Cogent.
4. In principle the model predicts to a high degree quantitatively the rate of the events. The scattering rates are proportional to an unknown parameter characterizing the transformation probability of tau-pion to a particle with ordinary value of Planck constant and this allows to perform some parameter tuning. This parameter would correspond to a mass insertion in the tau-pion line changing the value of Planck constant and have dimensions of mass squared.

The overall conclusion is that the discrepany between DAMA and XENON100 might be interpreted as favoring TGD view about dark matter and it is fascinating to see how the situation develops. This confusion is not the only confusion in recent day particle physics. All believed-to-be almost-certainties are challenged.

Has Fermi observed dark matter?

Resonaances (`http://tinyurl.com/y79x4v3y`) reports about a possible dark matter signal at Fermi satellite [C31]. Also Lubos Motl (`http://tinyurl.com/yd7xsfxol`) has a posting about the finding and mentions that the statistical significance is 3.3 sigma.

The proposed dark matter interpretation for the signal would be pair of monochromatic photons with second one detected at Earth. The interpretation would be that dark matter particles with mass m nearly at rest in galactic center annihilate to a pair of photons so that one obtains a pair of photons with energy equal to the cm energy which is in a good approximation the sum $E = 2 \times m$ for the masses of the particles. The mass value would be around m=130 GeV if the final state involves only 2 photons.

In TGD framework I would consider as a first guess a pion like state decaying to two photons with standard coupling given by the coupling to the "instanton density" $E \cdot B$ of electromagnetic field. The mass of this particle would be 260 GeV, in reasonable approximation 2 times the mass m=125 GeV of the Higgs candidate.

1. Similar coupling was assumed to [K115]. The anomaly would have been produced by tau-pions, which are pionlike states formed by pairs of colored excitations of tau and its antiparticle (or possibly their super-partners). What was remarkable that the mass had three values coming as powers of two: $M = 2^k \times 2m(\tau;)$, $k = 0, 1, 2$. The interpretation in terms of p-adic length scale hypothesis would be obvious: also the octaves of the basic state are there. The constraint from intermediate gauge boson decay widths requires that these states are dark in TGD sense and therefore correspond to a non-standard value of Planck constant coming as an integer multiple of the standard value.
2. Also the explanation of the findings of PAMELA discussed in this chapter require octaves of tau-pion produced in Earth's atmosphere.
3. Even ordinary pion should have 2-adic octaves. But doesn't this kill the hypothesis? We "know" that pion does not have any octaves! Maybe not, there is recent evidence for satellites of ordinary pion with energy scale of 40 MeV interpreted in terms of IR Regge trajectories assignable to the color magnetic flux tubes assignable to pion. There has been several wrong alarms about Higgs: at 115 GeV and 155 GeV at least. Could it be that there there is something real behind these wrong alarms: the scale for IR Regge trajectories would be about 20 GeV now!

So: could the dark matter candidates with mass around 260 GeV correspond to the first octave of M_{89} pion with mass around 125 GeV, the particle that colleagues want to call Higgs boson although its decay signatures suggest something different?

1. In this case it does not seem necessary to assume that the Planck constant has non-standard value although this is possible.
2. This particle should be produced in M_{89} strong interactions in the galactic center. This would require the presence of matter consisting of M_{89} nucleons emitting these pions in strong interactions. Galactic center (`http://tinyurl.com/y9clyfs`) is very exotic place and believed to contain even super-massive black hole. Could this environment accommodate also a scaled up copy of hadron physics? Presumably this would require very high temperatures with thermal energy of order.5 TeV correspond to the mass of M_{89} proton to make possible the presence of M_{89} matter. Or could M_{89} pion be produced in ultrastrong non-orthogonal electric and magnetic fields in the galactic center by the coupling to the instanton density. The needed field strengths would be extremely high. I have indeed proposed long time ago an explanation of very high energy cosmic rays in terms of the decay products of scaled up hadron physics (see "Cosmic Rays and Mersenne primes" in this chapter).

One can of course imagine that the photon pair is produced in the annilation of M_{89} pions with opposite charges via standard electromagnetic coupling. Also the annihilation of M_{89} spions consisting of squark pair can be considered in TGD framework where squarks could have same mass scale as quarks. In this case mass would be near 125 GeV identified as mass of neutral M_{89} pion. By scaling up the mass difference 139.570-134.976 MeV of the ordinary charged and neutral pion by the ratio of the pion M_{89} and M_{107} pion masses equal to $(125/140) \times 10^3$ one obtains that the charged M_{89} pion should have mass equal to 129.6 MeV to be compared with the 130 GeV mass suggested by experimental evidence.

The story did not end here as so often when observations cannot be replicated. The Estonian researchers Elmo Tempel, Andi Hektora and Martti Raidala have found a confirmation for the 130 GeV Fermi excess in gamma radiation from galactic center discovered by Cristoph Weniger [E4]. An important conclusion of these researchers is that best fit is obtained if the dark matter candidates decay by two-body annihilation to photons and have mass 145 GeV. The reason for why the gamma peak is at 130 GeV rather than 145 GeV would be due to the emission light particle pairs by the photons. There are also indications for a peak at 111 GeV: this could be assigned to γZ finals state of two-body decay.

In TGD framework the annihilating particles with mass about 145 GeV mass could be charged pion-like states of M_{89} hadron physics. They could be dark in the sense of having large value of Planck constant but it is not clear whether this is necessarily so. The TGD based on view about galactic dark matter locates in cosmic string like objects containing galaxies as pearls in necklace and no halo is needed to explain galactic rotation spectrum [K31]. An ultrahigh temperature would be needed to excite M_{89} hadron physics and if there is giant blackhole in galactic nucleus, there are hopes about this. M_{89} hadron physics could also produce ultrahigh energy cosmic rays as described in this chapter.

It is amusing that also CDF found for a couple of years ago evidence for a bump at the same 145 GeV energy (this has been forgotten long time ago by bloggers in 125 GeV Higgs hysteria). Estonians propose that also a particle with 290 GeV (mass would twice that of 145 GeV state) is needed. This brings further support for the idea about mass octaves of ground state of pionlike states needed to explain various anomalies (see this chapter and [K115]).

If one takes seriously the evidence for 125 GeV state and its identification as Eucdlian pion together with the evidence for galactic pionlike state with mass of 145 GeV identified as M_{89}, one has a nice support for the overall TGD based view about situation described in this chapter. The small splitting between pionlike states has possible counterpart in the ordinary hadron physics: there is evidence for satellites of pion, mesons, and baryons in 20-40 MeV scale for mass splittings and in TGD framework they would correspond to IR Regge trajectories with the scale of 10-20 GeV mass splittings (see this chapter).

We are living exciting times!

Two different lifetimes for neutron as evidence for dark protons

I found a popular article (see `http://tinyurl.com/hqsaqok`) about very interesting finding related to neutron lifetime [C98] (see `http://tinyurl.com/h88n57j`). Neutron lifetime turns out to be by about 8 seconds shorter when measured by looking what fraction of neutrons disappears via decays in a box than by measuring the number of protons produced in beta decays for a neutron beam travelling through a given volume. The lifetime of neutron is about 15 minutes so that relative lifetime difference is about $8/(15 \times 60) \simeq .8$ per cent. The statistical signficance is 4 sigma: 5 sigma is accepted as the significance for a finding acceptable as discovery.

How could one explain the finding? The difference between the methods is that the beam experiment measures only the disappearances of neutrons via beta decays producing protons whereas box measurement detects the outcome from all possible decay modes. The experiment suggests two alternative explanations.

1. Neutron has some other decay mode or modes, which are not detected in the box method since one measures the number of neutrons in initial and final state. For instance, in TGD framework one could think that the neutrons can transform to dark neutrons with some rate. But it is extremely unprobable that the rate could be just about 1 per cent of the decay rate. Why not 1 millionth? Beta decay should be involved with the process.

Could some fraction of neutrons decay to dark proton, electron, and neutrino so that dark protons would not be detected in beam experiment? No, if one takes seriously the basic assumption of TGD that particles with different value of $h_{eff}/h = n$ do not appear in the same vertex. Neutron should first transform to dark proton but then also the disappearance could take place also without the beta decay of dark proton and the discrepancy would be larger.

2. The proton produced in the ordinary beta decay of neutron can however transform to dark proton not detected in the beam experiment! This would automatically predict that the rate is some reasonable fraction of the beta decay rate. About 1 percent of the resulting protons would transform to dark protons. This makes sense and would give strong hold about the rate for ordinary-dark transition rate. The observation of decays of neutron to electron, and neutrino but not proton would provide a support for the hypothesis. Both neutrino and proton would represent missing mass!

Dark matter as hierarchy of phases of ordinary matter is now a basic prediction of adelic TGD and $h_{eff}/h = n$ has in terms of number theory and space-time topology [K120, **?**]. What is so nice is that the transformation of protons to dark protons is indeed the basic mechanism of TGD inspired quantum biology [K80, **?**]! For instance, it would occur in Pollack effect [L24] in with infrared irradiation of water bounded by gel phase generates so called exclusion zone (EZ), which is negatively charged, and creates what Pollack calls fourth phase of water. TGD explanation is that some fraction of protons transforms to dark protons at magnetic flux tubes outside the system. Negative charge of DNA and cell could be due to this mechanism. One also ends up to a model of genetic code with the analogs of DNA, RNA, tRNA and amino-acids represented as triplets of dark protons associated with magnetic flux tubes parallel to DNA strands [K118] [L36]. The model predicts correctly the numbers of DNAs coding a given amino-acid. Besides quantum biology, the model has applications to cold fusion [L27], and various phenomena referred to as "free energy phenomena" [K95, K8].

2.3.5 Has Pamela Observed Evidence For The Non-Dark Electro-PionOf M_{89} Lepto-Hadron Physics?

Resonaances (see `http://tinyurl.com/ybtqfgfnl`) tells that the Fermi collaboration confirms the claim of PAMELA collaboration about anomalous e^+e^- pairs in cosmic ray radiation (see that abstract *Consistency of fermi-lat and pamela cosmic ray lepton measurement* by P. Grandi *et al* at (see `http://tinyurl.com/y7mc59gx`).

The announcement of Pamela was my second birthday gift at October 30 for two and half years ago. The first gift was CDF anomaly which found a beautiful explanation in terms of tau-pions and the p-adically scaled up variants with color tau- lepton having mass scale by power of two. The tau-pion of mass about 14 GeV decaying in cascade like manner to lower octaves of basic tau-pion explained elegantly the observations reported by CDF.

For some time ago the dilemma posed by the contradictory claims of DAMA and Cogent collaborations on one hand and XENON100 collaboration on one hand finds also nice solution in terms of 14 GeV taupion decaying to charged taupions with mass about 7 GeV [K115].

The decays of electro-pions to gamma pair can explain the observed anomalous gammas from galactic nucleus with energy very nearly to electron rest mass. Could one understand also the anomalous positrons reported by PAMELA as decay products of lepto-pion like states, say tau-pions? Intriguingly, the first figures of the article by Alessandro Strumia (see `http://tinyurl.com/y9jp333p`) [C19] discussing the constraints on the possible explanations of the PAMELA anomaly show that the anomalous positron excess starts around 10 GeV, possible it starts already at 7 GeV. It is not possible to say anything certain below 10 GeV since the measurements are affected by the solar actvity below 10 GeV. What is however clear is that the excess cannot be explained by taupion decays with 14 GeV mass since the excess would be localized around energy of about 7 GeV. Higher mass is required.

The article by Alessandro Strumia summarizes various theoretical constraints on the new particle explaining positron and electron excesses. The conclusions are following.

1. DM should result in a decay of quite a narrow particle with a mass very near to 2M, which is nearly at rest. What narrow means quantitatively is not clear to me.

2. DM should carry a charge mediating long range interaction with the mediating boson which is must lighter than the particle itself: photon is the obvious candidate. Electromagnetically charged dark matter is however in conflict with the standard prejudices about dark matter and actually in dramatic conflict with its basic property of being invisible. Hierarchy of Planck constants is the only solution to the paradox of charged invisible dark matter.
3. DM must prefer the decays to leptons since otherwise there would be also antiproton and proton excess which has not been observed.
4. The mass of DM should be above 100 GeV.

These conditions encourage the identification of DM as a decay product of lepto-pion like state but with mass considerably higher than the 14 GeV mass. Tau-pions could of course be present but would not contribute to the anomaly at energies not too much above 7 GeV. Tau-pions would also give muon pair anomaly. Heavier lepto-pion like states are required and electro-pion would be the most natural candidate.

1. If a scaled up variant of ordinary hadron physics characterized by M_{89} is there as the recent bumps having interpretation as mesons of this physics suggest, there is no deep reason preventing the presence of also the scale variant of lepto-hadron physics in this scale. Even more, one can argue that colored leptons must appear as both dark and ordinary variants. Dark variants with non-standard value of Planck constant can have masses of ordinary leptons plus possibly their octaves as in the case of tau at least. The decay widths of intermediate gauge bosons require ordinary colored leptons to have mass higher than 45 GeV.
2. The mass of scaled up electro-pion would be obtained by scaling the mass of the dark electro-pion which for M_{89} electro-pion physics is in a good approximation $2m_e$=1 MeV by a factor $2^{(127-89)/2} = 2^{19}$. This gives electro-pion mass equal to 500 GeV. Ordinary colored electron would therefore have mass of 250 GeV consistent with the lower bound. The conclusion would be rather ironic: we would have seen dark colored electron (in TGD sense) already at seventies and covered it carefully under the rug and would be seeing now the ordinary colored electron and stubbornly trying to identify it as DM without caring about the fact that if dark matter is invisible in the standard sense it cannot be electromagnetically charged!
3. By stretching one's imagination one might play with the thought that superpartners of colored leptons with mass scale of order 100 GeV could form pion like states. The superpartners decay to partner and neutrino since R-parity is not exact invariance in TGD and all depends on how fast this process occurs.
4. Skeptic could wonder why the counterparts for colored excitations of quarks are not there and induce the increase of proton and antiproton fluxes.

To summarize, entire Zoo of not only new particles but even of new physics could be waiting for us at LHC energies if we live in TGD Universe!

2.3.6 Positron anomaly nine years later

The old PAMELA experiment [C126] (see `http://tinyurl.com/y7y9maac`) and perhaps newer ones by Fermi-LAT and AMS-02 have discovered lots of positrons in the cosmic rays, whose flux is generally higher than expected. The energies of positrons show steady rise in the range [10,100] GeV and presumably the rise will continue. Such positrons may originate from dark matter and could amount to an "almost direct detection" of the particles that make up dark matter. There are also other interpretations.

Dark matter explanations for the positron excess

Consider first new physics explanations postulating dark matter.

1. Dark spin 1 particles could decay to electron positron pair. The energy spectrum of energies is however discrete for dominating decay modes. For instance, vector mesons of new hadron physics could produce these events. Many neutral vector mesons say (Psi/J) were discovered in electron-positron annihilation.

2. Pion-like spin 0 pseudoscalars decaying to electron-positron pairs and gamma rays predicts continuous spectrum. In the case of ordinary pion most decays are to gamma pairs. The decay to electron-positron pair and gamma ray has quite reasonable branching ratio .01. The reason is that the diagram describing this process is diagram for the decay to gamma pair with second gamma decaying to e^+e^- so that the rate is roughly the rate for the decay to gamma pair multiplied by $\alpha_{em} \sim 1/137$. This relation is expected to hold true for the decays of all pion-like states. For the decay to electron positron pair branching ratio about 6.5×10^{-8}. For pion-like states X the decay $X \rightarrow e^+e^- + \gamma$ for pion-like state could give a continuous spectrum. The mass of X should be of the order of 100 GeV for this option.

Standard physics explanation for the positron excess

One of the standard physics explanations is that the positrons emerge from pulsars. The beams from pulsars contain electrons accelerated to very high energies in the gigantic magnetic field of pulsar. This beam collides with the matter surrounding the pulsar and both gamma rays and positrons are generated in these interactions.

The standard physics proposal has been put to a test. One can predict the intensity of gamma rays coming from pulsars using standard model physics and deduce from it the density of electrons needed to generate it. Both positrons and gamma rays would be created when electrons from the pulsar are accelerated to very high energies in enormous magnetic field of the pulsar and collide with surrounding matter. This is like particle accelerator. The energies of the produced gamma rays and also positrons extend to TeV range, which corresponds to the energy range for LHC.

It turns out that the flux of electrons implied by the gamma ray intensity is too low to explain the flux of positrons detected by PAMELA [C126] and some other experiments. See the popular article at `http://tinyurl.com/ycw6xjs6` and the research article "Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth" in Science [C50] (see `http://tinyurl.com/yach5g83`).

TGD based model for positron excess

Also TGD suggests an explanation for the positron excess (I learned about PAMELA experiment at my birth day nine years ago and it was an excellent birthday present!). TGD allows a hierarchy of scaled up copies of hadron physics labelled by ordinary Mersenne primes $M_n = 2^n - 1$ or by Gaussian Mersennes $M_{G,n} = (1+i)^n - 1$. Ordinary hadron physics would correspond to M_{107}.

1. M_{89} hadron physics would have mass scale which is 512 times higher than that for ordinary hadron physics: the size scale of these hadrons is by factor 1/512 shorter than that for ordinary hadrons. There are indications for the copies also in other scales: M_{79} for instance [K66]. X boson provides indication for $M_{G,113}$ pions in nuclear scale. Even copies of hadron physics in biologically important length scales labelled by Gaussian Mersennes $M_{G,k}$, $k = 151, 157, 163, 167$ could exist and play key role in living matter [K59]. By the way, the appearance of four Gaussian Mersennes in this length scale range is number theoretical miracle.
2. M_{89} hadrons can also appear as dark states with Planck constant $h_{eff} = n \times h$. For $n = 512$ they would have the size of ordinary hadrons. This could explain the strange anomalies observed at RHIC and later at LHC and hinting about the presence of string like structures in what was expected to be color deconfinement phase transition predicting thermal spectrum should have been observed instead of strong correlations suggesting for quantum criticality characterized by long range correlations and fluctuations for which $h_{eff}/h = n$ would be an explanation.
3. A large number of bumps, whose masses correspond to the masses of ordinary hadron physics scaled up by factor 512, have been reported at LHC. Unfortunately these bumps cannot be explained by SUSY and other main stream models so that they have been forgotten.

TGD based model could be combined with the pulsar model for the positron excess. The collisions between protons from the pulsar accelerated in its magnetic field and the matter surrounding the pulsar would be analogous to those taking place between proton beams at LHC. If the collision energy is high enough (as it seems since gamma rays up to TeV range have been observed) they could produce dark M_{89} mesons, in particular pions, which then decay to gamma rays and lepton pairs, in particular electron-positron pairs. Similar collisions could occur also in the atmosphere of Earth between ultrahigh energy cosmic rays and nuclei of atmosphere and be responsible for the exotic cosmic ray events like Centauro challenging standard model physics [K67].

Other evidence for dark pion like states

There is also other evidence for pion-like states dark in TGD sense.

1. There is an old observation that gamma ray pairs with energy essential that of electrons rest must come from the center of Milky Way presumably resulting in decays of a particle with mass slightly larger than two times the mass of electron. These particles would also decay to electron positron pairs and the resulting electrons and positrons would be accelerated in the magnetic field of say pulsar to high energies. The rate for the decay to electron positron pairs is quite too slow as compared to the decay rate to gamma pairs. Therefore this mechanism cannot explain positron surplus.
2. The TGD model for the pion-like states decaying to gamma pairs is as leptopion [K115], which would be a pion-like bound state of color excitations of electrons predicted to be possible in TGD Universe. "Electropion" like states were discovered experimentally in CERN already at seventies and later evidence also for the muopions and taupions has emerged but since they did not fit with standard model, their existence was forgotten. This has been the fate of many other anomalies in particle physics. In nuclear physics there are century old forgotten anomalies re-discovered several times only to be "forgotten" again. The laws of Nature are not discovered nowadays as in good old days: they are decided by the hegemony, which happens to be in power. SUSY, superstring models, and M-theory already disappearing in the sands of time are basic examples of this new political science.
3. The reason for not accepting the existence of leptopion like states was that in standard model intermediate bosons should decay to them and their decay widths would be larger than their experimental values. However, if leptopions are dark matter in TGD sense having non-standard value of Planck constant $h_{eff}/h = n$, the problem can be circumvented.

2.3.7 Could Lepto-Hadrons Be Replaced With Bound States Of Exotic Quarks?

Can one then exclude the possibility that electron-hadrons correspond to colored quarks condensed around $k = 127$ hadronic space-time sheet: that is M_{127} hadron physics? There are several objections against this identification.

1. The recent empirical evidence for the colored counterpart of μ and τ supports the view that colored excitations of leptons are in question.
2. The octet character of color representation makes possible the mixing of leptons with leptobaryons of form $L\nu_L\overline{\nu}_L$ by color magnetic coupling between leptogluons and ordinary and colored lepton. This is essential for understanding the production of electron-positron pairs.
3. In the case CDF anomaly also the assumption that colored variant of τ neutrino is very light is essential. In the case of colored quarks this assumption is not natural.

2.3.8 About The Masses Of Lepto-Hadrons

The progress made in understanding of dark matter hierarchy [K43] and non-perturbative aspects of hadron physics [K71, K66] allow to sharpen also the model of lepto-hadrons.

The model for the masses of ordinary hadrons [K71] applies also to the scaled up variants of the hadron physics. The two contributions to the hadron mass correspond to quark contribution and a contribution from super-symplectic bosons. For quarks labeled identical p-adic primes mass squared is additive and for quarks labeled by different primes mass is additive. Quark contribution is calculable once the p-adic primes of quarks are fixed.

super-symplectic contribution comes from super-symplectic bosons at hadronic space-time sheet labeled by Mersenne prime and is universal if one assumes that the topological mixing of the super-symplectic bosons is universal. If this mixing is same as for U type quarks, hadron masses can be reproduced in an excellent approximation if the super-symplectic boson content of hadron is assumed to correlate with the net spin of quarks.

In the case of baryons and pion and kaon one must assume the presence of a negative color conformal weight characterizing color binding. The value of this conformal weight is same for all baryons and super-symplectic contribution dominates over quark contribution for nucleons. In the case of mesons binding conformal weight can be assumed to vanish for mesons heavier than kaon and one can regard pion and kaon as Golstone bosons in the sense that quark contribution gives the mass of the meson.

This picture generalizes to the case of lepto-hadrons.

1. By the additivity of the mass squared leptonic contribution to lepto-pion mass would be $\sqrt{2}m_e(k)$, where k characterizes the p-adic length scale of colored electron. For $k = 127$ the mass of lepto-pion would would be .702 MeV and too small. For $k = 126$ the mass would be $2m_e = 1.02$ MeV and is very near to the mass of the lepto-pion. Note that for ordinary hadrons quarks can appear in several scaled up variants inside hadrons and the value of k depends on hadron. The prediction for the mass of leptoρ would be $m_{\pi_L} + \sqrt{7}m_{127} \simeq 1.62$ MeV ($m_{127} = m_e/\sqrt{5}$).

2. The state consisting of three colored electrons would correspond to leptonic variant of Δ_{++} having charge $q = -3$. The quark contribution to the mass of $\Delta_L \equiv \Delta_{L,3-}$ would be by the additivity of mass squared $\sqrt{3} \times m_e(k = 126) = 1.25$ MeV. If super-symplectic particle content is same as for Δ_L, super-symplectic contribution would be $m_{SC} = 5 \times m_{127}$, and equal to $m_{SC} = .765$ MeV so that the mass of Δ_L would be $m_{\Delta_L} = 2.34$ MeV. If colored neutrino corresponds to the same p-adic prime as colored electron, also leptoproton has mass in MeV scale.

2.3.9 Do X And Y Mesons Provide Evidence For Color Excited Quarks Or Squarks?

Now and then come the days when head is completely empty of ideas. One just walks around and gets more and more frustrated. One can of course make authoritative appearances in blog groups and express strong opinions but sooner or later one is forced to look for web if one could find some problem. At this time I had good luck. By some kind of divine guidance I found myself immediately in Quantum Diaries and found a blog posting with title *Who ordered that?! An X-traordinary particle?* (see `http://tinyurl.com/3k9pts5`) [C16].

Not too many unified theorists take meson spectroscopy seriously. Although they are now accepting low energy phenomenology (*the* physics for the rest of us) as something to be taken seriously, meson physics is for them a totally uninteresting branch of botany. They could not care less. As a crackpot I am however not well-informed about what good theoretician should do and shouldn't do and got interested. Could this give me a problem that my poor crackpot brain is crying for?

The posting told me that in the spectroscopy of $c\bar{c}$ type mesons is understood except for some troublesome mesons christened imaginatively with letters X and Y plus brackets containing their mass in MeVs. X(3872) is the firstly discovered troublemaker and what is known about it can be found in the blog posting and also in Particle Data Tables (see `http://tinyurl.com/y7x23br5`) [C8]. The problem is that these mesons should not be there. Their decay widths seem to be narrow taking into account their mass and their decay characteristics are strange: in particular the kinematically allow decays to $D\overline{D}$ dominating the decays of $\Psi(3770)$ with branching ratio 93 per cent has not been observed whereas the decay to $D\overline{D}\pi^0$ occurs with a branching fraction $> 3.2 \times 10^{-3}$. Why the pion is needed? $X(3872)$ should decay to photon and charmonium state in a predictable way but it does not.

Could these be the good questions?

TGD predicts a lot of exotic physics and I of course started to exclude various alternatives. First one must however try to invent a good question. Maybe the following questions might satisfy the criterion of goodness.

1. Why these exotic states appear only for mesons made of heavy quark and antiquark? Why not for light mesons? Why not for mesons containing one heavy quark and light quark? Could it be that also $b\overline{b}$ mesons could have exotic partners not yet detected? Could it be that also exotic $b\overline{c}$ type mesons could be there? Why the presence of light quark would eliminate the exotic partner from the spectrum?
2. Do the decays obey some selection rules? There is indeed this kind of rule: the numbers of c and $\overline{c}$ quarks in the final state are equal to one.
   (a) If c and $\overline{c}$ exist in the initial state and the decay involves only strong interactions, the rule holds true.
   (b) If c and $\overline{c}$ are not present in the initial state the only option that one can imagine is the exhange of two W bosons transforming d type quarks to c type quarks must be present. If this were the case the initial state should correspond to $d\overline{d}$ like state rather than $c\overline{c}$ and this looks very strange from the standard physics point of view. Also the rate for this kind of decays would be very small and it seems that this option cannot make sense.

Both leptons and quarks have color excitations in TGD Universe

TGD predicts that both leptons and quarks have color excitations [K115]. For leptons they correspond to color octets and there is a lot of experimental evidence for them. Why we do not have any evidence for color excited quarks? Or do we actually have?! Could these strange X: s and Y: s provide this evidence?

Ordinary quarks correspond to triality one color triplet partial waves in CP_2. The higher color partial waves would also correspond to triality one states but in higher color partial waves in CP_2. The representations of the color group are labelled by two integers (p, q) and the dimension of the representation is given by

$$d = \frac{(p+1)(q+1)(p+q+2)}{2} \quad .$$

A given $t = \pm 1$ representation is accompanied by its conjugate with the same dimension and opposite triality $t = \mp 1$. $t = 1$ representations satisfy $p - q = 1$ modulo 3 and come as (1, 0), (0, 2), (3, 0), (2, 1), with dimensions 3, 6, 10, 15, ... The simplest candidate for the color excitations would correspond to the representation $\overline{6}$. It does not correspond directly the a solution of the Dirac equation in CP_2 since physical states involve also color Kac-Moody generators [K61].

Some remarks are in order:

1. The tensor product of gluon octet with $t = 1$ with color triplet representation contains $8 \times 3 = 24$ states and decomposes into $t = 1$ representations as $3 \oplus \overline{6} \oplus 15$. The coupling of gluons by Lie algebra action can couple given representation only with itself. The coupling between triplet and $\overline{6}$ and 15 is therefore not by Lie algebra action. The coupling constant between quarks and color excited quarks is *assumed* to be proportional to color coupling.
2. The existence of this kind of coupling would explain the selection rules elegantly. If this kind of coupling is not allowed then only the annihilation of exotic quark to gluon decaying to quark pair can transform exotic mesons to ordinary ones and I have not been able to explain selection rules using this option.

The basic constraint applying to all variants based on exotic states of quarks comes from the fact that the decay widths of intermediate gauge bosons do not allow new light particles. This objection is encountered already in the model of lepto-hadrons [K115]. The solution is that the light exotic states are possible only if they are dark in TGD sense having therefore non-standard value of Planck constant and behaving as dark matter. The value of Planck constant is only effective and has purely geometric interpretation in TGD framework. This implies that a phase transition transforming quarks and gluons to their dark counterparts is the key element of the model. After this a phase transition a gluon exchange would transform the quark pair to an exotic quark pair.

Also squarks could explain exotic charmonium states

Supersymmetry provides an alternative mechanism. Right-handed neutrino generates super-symmetries in TGD Universe and quarks are accompanied by squarks consisting in a well-defined sense of of quark and right-handed neutrino. Super-symmetry would allow completely standard couplings to gluons by adding to the spectrum squarks and gluinos.Exactly the same selection rules result if these new states are mesonlike states from from squark and anti-squark and the exchange of gluino after the $\hbar$ changing phase transition transforms exotic meson to ordinary one and vice versa.

In the sequel it will be shown that the existence of color excited quarks or of their super-partners could indeed allow to understand the origin of X and Y mesons and also the absence of analogous states accompanying mesons containing light quarks or antiquarks.

This picture would lead to a completely new view about detection of squarks and gluinos.

1. In the standard scenario the basic processes are production of squark and gluino pair. The creation of squark-antisquark pair is followed by the decay of squark (anti-squark) to quark (antiquark) and neutralino or chargino. If R-parity is conserved, the decay chain eventually gives rise to at least two hadron jets and lightest neutralinos identifiable as missing energy. Gluinos in turn decay to quark and anti-squark (squark and antiquark) and squark (anti-squark) in turn to quark (anti-quark) and neutralino or chargino. At least four hadron jets and missing energy is produced. In TGD framework neutralinos would decay eventually to zinos or photinos and right-handed neutrino transforming to ordinary neutrino (R-parity is not conserved). This process might be however slow.

2. In the recent case quite different scenario relying on color confinement and "shadronization" suggests itself. By definition smesons consist of squarks and antisquark. Sbaryons could consist of two squarks containing right-handed neutrino and its antineutrino ($\mathcal{N} = 2$ SUSY) and one quark and thus have same quantum numbers as baryon. Note that the squarks are dark in TGD sense.

   Also now dark squark or gluino pair would be produced at the first step and would require $\hbar$ changing phase transition of gluon. These would shadronize to form a dark shadron. One can indeed argue that the required emisson of winos and zinos and photinos is too slow a process as compared to shadronization. Shadrons (mostly smesons) would in turn decay to hadrons by the exchange of gluinos between squarks. No neutralinos (missing energy) would be produced. This would explain the failure to detect squarks and gluinos at LHC.

   This mechanism does not however apply to sleptons so that it seems that the p-adic mass scale of sleptons must be much higher for sleptons than that for squarks as I have indeed proposed.

Could exotic charmonium states consist of color excited c and $\bar{c}$ or of their spartners?

Could one provide answers to the questions presented in the beginning assuming that exotic charmonium states consists of dark color excited c and $\bar{c}$: or more generally, a mixture of ordinary charmonium and exotic charmonium state? The mixing is expected since $\hbar$ changing phase transition followed by a gluon exchange can transform these meson states to each other. Also annihilation to gluon and back to quark pair can induce this mixing. The mixing is however small for heavy quarks for which $\alpha_s \simeq .1$ holds true. Exactly the same arguments apply to the meson like bound states of squarks and in the following only the first option will be discussed.

1. In the case of charged leptons colored excitations have have same p-adic mass scale: for τ however several p-adic mass scales appear as the model if the two year old CDF anomaly is taken seriously [K115]. Assume that p-adic mass scales - but not necessarily masses- are the same also now. This assumption might be non-sensical since also light mesons would have exotic counterparts and somehow they should disappear from the spectrum. To simplify the estimates one could even assume even that the masses are same.

2. In the presence of small mixing the decay amplitude would come solely from the small contribution of the ordinary $c\overline{c}$ state present in the state dominated by color excited pair. The two ways to see the situation should give essentially the same answer.

3. The decays would take place via strong interactions.

The challenge is to understand why the dominating decays to $D\overline{D}$ with branching fraction of 93 per cent are not allowed whereas $D\overline{D}\pi^0$ takes place. Why the pion is needed? The second challenge is to understand why X does not decay to charmonium and photon.

1. For ordinary charmonium the decay to $D\overline{D}$ could take place by the emission of gluon from either c or $\overline{c}$ which then decays to light quark pair whose members combine with c and $\overline{c}$ to form D and $\overline{D}$. Now this mechanism does not work. At least *two* gluons must be emitted to transform colored excited $c\overline{c}$ to ordinary $c\overline{c}$. If these gluons decay to light quark pairs one indeed obtains an additional pion in hadronization. The emission of two gluons instead of only one is expected to reduce the rate roughly by $\alpha_s^2 \simeq 10^{-2}$ factor.

2. Also ordinary decays are predicted to occur but with a slower rate. The first step would be an exchange of gluon transforming color excited charmed quark pair to an ordinary charmed quark pair. After the transformation to off mass shell $c\overline{c}$ pair, the only difference to the decays of charmonium states would be due to the fact that charmonium would be replaced with $c\overline{c}$ pair. The exchange of the gluon preceding this step could reduce the decay rate with respect to charmonium decay rates by a factor of order $\alpha_s^2 \simeq 10^{-2}$. Therefore also the ordinary decay modes should be there but with a considerably reduced rate.

3. Why the direct decays to photon and charmonium state do not occur in the manner predicted by the model of charmonium? For ordinary charmonium the decay proceeds by an emission of photon by either quark or antiquark. Same mechanism applies for exotic charmonium states but leads to final state which consists of *exotic* charmonium and photon. In the case of $X(3872)$ there exists no lighter exotic charmonium state so that the decay is forbidden in this order of perturbation theory. Heavier exotic charmonium states can however decay to photon plus exotic charmonium state in this order of perturbation theory if discrete symmetries favor this.

Essentially identical arguments go through if c and $\overline{c}$ are replaced with their dark spartners and exchange of gluon by the emission of gluino. The transformation of gluon to its dark variants is an essential element in the process.

Why the color excitations/spartners of light quarks would be effectively absent?

Can one understand the effective absence of mesons consisting of color excited light quarks or squarks if the excitations have same mass scale and even mass as the light quarks? The following arguments are for color excited quarks but they apply also to squarks.

1. Suppose that the mixing induced by $\hbar$ changing phase transition followed by a gluon exchange and annihilation is described by mass squared matrix containing besides diagonal components $M_1^2 = M_2^2$ also non-diagonal component $M_{12}^2 = \overline{M_{21}^2}$. The eigenstates of the mass squared matrix correspond to the physical states which are mixtures of states consisting of ordinary quark pair and pair of color excited quarks. The non-diagonal elements of the mass squared matrix corresponds to gluon exchange and since color interactions get very strong at low energy scales, one expects that these elements get very large. In the degenerate case $M_1^2 = M_2^2$ the mass squared eigen values are given by

$$M_\pm^2 = M_0^2 \pm |M_{12}|^2 \quad . \tag{2.3.4}$$

2. Suppose that $M_0^2 = 0$ holds true in accordance with approximate pseudo Goldstone nature of pion and more generally all light pseudo-scalar mesons. In fact assume that this is the case before color magnetic spin-spin splitting has taken place so that in this approximation pion and ρ would have same mass $m_\pi^2 = m_\rho^2 = M_0^2$. In TGD based model for color magnetic spin-spin splitting M_0^2 energy is replaced with mass squared [K71] and M_0^2 is obtained in terms of physical masses of π and ρ from the basic formulas

$$
\begin{aligned}
m_\pi^2 &= M_0^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_0^2 + \frac{3}{4}\Delta \ , \\
M_0^2 &= \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \ \Delta = m_\rho^2 - m_\pi^2 \ .
\end{aligned}
\tag{2.3.5}
$$

The exotic π and ρ would have masses

$$
\begin{aligned}
m_{\pi_{ex}}^2 &= -M_0^2 - \frac{1}{4}\Delta = m_\pi^2 - 2M_0^2 \ , \\
m_{\rho_{ex}}^2 &= -M_0^2 + \frac{3}{4}\Delta = m_{rho}^2 - 2M_0^2\Delta \ .
\end{aligned}
\tag{2.3.6}
$$

For $m_\pi = 140MeV$ and $m_\rho = 770$ MeV the calculation gives $m_{\pi_{ex}} = i\times 685$ MeV so a tachyon would be in question. For ρ one would have $m_{\pi_{ex}} = 323$ MeV so that the mass would not be tachyonic.

One can try to improve the situation by allowing $M_1^2 \neq M_2^2$ giving additional flexibility and hopes about tachyonicity of the exotic ρ.

1. In this case one obtains the equations

$$
\begin{aligned}
m_\pi^2 &= M_+^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_+^2 + \frac{3}{4}\Delta \\
m_{\pi_{ex}}^2 &= M_-^2 - \frac{1}{4}\Delta \ , \ m_{\rho_{ex}}^2 = M_-^2 + \frac{3}{4}\Delta \ , \\
M_+^2 &= \frac{M_1^2+M_2^2}{2} + \sqrt{(\frac{M_1^2+M_2^2)}{2})^2 + M_{12}^4} = \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \\
M_-^2 &= \frac{M_1^2+M_2^2}{2} - \sqrt{\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} = M_+^2 - 2\sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4}
\end{aligned}
\tag{2.3.7}
$$

2. The condition that ρ_{ex} is tachyonic gives

$$
m_{\rho_{ex}}^2 = M_-^2 + \frac{3}{4}\Delta < 0 \ ,
\tag{2.3.8}
$$

giving

$$
\begin{aligned}
m_\rho^2 &< 2\sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} \ , \\
M_+^2 &= \frac{M_1^2+M_2^2}{2} + \sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} = \frac{m_\rho^2 + 3m_\pi^2}{2} \ ,
\end{aligned}
\tag{2.3.9}
$$

3. In the parameterization $(m_1^2, m_2^2, M_{12}^2) = (x,y,z)m_\rho^2$ one obtains the conditions

$$
\begin{aligned}
D \equiv \sqrt{(x+y)^2 + z^2} &> 1/2 \ , \\
\frac{x+y}{2} + D = \frac{1}{2} + \frac{3}{2}\frac{m_\pi^2}{m_\rho^2} & \ .
\end{aligned}
\tag{2.3.10}
$$

4. These equations imply the conditions

$$\begin{aligned} x+y &< 3\frac{m_\pi^2}{m_\rho^2} \simeq .099 \ , \\ .490 &< z < .599 \ . \end{aligned} \tag{2.3.11}$$

The first condition implies $\sqrt{m_1^2+m^2} < 242.7$ MeV. Second condition gives $339 < M_{12}/MeV < 595.9$ so that rather stringent bounds on the parameters are obtained. The simplest solution to the conditions corresponds to $x = y = 0$ and $z = .599$. This solution would mean vanishing masses in the absence of mixing and spin-spin splitting and could be defended by the Golstone boson property of pions mass degenerate with ρ mesons.

This little calculation encourages to consider the possibility that all exotic counterparts of light mesons are tachyonic and that this due the very large mixing induced by gluon exchange (gluino exchange squark option) at low energies. It would be nice if also mesons containing only single heavy quark were tachyonic and this could be the case if the p-adic length scale defining the strength of color interactions corresponds to that of the light quark so that the mass matrix has large enough non-diagonal component. Here one must be however very cautious since experimental situation is far from clear.

The model suggests that ordinary charmonium states and their exotic partners are in 1-1 correspondence. If so then many new exotic states are waiting to be discovered.

The option based on heavy color excitations/spartners of light quarks

An alternative option is that color excitations/spartners of light quarks have large mass: this mass should not be however larger than the mass of c quarks if we want to explain X: s and Y: s as pairs of color excitations of light quarks. Suppose that the p-adic mass scale is same as that for c quarks or near it (not that the scales come as powers of $\sqrt{2}$). This raises the question whether exotic $c\overline{c}$ mesons really consist of exotic c and $\overline{c}$: why not color excitations of u, d, s and their antiquarks? As a matter fact, we cannot be sure about the quark content of X and Y mesons. Could these states be $d\overline{d}$ and $u\overline{u}$ states for their color excitations? It however seems that the presence of two W exchanges makes the decay rate quite too low so that this option seems to be out of question.

One can however consider the option in which the squarks associated with light quarks are heavy. This option is indeed realized in standard SUSY were the mass scales of particles families are inverted so that stop and sbottom are the lightest squarks and super-partners of u and d the heaviest ones. This would would predict that the smesons associated with $\overline{t}$ and $b\overline{b}$ are lighter than X and Y (s)mesons. This option does not look at all natural in TGD but of course deserves experimential checking.

How to test the dark squark option?

The identification of X and Y as dark smesons looks like a viable option and explains the failure to find SUSY at LHC if shadronization is a fast process as compared to the selectro-weak decays. The option certainly deserves an experimental testing. One could learn a lot about SUSY in TGD sense (or maybe in some other sense!) by just carefully scanning the existing data at lower energies. For instance, one could try to answer the following questions by analyzing the already existing experimental data.

1. Are X and Y type mesons indeed in 1-1 correspondence with charmonium states? One could develop numerical models allowing to predict the precise masses of scharmonium states and their decay rates to various final states and test the predictions experimentally.
2. Do $b\overline{b}$ mesons have smesonic counterparts with the same mass scale? What about B_c type smesons containing two heavy squarks?
3. Do the mesons containing one heavy quark and one light quark have smesonic counterparts? My light-hearted guess that this is not the case is based on the assumption that the general mass scale of the mass squared matrix is defined by the p-adic mass scale of the heavy quark and the non-diagonal elements are proportional to the color coupling strength at p-adic length

scale associated with the light quark and therefore very large: as a consequence the second mass eigenstate would be tachyonic.

4. What implications the strong mixing of light mesons and smesons would have for CP breaking? CP breaking amplitudes would be superpositions of diagrams representing CP breaking for mesons *resp.* smesons. Could the presence of smesonic contributions perhaps shed light on the poorly understood aspects of CP breaking?

Objection against covariantly constant neutrinos as SUSY generators

TGD SUSY in its simplest form assumes that covariantly constant right-handed neutrino generates SUSY. The second purely TGD based element is that squarks would correspond to the same p-adic mass scale as partners.

This looks nice but there are objections.

1. The first objection relates to the tachyonicity needed to get rid of double degeneracy of light mesons consisting of u, d, and s quarks. Mesons and smesons consisting of squark pair mix and for large α_s the mixing is large and can indeed make second eigenvalue of the mass squared matrix negative. If so, these states disappears from spectrum. At least to me this looks however somewhat unaesthetic.

   Luckily, the transformation of second pion-like state to tachyon and disappearance from spectrum is not the only possibility. After a painful search I found experimental work (see `http://tinyurl.com/ybq323yy`) [C149] claiming the existence of states analogous to ordinary pion with masses 60, 80, 100, 140, ... MeV. Also nucleons have this kind of satellite states. Could it be that one of these states is spion predicted by TGD SUSY for ordinary hadrons? But what about other states? They are not spartners: what are they?

2. The second objection relates to the missing energy. SUSY signatures involving missing energy have not been observed at LHC. This excludes standard SUSY candidates and could do the same in the case of TGD. In TGD framework the missing energy would be eventually right handed neutrinos resulting from the decays of sfermions to fermion and sneutrino in turn decaying to neutrino and right handed neutrino. The naïve argument is that shadronization would be much faster process than the decay of squarks to quarks and spartners of electroweak gauge bosons and missing energy so that these events would not be observed. Shadrons would in turn decay to hadrons by gluino exchanges. The problem with this argument is that the weak decays of squarks producing right handed neutrinos as missing energy are still there!

   This objection forces to consider the possibility that covariantly constant right handed neutrino which generates SUSY is replaced with a color octet. Color excitations of leptons of lepto-hadron hypothesis [K115] would be sleptons which are color octets so that SUSY for leptons would have been seen already at seventies in the case of electron. The whole picture would be nicely unified. Sleptons and squark states would contain color octet right handed neutrino the same wormhole throats as their em charge resides. In the case of squarks the tensor product $3 \otimes 8 = 3 + \overline{6} + 15$ would give several colored exotics. Triplet squark would be like ordinary quark with respect to color.

   Covariantly constant right-handed neutrino as such would represent pure gauge symmetry, a super-generator annihilating the physical states. Something very similar can occur in the reduction of ordinary SUSY algebra to sub-algebra familiar in string model context. By color confinement missing energy realized as a color octet right handed neutrino could not be produced and one could overcome the basic objections against SUSY by LHC.

What about the claimed anomalous trilepton events at LHC interpreted in terms of SUSY, which however breaks either the conservation of lepton or baryon number. I have proposed TGD based interpretation [K66] is in terms of the decays of W to $\tilde{W}$ and $\tilde{Z}$, which in turn decay and produce the three lepton signature. Suppose that $\tilde{W}$ and $\tilde{Z}$ are color octets and that sleptons replace the color octet excitations of leptons responsible for lepto-hadron physics [K115]. One possible decay chain would involve the decays $\tilde{W}^+ \rightarrow \tilde{L}^+ + \overline{\nu}_L$ and $\tilde{Z} \rightarrow L^+ + \tilde{L}^-$. Color octet sleptons pair combine to form lepto-pion which decays to lepton pair. This decay cascade would produce missing energy as neutrino and this seems to be the case for other options too.e could overcome the basic objections against SUSY by LHC.

This view about TGD SUSY clearly represents a hybrid of the two alternative views about X and Y bosons as composites of either color excitations of quarks or of squarks and is just one possibility. The situation is not completely settled and one must keep mind open.

2.4 Appendix

2.4.1 Evaluation Of Lepto-Pion Production Amplitude

General form of the integral

The amplitude for lepto-pion production with four momentum

$$\begin{aligned} p &= (p_0,\bar{p}) = m\gamma_1(1,vsin(\theta)cos(\phi),vsin(\theta)sin(\phi),vcos(\theta)) \ , \\ \gamma_1 &= 1/(1-v^2)^{1/2} \ , \end{aligned} \tag{2.4.1}$$

is essentially the Fourier component of the instanton density

$$U(b,p) = \int e^{ip\cdot x} E\cdot B d^4x \tag{2.4.2}$$

associated with the electromagnetic field of the colliding nuclei.

In order to avoid cumbersome numerical factors, it is convenient to introduce the amplitude $A(b,p)$ as

$$\begin{aligned} A(b,p) &= N_0\times \frac{4\pi}{Z_1Z_2\alpha_{em}}\times U(b,p) \ , \\ N_0 &= \frac{(2\pi)^7}{i} \end{aligned} \tag{2.4.3}$$

Coordinates are chosen so that target nucleus is at rest at the origin of coordinates and colliding nucleus moves along positive z direction in $y=0$ plane with velocity β. The orbit is approximated with straight line with impact parameter b.

Instanton density is just the scalar product of the static electric field E of the target nucleus and magnetic field B the magnetic field associated with the colliding nucleus, which is obtained by boosting the Coulomb field of static nucleus to velocity β. The flux lines of the magnetic field rotate around the direction of the velocity of the colliding nucleus so that instanton density is indeed non vanishing.

The Fourier transforms of E and B for nuclear charge 4π (chose for convenience) giving rise to Coulomb potential $1/r$ are given by the expressions

$$\begin{aligned} E_i(k) &= N\delta(k_0)k_i/k^2 \ , \\ B_i(k) &= N\delta(\gamma(k_0-\beta k_z))k_j\varepsilon_{ijz}e^{ik_xb}/((\frac{k_z}{\gamma})^2+k_T^2) \ , \\ N &= \frac{1}{(2\pi)^2} \ . \end{aligned} \tag{2.4.4}$$

The normalization factor corresponds to momentum space integration measure d^4p. The Fourier transform of the instanton density can be expressed as a convolution of the Fourier transforms of E and B.

$$\begin{aligned} A(b,p) &\equiv = N_0N_1\int E(p-k)\cdot B(k)d^4k \ , \\ N_1 &= \frac{1}{(2\pi)^4} \ . \end{aligned} \tag{2.4.5}$$

Where the fields correspond to charges $\pm 4\pi$. In the convolution the presence of two delta functions makes it possible to integrate over k_0 and k_z and the expression for U reduces to a two-fold integral

$$\begin{aligned}
A(b,p) &= \beta\gamma \int dk_x dk_y exp(ikxb)(k_x p_y - k_y p_x)/AB \quad , \\
A &= (p_z - \frac{p_0}{\beta})^2 + p_T^2 + k_T^2 - 2k_T \cdot p_T \\
B &= k_T^2 + (\frac{p_0}{\beta\gamma})^2 \quad , \\
p_T &= (p_x, p_y) \quad . \qquad (2.4.6)
\end{aligned}$$

To carry out the remaining integrations one can apply residue calculus.

1. k_y integral is expressed as a sum of two pole contributions
2. k_x integral is expressed as a sum of two pole contributions plus two cut contributions.

k_y-integration

Integration over k_y can be performed by completing the integration contour along real axis to a half circle in upper half plane (see **Fig. ??**).

The poles of the integrand come from the two factors A and B in denominator and are given by the expressions

$$\begin{aligned}
k_y^1 &= i(k_x^2 + (\frac{p_0}{\beta\gamma})^2)^{1/2} \quad , \\
k_y^2 &= p_y + i((p_z - \frac{p_0}{\beta})^2 + p_x^2 + k_x^2 - 2p_x k_x)^{1/2} \quad . \qquad (2.4.7)
\end{aligned}$$

One obtains for the amplitude an expression as a sum of two terms

$$A(b,p) = 2\pi i \int e^{ik_x b}(U_1 + U_2)dk_x \quad , \qquad (2.4.8)$$

corresponding to two poles in upper half plane.

The explicit expression for the first term is given by

$$\begin{aligned}
U_1 &= RE_1 + iIM_1 \quad , \\
RE_1 &= (k_x \frac{p_0}{\beta} y - p_x re_1/2)/(re_1^2 + im_1^2) \quad , \\
IM_1 &= (-k_x p_y re_1/2K_1^{1/2} - p_x p_y K_1^{1/2})/(re_1^2 + im_1^2) \quad , \\
re_1 &= (p_z - \frac{p_0}{\beta})^2 + p_T^2 - (\frac{p_0}{\beta\gamma})^2 - 2p_x k_x \quad , \\
im_1 &= -2K_1^{1/2} p_y \quad , \\
K_1 &= k_x^2 + (\frac{p_0}{\beta\gamma})^2 \quad . \qquad (2.4.9)
\end{aligned}$$

The expression for the second term is given by

$$\begin{aligned}
U_2 &= RE_2 + iIM_2 \quad , \\
RE_2 &= -((k_x p_y - p_x p_y)p_y + p_x re_2/2)/(re_2^2 + im_2^2) \quad , \\
IM_2 &= (-(k_x p_y - p_x p_y)re_2/2K_2^{1/2} + p_x p_y K_2^{1/2})/(re_2^2 + im_2^2) \quad , \\
re_2 &= -(p_z - \frac{p_0}{\beta})^2 + (\frac{p_0}{\beta\gamma})^2 + 2p_x k_x + \frac{p_0}{\beta} y - \frac{p_0}{\beta} x \quad , \\
im_2 &= 2p_y K_2^{1/2} \quad , \\
K_2 &= (p_z - \frac{p_0}{\beta})^2 + \frac{p_0}{\beta} x + k_x^2 - 2p_x k_x \quad . \qquad (2.4.10)
\end{aligned}$$

A little inspection shows that the real parts cancel each other: $RE_1 + RE_2 = 0$. A further useful result is the identity $im_1^2 + re_1^2 = re_2^2 + im_2^2$ and the identity $re_2 = -re_1 + 2p_y^2$.

k_x-integration

One cannot perform k_x-integration completely using residue calculus. The reason is that the terms IM_1 and IM_2 have cuts in complex plane. One can however reduce the integral to a sum of pole terms plus integrals over the cuts.

The poles of U_1 and U_2 come from the denominators and are in fact common for the two integrands. The explicit expressions for the pole in upper half plane, where integrand converges exponentially are given by

$$\begin{aligned}
re_i^2 &+ im_i^2 = 0 \ , \ \ i = 1,2 \ , \\
k_x &= (-b + i(-b^2 + 4ac)^{1/2})/2a \ , \\
a &= 4p_T^2 \ , \\
b &= -4((p_z - \frac{p_0}{\beta})^2 + p_T^2 - (\frac{p_0}{\beta\gamma})^2)p_x \ per, \\
c &= ((p_z - \frac{p_0}{\beta})^2 + p_T^2 - (\frac{p_0}{\beta\gamma})^2)^2 + 4(\frac{p_0}{\beta\gamma})^2 p_y^2 \ .
\end{aligned} \tag{2.4.11}$$

A straightforward calculation using the previous identities shows that the contributions of IM_1 and IM_2 at pole have opposite signs and the contribution from poles vanishes identically!

The cuts associated with U_1 and U_2 come from the square root terms K_1 and K_2. The condition for the appearance of the cut is that K_1 (K_2) is real and positive. In case of K_1 this condition gives

$$k_x = it, \ t \in (0, \frac{p_0}{\beta\gamma}) \ . \tag{2.4.12}$$

In case of K_2 the same condition gives

$$k_x = p_x + it, \ t \in (0, \frac{p_0}{\beta} - p_z) \ . \tag{2.4.13}$$

Both cuts are in the direction of imaginary axis.

The integral over real axis can be completed to an integral over semi-circle and this integral in turn can be expressed as a sum of two terms (see **Fig. 2.4**).

$$A(b,p) = 2\pi i(CUT_1 + CUT_2) \ . \tag{2.4.14}$$

The first term corresponds to contour, which avoids the cuts and reduces to a sum of pole contributions. Second term corresponds to the addition of the cut contributions.

In the following we shall give the expressions of various terms in the region $\phi \in [0, \pi/2]$. Using the symmetries

$$\begin{aligned}
A(b, p_x, -p_y) &= -A(b, p_x, p_y) \ , \\
A(b, -p_x, -p_y) &= \bar{A}(b, p_x, p_y) \ .
\end{aligned} \tag{2.4.15}$$

of the amplitude one can calculate the amplitude for other values of ϕ.

The integration variable for cuts is the imaginary part t of complexified k_x. To get a more convenient form for cut integrals one can perform a change of the integration variable

$$\begin{aligned}
cos(\psi) &= \frac{t}{(\frac{p_0}{\beta\gamma})} \ , \\
cos(\psi) &= \frac{t}{(\frac{p_0}{\beta} - p_z)} \ , \\
\psi &\in [0, \pi/2] \ .
\end{aligned} \tag{2.4.16}$$

1. The contribution of the first cut

By a painstaking calculation one verifies that the expression for the contribution of the first cut is given by

$$\begin{aligned}
CUT_1 &= D_1 \times \int_0^{\pi/2} exp(-\frac{b}{b_0} cos(\psi)) A_1 d\psi \ , \\
D_1 &= -\frac{1}{2}\frac{sin(\phi)}{sin(\theta)} \ , \ b_0 = \frac{\hbar}{m}\frac{\beta\gamma}{\gamma_1} \ , \\
A_1 &= \frac{A + iBcos(\psi)}{cos^2(\psi) + 2iCcos(\psi) + D} \ , \\
A &= sin(\theta)cos(\phi) \ , \ B = K \ , \\
C &= K\frac{cos(\phi)}{sin(\theta)} \ , \ D = -sin^2(\phi) - \frac{K^2}{sin^2(\theta)} \ , \\
K &= \beta\gamma(1 - \frac{v_{cm}}{\beta}cos(\theta)) \ , \ v_{cm} = \frac{2v}{1+v^2} \ .
\end{aligned} \tag{2.4.17}$$

The definitions of the various kinematical variables are given in previous formulas. The notation is tailored to express that A_1 is rational function of $cos(\psi)$.

1. The exponential $exp(-bcos(\psi)/b_0)$ is very small in the condition

$$cos(\psi) \geq cos(\psi_0) \equiv \frac{\hbar}{mb}\frac{\beta\gamma}{\gamma_1 cos(\phi)} \tag{2.4.18}$$

holds true. Here $\hbar = 1$ convention has been given up to make clear that the increase of the Compton length of lepto-pion due to the scaling of $\hbar$ increase the magnitude of the contribution. If the condition $cos(\psi_0) << 1$ holds true, the integral over ψ receives contributions only from narrow range of values near the upper boundary $\psi = \pi/2$ plus the contribution corresponding to the pole of X_1. The practical condition is in terms of critical parameter b_{max} above which exponential approaches zero very rapidly.

2. For $cos(\psi_0) << 1$, that is for $b > b_{max}$ and in the approximation that the function multiplying the exponent is replaced with its value for $\psi = \pi/2$, one obtains for CUT_1 the expression

$$\begin{aligned}
CUT_1 &\simeq D_1 A_1(\psi = \pi/2)\frac{\hbar}{mb} \\
&= \frac{1}{2} \times \frac{\beta\gamma}{\gamma_1} \times \frac{\hbar}{mb} \times \frac{sin^2(\theta)cos(\phi)sin(\phi)}{sin^2(\theta)sin^2(\phi) + K^2} \ .
\end{aligned} \tag{2.4.19}$$

3. For $cos(\psi_0) >> 1$ exponential factor can be replaced by unity in good approximation and the integral reduces to an integral of rational function of $cos(\psi)$ having the form

$$D_1\frac{A + iBcos(\psi)}{cos^2(\psi) + 2iC \times cos(\psi) + D} \ . \tag{2.4.20}$$

which can be expressed in terms of the roots $c_\pm$ of the denominator as

$$D_1 \times \sum_\pm \frac{A \mp iBc_\pm}{cos(\psi) - c_\pm} \quad , \quad c_\pm) \quad = \quad -iC \pm \sqrt{-C^2 - D} \quad . \tag{2.4.21}$$

Integral reduces to an integral of rational function over the interval $[0,1]$ by the standard substitution $tan(\psi/2) = t$, $d\psi = 2dt/(1+t^2)$, $cos(\psi) = (1-t^2)/(1+t^2)$, $sin(\psi) = 2t/(1+t^2)$.

$$I \quad = \quad 2D_1 \sum_\pm \int_0^1 dt \frac{A \mp iBc_\pm}{1 - c_\pm - (1 + c_\pm)t^2} \tag{2.4.22}$$

This gives

$$I \quad = \quad 2D_1 \sum_\pm \frac{A \mp iBc_\pm}{s_\pm} \times arctan(\frac{1 + c_\pm}{1 - c_\pm}) \quad . \tag{2.4.23}$$

$s_\pm$ is defined as $\sqrt{1 - c_\pm^2}$ and one must be careful with the signs. This gives for CUT_1 the approximate expression

$$\begin{aligned} CUT_1 \quad &= \quad D_1 \sum_\pm \frac{sin(\theta)cos(\phi) \mp iKc_\pm}{s_\pm} \times arctan(\frac{1 + c_\pm}{1 - c_\pm}) \quad , \\ c_\pm \quad &= \quad \frac{-iKcos(\phi) \pm sin(\phi)\sqrt{sin^2(\theta) + K^2}}{sin(\theta)} \quad . \end{aligned} \tag{2.4.24}$$

Arcus tangent function must be defined in terms of logarithm functions since the argument is complex.

4. In the intermediate region, where the exponential differs from unity one can use expansion in Taylor polynomial to sum over integrals of rational functions of $cos(\psi)$ and one obtains the expression

$$\begin{aligned} CUT_1 \quad &= \quad D_1 \sum_{n=0}^{\infty} \frac{(-1)^n}{n!} (\frac{b}{b_0})^n I_n \quad , \\ I_n \quad &= \quad \sum_\pm (A \mp iBc_\pm I_n(c_\pm) \quad , \\ I_n(c) \quad &= \quad \int_0^{\pi/2} \frac{cos^n(\psi)}{cos(\psi) - c} \quad . \end{aligned} \tag{2.4.25}$$

$I_n(c)$ can be calculated explicitly by expanding in the integrand $cos(\psi))^n$ to polynomial with respect to $cos(\psi)) - c$, $c \equiv c_\pm$

$$\frac{cos^n(\psi)}{cos(\psi) - c} = \sum_{m=0}^{n-1} \left(\begin{array}{c} n \\ m \end{array} \right) c^m (cos(\psi) - c)^{n-m-1} + \frac{c^n}{cos(\psi) - c} \quad . \tag{2.4.26}$$

After the change of the integration variable the integral reads as

$$
\begin{aligned}
I_n(c) &= \sum_{m=0}^{n-1}\sum_{k=0}^{n-m-1}\left(\begin{array}{c} n \\ m \end{array}\right)\left(\begin{array}{c} n-m-1 \\ k \end{array}\right)(-1)^k(1-c)^{n-m-1-k}(1+c)^k c^m I(k,n-m) \\
&+ \frac{c^n}{1-c}\times log[\frac{\sqrt{1-c}+\sqrt{1+c}}{\sqrt{1-c}-\sqrt{1+c}}] \ , \\
I(k,n) &= 2\int dt\frac{t^{2k}}{(1+t^2)^n} \ . \qquad (2.4.27)
\end{aligned}
$$

Partial integration for $I(k,n)$ gives the recursion formula

$$
I(k,n) = -\frac{2^{-n+1}}{n-1}+\frac{2k-1}{2(n-1)}\times I(k-1,n-1) \ . \qquad (2.4.28)
$$

The lowest term in the recursion formula corresponds to $I(0,n-k)$, can be calculated by using the expression

$$
\begin{aligned}
(1+t^2)^{-n} &= \sum_{k=0}^{n} c(n,k)[(1+it)^{-k}+(1-it)^{-k}] \ , \\
c(n,k) &= \sum_{l=0}^{n-k-1} c(n-1,k+l)2^{-l-2}+c(n-1,n-1)2^{-n+k-1} \ . \qquad (2.4.29)
\end{aligned}
$$

The formula is deducible by assuming the expression to be known for n and multiplying the expression with $(1+t^2)^{-1} = [(1+it)^{-1}+(1-it)^{-1}]/2$ and applying this identity to the resulting products of $(1+it)^{-1}$ and $(1-it)^{-1}$. This gives

$$
I(0,n) = -2i\sum_{k=2,n}\frac{c(n,k)}{(k-1)}[1+2^{(k-1)/2}sin((k-1)\pi/4)]+c(n,1)log(\frac{1+i}{1-i}) \qquad (2.4.30)
$$

This boils down to the following expression for CUT_1

$$
\begin{aligned}
CUT_1 &= D_1\sum_{n=0}^{\infty}\frac{(-1)^n}{n!}(\frac{b}{b_0})^n I_n \ , \\
I_n &= \sum_{\pm}[A\mp iBc_{\pm}]I_n(cos(c_{\pm}) \ , \\
I_n(c) &= \sum_{m=1}^{n-1}\sum_{k=0}^{n-m-1}\left(\begin{array}{c} n \\ m \end{array}\right)\left(\begin{array}{c} n-m-1 \\ k \end{array}\right)(1-c)^{n-m-1-k}(1+c)^k c^m I(k,n-m-1) \\
&+ \frac{c^n}{1-c}\times log[\frac{\sqrt{1-c}+\sqrt{1+c}}{\sqrt{1-c}-\sqrt{1+c}}] \ , \\
I(k,n) &= -\frac{2^{-n+1}}{n-1}+\frac{2k-1}{2(n-1)}\times I(k-1,n-1) \ , \\
I(0,n) &= -2i\sum_{k=2}^{n}\frac{c(n,k)}{(k-1)}[1+2^{(k-1)/2}sin((k-1)\pi/4)]-c(n,1) \ , \\
c(n,k) &= \sum_{l=0}^{n-k-1} c(n-1,k+l)2^{-l-2}+c(n-1,n-1)2^{-n+k-1} \ . \qquad (2.4.31)
\end{aligned}
$$

This expansion in powers of $c_{\pm}$ fails to converge when their values are very large. This happens in the case of τ-pion production amplitude. In this case one typically has however the situation in which the conditions $A_1 \simeq iBcos(\psi)/D$ holds true in excellent approximation and one can write

$$
\begin{aligned}
CUT_1 &\simeq i\frac{D_1 B}{D} \times \sum_{n=0,1,\ldots} \frac{(-1)^n}{n! 2^n} (\frac{b}{b_0})^n I_n \times \ , \\
I_n &= \int_0^{\pi/2} cos(\psi)^{n+1} d\psi = \sum_{k=0}^{n+1} \left(\begin{array}{c} n+1 \\ k \end{array} \right) \frac{i^{n-2k}-1}{n+1-2k} \ . \qquad (2.4.32)
\end{aligned}
$$

The denominator X_1 vanishes, when the conditions

$$
\begin{aligned}
cos(\theta) &= \frac{\beta}{v_{cm}} \ , \\
sin(\phi) &= cos(\psi) \qquad (2.4.33)
\end{aligned}
$$

hold. In forward direction the conditions express the vanishing of the z-component of the lepto-pion velocity in velocity cm frame as one can realize by noticing that condition reduces to the condition $v = \beta/2$ in non-relativistic limit. This corresponds to the production of lepto-pion with momentum in scattering plane and with direction angle $cos(\theta) = \beta/v_{cm}$.

CUT_1 diverges logarithmically for these values of kinematical variables at the limit $\phi \to 0$ as is easy to see by studying the behavior of the integral near as K approaches zero so that X_1 approaches zero at $sin(\phi) = cos(\Phi)$ and the integral over a small interval of length $\Delta\Psi$ around $cos(\Psi) = sin(\phi)$ gives a contribution proportional to $log(A + B\Delta\Psi))/B$, $A = K[K - 2isin(\theta)sin^2(\phi)]$ and $B = 2sin(\theta)cos(\phi)[sin(\theta)sin(\phi) - iKcos(\phi)]$. Both A and B vanish at the limit $\phi \to 0$, $K \to 0$. The exponential damping reduces the magnitude of the singular contribution for large values of $sin(\phi)$ as is clear form the first formula.

2. The contribution of the second cut

The expression for CUT_2 reads as

$$
\begin{aligned}
CUT_2 &= D_2 exp(-\frac{b}{b_2}) \times \int_0^{\pi/2} exp(i\frac{b}{b_1} cos(\psi)) A_2 d\psi \ , \\
D_2 &= -\frac{sin(\frac{\phi}{2})}{usin(\theta)} \ , \\
b_1 &= \frac{\hbar}{m}\frac{\beta}{\gamma_1} \ , \ b_2 = \frac{\hbar}{mb}\frac{1}{\gamma_1 \times sin(\theta)cos(\phi)} \\
A_2 &= \frac{Acos(\psi) + B}{cos^2(\psi) + 2iCcos(\psi) + D} \ , \\
A &= sin(\theta)cos(\phi)u \ , \ B = \frac{w}{v_{cm}} + \frac{v}{\beta} sin^2(\theta)[sin^2(\phi) - cos^2(\phi)] \ , \\
C &= \frac{\beta w}{uv_{cm}} \frac{cos(\phi)}{sin(\theta)} \ , \ D = -\frac{1}{u^2}(\frac{sin^2(\phi)}{\gamma^2} + \beta^2(v^2 sin^2(\theta) - \frac{2vw}{v_{cm}})cos^2(\phi)) \\
&+ \frac{w^2}{v_{cm}^2 u^2 sin^2(\theta)} + 2i\frac{\beta v}{u} sin(\theta)cos(\phi) \ , \\
u &= 1 - \beta v cos(\theta) \ , \ w = 1 - \frac{v_{cm}}{\beta} cos(\theta) \ . \qquad (2.4.34) \\
& \qquad (2.4.35)
\end{aligned}
$$

The denominator X_2 has no poles and the contribution of the second cut is therefore always finite.

1. The factor $exp(-b/b_2)$ gives an exponential reduction and the contribution of CUT_2 is large only when the criterion

$$
b < \frac{\hbar}{m} \times \frac{1}{v\gamma_1 sin(\theta)cos(\phi)}
$$

for the impact parameter b is satisfied. Large values of $\hbar$ increase the range of allowed impact parameters since the Compton length of lepto-pion increases.

2. At the limit when the exponent becomes very large the variation of the phase factor implies destructive interference and one can perform stationary phase approximation around $\psi = \pi/2$. This gives

$$\begin{aligned} CUT_2 &\simeq \sqrt{\frac{2\pi b_1}{b}} \times D_2 \times exp(\frac{b}{b_2}) A_2(\psi = 0) \ , \\ D_2 &= -\frac{sin(\frac{\phi}{2})}{usin(\theta)} \ , \ A_2 = \frac{A}{D} \ . \end{aligned} \tag{2.4.36}$$

3. As for CUT_1, the integral over ψ can be expressed as a finite sum of integrals of rational functions, when the value of $(b/b_1)cos(\psi)$ is so small that $exp(i(b/b_1)cos(\psi))$ can be approximated by a Taylor polynomial. More generally, one obtains the expansion

$$\begin{aligned} CUT_2 &= D_2 exp(-\frac{b}{b_2}) \times \sum_{n=0}^{\infty} \frac{1}{n!} i^n (\frac{b}{b_1})^n I_n(A,B,C,D) \ , \\ I_n(A,B,C,D) &= \int_0^{\pi/2} cos(\psi)^n \frac{A + iBcos(\psi)}{cos^2(\psi) + Ccos(\psi) + D} \ . \end{aligned} \tag{2.4.37}$$

The integrand of $I_n(A,B,C,D)$ is same rational function as in the case of CUT_1 but the parameters A, B, C, D given in the expression for CUT_2 are different functions of the kinematical variables. The functions appearing in the expression for integrals $I_n(c)$ correspond to the roots of the denominator of A_2 and are given by $c_\pm = -iC \pm \sqrt{-C^2 - D}$, where C and D are the function appearing in the general expression for CUT_2 in Eq. 2.4.35.

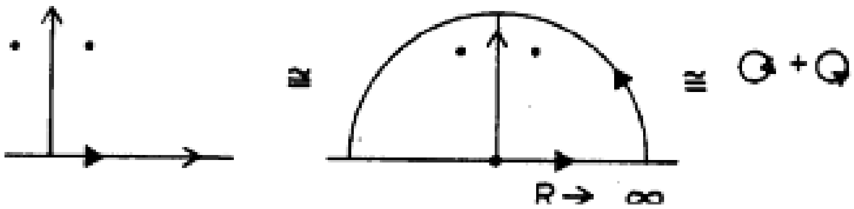

Figure 2.3: Evaluation of k_y-integral using residue calculus.

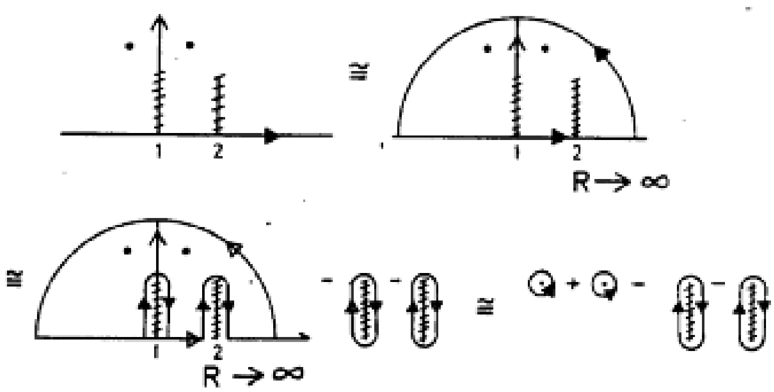

Figure 2.4: Evaluation of k_x-integral using residue calculus.

2.4.2 Production Amplitude In Quantum Model

The previous expressions for CUT_1 and CUT_2 as such give the production amplitude for given b in the classical model and the cross section can be calculated by integrating over the values of b. The finite Taylor expansion of the amplitude in powers of b allows explicit formulas when impact parameter cutoff is assumed.

General expression of the production amplitude

In quantum model the production amplitude can be reduced to simpler form by using the defining integral representation of Bessel functions

$$\begin{aligned}
f_B &= i\int F(b)J_0(\Delta kb)(CUT_1+CUT_2)bdb \ , \\
F &= 1 \quad \text{for } exp(i(S)) \text{ option } \ , \\
F(b\geq b_{cr}) &= \int dz\frac{1}{\sqrt{z^2+b^2}} = 2ln(\frac{\sqrt{a^2-b^2}+a}{b}) \ \text{ for } exp(i(S))-1 \text{ option } \ , \\
\Delta k &= 2ksin(\frac{\alpha}{2}) \ , \quad k=M_R\beta \quad .
\end{aligned} \tag{2.4.38}$$

Note that F is a rather slowly varying function of b and in good approximation can be replaced by its average value $A(b,p)$, which has been already explicitly calculated as power series in b. α_{em} corresponds to the value of α_{em} for the standard value of Planck constant.

The limit $\Delta k = 0$

The integral of the contribution of CUT_1 over the impact parameter b involves integrals of the form

$$\begin{aligned}
J_{1,n} &= b_0^2\int J_0(\Delta kb)F(b)x^{n+1}dx \ , \\
x &= \frac{b}{b_0} \ .
\end{aligned} \tag{2.4.39}$$

Here a is the upper impact parameter cutoff. For CUT_2 one has integrals of the form

$$\begin{aligned}
J_{2,n} &= b_1^2(\frac{b_2}{b_1})^{n+2}\int J_0(\Delta kb)F(b)exp(-x)x^{n+1}dx \ , \\
x &= \frac{b}{b_2} \ .
\end{aligned} \tag{2.4.40}$$

Using the following approximations it is possible to estimate the integrals analytically.

1. The logarithmic term is slowly varying function and can be replaced with its average value

$$F(b) \rightarrow \langle F(b)\rangle \equiv F \ . \tag{2.4.41}$$

2. Δk is fixed once the value of the impact parameter is known. At the limit $\Delta k = 0$ making sense for very high energy collisions one can but the value of Bessel function to $J_0(0) = 1$. Hence it is advantageous to calculated the integrals of $\int CUT_ibdb$.

Consider first the integral $\int CUT_1bdb$. If exponential series converges rapidly one can use Taylor polynomial and calculate the integrals explicitly. When this is not the case one can calculate integral approximately and the total integral is sum over two contributions:

$$\int CUT_1bdb = I_a + I_b \ . \tag{2.4.42}$$

1. The region in which Taylor expansion converges rapidly gives rise integrals

$$\begin{aligned} I_{1,n} &\simeq b_0^2\int x^{n+1}dx = b_0^2\frac{1}{n+2}[(\frac{b_{max}}{b_0})^{n+2}-(\frac{b_{cr}}{b_0})^{n+2}] \simeq b_0^2\frac{1}{n+2}(\frac{b_{max}}{b_0})^{n+2} \ , \\ I_{2,n} &\simeq b_1^2(\frac{b_2}{b_1})^{n+2}\int exp(-x)x^{n+1}dx = b_1^2(\frac{b_2}{b_1})^{n+2}(n+1)! \ . \end{aligned} \tag{2.4.43}$$

2. For the perturbative part of CUT_1 one obtains the expression

$$\begin{aligned} I_a &= \int_0^{b_{max}} CUT_1 bdb = D_1\times b_0^2\times\sum_{n=0}^{\infty}\frac{1}{n!(n+2)}(\frac{b_{max}}{b_0})^{n+2}I_n(A,B,C,D) \ , \\ D_1 &= -\frac{1}{2}\frac{sin(\phi)}{sin(\theta)} \ , \ b_0=\frac{\hbar\beta\gamma}{m\gamma_1} \ . \end{aligned} \tag{2.4.44}$$

There b_{max} is the largest value of b for which the series converges sufficiently rapidly.

3. The convergence of the exponential series is poor for large values of b/b_0, that is for $b>b_m$. In this case one can use the approximation in which the multiplier of exponent function in the integrand is replaced with its value at $\psi=\pi/2$ so that amplitude becomes proportional to b_0/b. In this case the integral over b gives a factor proportional to ab_0, where a is the impact parameter cutoff.

$$\begin{aligned} I_b\equiv\int_{b_m}^{a} CUT_1 bdb &\simeq b_0(a-b_m)D_1\times A_1(\psi=\pi/2) \\ &= \frac{\beta\gamma}{\gamma_1}\times\frac{\hbar}{m}\times\frac{sin^2(\theta)cos(\phi)sin(\phi)}{sin^2(\theta)sin^2(\phi)+K^2} \ , \\ D_1 &= -\frac{1}{2}\frac{sin(\phi)}{sin(\theta)} \ , \ A_1(\psi=\pi/2)=\frac{A}{D} \ . \end{aligned} \tag{2.4.45}$$

4. As already explained, the expansion based on partial fractions does not converge, when the roots $c_\pm$ have very large values. This indeed occurs in the case of τ-pion production cross section. In this case one has $A_1\simeq iBcos(\psi)/D$ in excellent approximation and one can calculate CUT_1 in much easier manner. Using the formula of Eq. 2.4.32 for CUT_1, one obtains

$$\begin{aligned} \int CUT_1 bdb &\simeq b_0^2\frac{D_1B}{D}\times\sum_{n=0,1,...}\frac{(-1)^n}{n!(n+2)2^n}\times\sum_{k=0}^{n+1}\begin{pmatrix} n+1 \\ k\end{pmatrix} c_{n,k}\times(\frac{b_{max}}{b_0})^n \ , \\ c_{n,k} &= \frac{i^{n+1-2k}-1}{n+1-2k} for \ n\neq 2k-1 \ , \ c_{n,k}=\frac{i\pi}{2} \ for \ n=2k-1 \ , \end{aligned} \tag{2.4.46}$$

Note that for $n=2k+1=k$ the coefficient diverges formally and actua

Highly analogous treatment applies to the integral of CUT_2.

1. For the perturbative contribution to $\int CUT_2 bdb$ one obtains

$$\begin{aligned} I_a &= \int_0^{b_{1,max}} CUT_2 bdb = b_1^2 D_2\sum_{n=0}^{\infty}(n+1)i^n I_n(A,B,C,D)\times(\frac{b_2}{b_1})^{n+2} \ , \\ D_2 &= -\frac{sin(\frac{\phi}{2})}{usin(\theta)} \ , \\ b_1 &= \frac{\hbar\beta}{m\gamma_1} \ , \ b_2=\frac{\hbar}{m\gamma_1}\frac{1}{sin(\theta)cos(\phi)} \ . \end{aligned} \tag{2.4.47}$$

2. Taylor series converges slowly for

$$\frac{b_1}{b_2} = \frac{sin(\theta)cos(\phi)}{\beta} \rightarrow 0 \ .$$

In this case one can replace $exp(-b/b_2)$ with unity or expand it as Taylor series taking only few terms. This gives the expression for the integral which is of the same general form as in the case of CUT_1

$$I_a = \int_0^{b_{max}} CUT_2 bdb = b_1^2 D_2 \sum_{n=0}^{\infty} \frac{i^n}{n!(n+2)} I_n(A,B,C,D)(\frac{b_{max}}{b_1})^{n+1} \ . \tag{2.4.48}$$

3. Also when b/b_1 becomes very large, one must apply stationary phase approximation to calculate the contribution of CUT_2 which gives a result proportional to $\sqrt{b_1/b}$. Assume that $b_m >> b_1$ is the value of impact parameter above which stationary phase approximation is good. This gives for the non-perturbative contribution to the production amplitude the expression

$$\begin{aligned} I_b &= \int_{b_m}^{a} CUT_2 bdb = k\sqrt{\frac{2\pi b_1}{b_2}} b_2^2 \times D_2 \times A_2(\psi = \pi/2) \ , \\ k &= \int_{x_1}^{x_2} exp(-x)x^{1/2}dx = 2\int_{\sqrt{x_1}}^{\sqrt{x_2}} exp(-u^2)u^2 du \ , \\ x_1 &= \frac{b_m}{b_2} \ , \ x_2 = \frac{a}{b_2} \ . \end{aligned} \tag{2.4.49}$$

In good approximation one can take $x_2 = \infty$. $x_1 = 0$ gives the upper bound $k \leq \sqrt{\pi}$ for the integral.

Some remarks relating to the numerics are in order.

1. The contributions of both CUT_1 and CUT_2 are proportional to $1/sin(\theta)$ in the forward direction. The denominators of A_i however behave like $1/sin^2(\theta)$ at this limit so that the amplitude behaves as $sin(\theta)$ at this limit and the amplitude approaches to zero like $sin(\theta)$ Therefore the singularity is only apparent but must be taken into account in the calculation since one has $c_\pm \rightarrow i\infty$ at this limit for CUT_2 and for CUT_1 the roots approach to $c_+ = c_- = i\infty$. One must pose a cutoff θ_{min} below which the contribution of CUT_1 and CUT_2 are calculated directly using approximate he expressions for D_iA_i.

$$\begin{aligned} D_1A_1 &\rightarrow -\frac{i}{K}cos(\psi) \times sin(\theta) \rightarrow 0 \\ D_2A_2 &\rightarrow -\frac{uv_{cm}}{w} \times sin(\theta) \rightarrow 0 \ . \end{aligned} \tag{2.4.50}$$

In good approximation both contributions vanish since also $sin^2(\theta)$ factor from the phase space integration reduces the contribution.

2. A second numerical problem is posed by the possible vanishing of

$$K = \beta\gamma(1 - \frac{v_c m}{\beta}cos(\theta)) \ .$$

In this case the roots $c_\pm = \pm sin(\phi)$ are real and c_+ gives rise to a pole in the integrand.

The singularity to the amplitude comes from the logarithmic contributions in the Taylor series expansion of the amplitude. The sum of the singular contributions coming from c_+ and c_- are of form

$$\frac{c_n}{2}(\sqrt{1-sin(\phi)}+\sqrt{1+sin(\phi)}log(\frac{1+u}{1-u}) \ , \ u=\sqrt{\frac{1+sin(\phi)}{1-sin(\phi)}} \ .$$

Here c_n characterizes the $1/(cos(\psi)-c_{\pm})$ term of associated with the $cos(\psi)^n$ term in the Taylor expansion. Logarithm becomes singular for the two terms in the sum at the limit $\phi \rightarrow 0$. The sum however behaves as

$$\frac{c_n}{2}sin(\phi)log(\frac{sin(\phi)}{2}) \ .$$

so that the net result vanishes at the limit $\phi \rightarrow 0$. It is essential that the logarithmic singularities corresponding to the roots c_+ and c_- cancel each other and this must be taken into account in numerics. There is also apparent singularity at $\phi = \pi/2$ canceled by $cos(\phi)$ factor in D_1. The simplest manner to get rid of the problem is to exclude small intervals $[0,\epsilon]$ and $[\pi/2-\epsilon, \pi/2]$ from the phase space volume.

Improved approximation to the production cross section

The approximation $J_0(\Delta k_T(b)b) = 1$ and $F(b) = F = constant$ allows to perform the integrations over impact parameter explicitly (for $exp(iS)$ option $F = 1$ holds true identically in the lowest order approximation). An improved approximation is obtained by diving the range of impact parameters to pieces and performing the integrals over the impact parameter ranges exactly using the average values of these functions. This requires only a straightforward generalization of the formulas derived above involving integrals of the functions x^n and $exp(-x)x^n$ over finite range. Obviously this is still numerically well-controlled procedure.

2.4.3 Evaluation Of The Singular Parts Of The Amplitudes

The singular parts of the amplitudes $CUT_{1,sing}$ and $B_{1,sing}$ are rational functions of $cos(\psi)$ and the integrals over ψ can be evaluated exactly.

In the classical model the expression for $U_{1,sing}$ appearing as integrand in the expression of $CUT_{1,sing}$ reads as

$$\begin{aligned}
A_{1,sing} &= -\frac{1}{2\sqrt{K^2+sin^2(\theta)}}(sin(\theta)cos(\phi)A_a+iKA_b) \ , \\
A_a &= I_1(\beta,\pi/2) = \int_0^{\pi/2} d\psi f_1 \ , \\
A_b &= I_2(\beta,\pi/2) = \int_0^{\pi/2} d\psi f_2 \ , \\
f_1 &= \frac{1}{(cos(\psi)-c_1)(cos(\psi)-c_2)} \ , \\
f_2 &= cos(\psi) f_1 \ , \\
c_1 &= \frac{-iKcos(\phi)+sin(\phi)\sqrt{K^2+sin^2(\theta)}}{sin(\theta)} \ , \\
c_2 &= -\bar{c}_1 \ .
\end{aligned} \tag{2.4.51}$$

Here c_i are the roots of the polynomial X_1 appearing in the denominator of the integrand.

In quantum model the approximate expression for the singular contribution to the production amplitude can be written as

$$\begin{aligned}
B_{1,sing} &\simeq k_1 \frac{sin(\theta)sin(\phi)}{2\sqrt{K^2+sin^2(\theta)}} \sum_n \langle F\rangle_n (I(x(n+1)) - I(x(n)) \ , \\
I(x) &= exp(-\frac{sin(\phi)x}{sin(\phi_0)})(sin(\theta)cos(\phi)A_a(\Delta ka, x) + iKA_b(\Delta ka, x)) \ , \\
k_1 &= 2\pi^2 M_R Z_1 Z_2 \alpha_{em} \frac{\sqrt{2}}{\sqrt{\Delta k \pi}} sin(\phi_0) \ .
\end{aligned} \tag{2.4.52}$$

The expressions for the amplitudes $A_a(k,x)$ and $A_b(k,x)$ read as

$$\begin{aligned}
A_a(k,x) &= cos(kx)I_3(k,0,\pi/2) + isin(\phi_0)ksin(kx)I_5(k,0,\pi/2) \ , \\
A_b(k,x) &= cos(kx)I_4(k,0,\pi/2) + isin(\phi_0)ksin(kx)I_3(k,0,\pi/2) \ , \\
I_i(k,\alpha,\beta) &= \int_\alpha^\beta f_i(k)d\psi \ , \\
f_3(k) &= \frac{cos(\psi)}{(cos^2(\psi) + sin^2(\phi_0)k^2)} f_1(k) \ , \\
f_4(k) &= cos(\psi)f_3(k) \ , \\
f_5(k) &= \frac{1}{(cos^2(\psi) + sin^2(\phi_0)k^2)} f_1(k) \ .
\end{aligned} \tag{2.4.53}$$

The expressions for the integrals I_i as functions of the endpoints α and β can be written as

$$\begin{aligned}
I_1(k,\alpha,\beta) &= I_0(c_1,\alpha,\beta) - I_0(c_2,\alpha,\beta) \ , \\
I_2(\alpha,\beta) &= c_1 I_0(c_1,\alpha,\beta) - c_2 I_0(c_2,\alpha,\beta) \ , \\
I_3 &= C_{34} \sum_{i=1,2,j=3,4} \frac{1}{(c_i - c_j)} (c_i I_0(c_i,\alpha,\beta) - c_j I_0(c_j,\alpha,\beta)) \ , \\
I_4 &= C_{34} \sum_{i=1,2,j=3,4} \frac{1}{(c_i - c_j)} ((c_i - c_j)(\beta-\alpha) - c_i^2 I_0(c_i,\alpha,\beta) + c_j^2 I_0(c_j,\alpha,\beta)) \ , \\
I_5 &= C_{34} \sum_{i=1,2,j=3,4} \frac{1}{(c_i - c_j)} (I_0(c_i,\alpha,\beta) - I_0(c_j,\alpha,\beta)) \ , \\
C_{34} &= \frac{1}{c_3 - c_4} = \frac{1}{2ikasin(\phi_0)} \ .
\end{aligned} \tag{2.4.54}$$

The parameters c_1 and c_2 are the zeros of X_1 as function of $cos(\psi)$ and c_3 and c_4 the zeros of the function $cos^2(\psi) + k^2a^2sin^2(\phi_0)$:

$$\begin{aligned}
c_1 &= \frac{-iKcos(\phi) + sin(\phi)\sqrt{K^2+sin^2(\theta)}}{sin(\theta)} \ , \\
c_2 &= \frac{-iKcos(\phi) - sin(\phi)\sqrt{K^2+sin^2(\theta)}}{sin(\theta)} \ , \\
c_3 &= ikasin(\phi_0) \ , \\
c_4 &= -ikasin(\phi_0) \ .
\end{aligned} \tag{2.4.55}$$

The basic integral $I_0(c,\alpha,\beta)$ appearing in the formulas is given by

$$
\begin{aligned}
I_0(c,\alpha,\beta) &= \int_\alpha^\beta d\psi \frac{1}{(cos(\psi)-c)} \ , \\
&= \frac{1}{\sqrt{1-c^2}}(f(\alpha)-f(\beta)) \ , \\
f(x) &= ln(\frac{(1+tan(x/2)t_0)}{(1-tan(x/2)t_0)}) \ , \\
t_0 &= \sqrt{\frac{1-c}{1+c}} \ .
\end{aligned} \tag{2.4.56}
$$

From the expression of I_0 one discovers that scattering amplitude has logarithmic singularity, when the condition $tan(\alpha/2) = 1/t_0$ or $tan(\beta/2) = 1/t_0$ is satisfied and appears, when c_1 and c_2 are real. This happens at the cone $K = 0$ ($\theta = \theta_0$), when the condition

$$
\begin{aligned}
\sqrt{\frac{(1-sin(\phi))}{(1+sin(\phi))}} &= tan(x/2) \ , \\
x &= \alpha \text{ or } \beta \ .
\end{aligned} \tag{2.4.57}
$$

holds true. The condition is satisfied for $\phi \simeq x/2$. $x = 0$ is the only interesting case and gives singularity at $\phi = 0$. In the classical case this gives logarithmic singularity in production amplitude for all scattering angles.

Chapter 3

TGD and Nuclear Physics

3.1 Introduction

Despite the immense amount of data about nuclear properties, the first principle understanding of the nuclear strong force is still lacking. The conventional meson exchange description works at qualitative level only and does not provide a viable perturbative approach to the description of the strong force. The new concept of atomic nucleus forced by TGD suggests quite different approach to the quantitative description of the strong force in terms of the notion of field body, join along boundaries bond concept, long ranged color gauge fields associated with dark hadronic matter, and p-adic length scale hierarchy.

3.1.1 P-Adic Length Scale Hierarchy

p-Adic length scale hypothesis

The concept of the p-adic topological condensate is the corner stone of p-adic TGD. Various levels of the topological condensate obey effective p-adic topology and are assumed to form a p-adic hierarchy ($p_1 \leq p_2$ can condense on p_2). By the length scale hypothesis, the physically interesting length scales should come as square roots of powers of 2: $L(k) \simeq 2^{\frac{k}{2}} l$, $l \simeq 1.288E + 4\sqrt{G}$ and prime powers of k are especially interesting. In biological scales the scaled up Compton length scales of electron given by $L_e(k) = \sqrt{5}L(k)$ seem to be more relevant.

For nuclear physics applications the most interesting values of k are: $k = 107$ (hadronic space-time sheet at which quarks feed their color gauge fluxes), $k = 109$ (radius of light nucleus such as alpha particle, $k = 113$ (the space-time at which quarks feed their electromagnetic gauge fluxes), $k = k_{em} = 127$ or 131 (electronic or atomic space-time sheet receiving electromagnetic gauge fluxes of nuclei).

The so called Gaussian primes are to complex integers what primes are for the ordinary integers and the Gaussian counterparts of the Mersenne primes are Gaussian primes of form $(1 \pm i)^k - 1$. Rather interestingly, $k = 113$ corresponds to a Gaussian Mersenne. Also the primes $k = 151, 157, 163, 167$ defining biologically important length scales correspond to Gaussian Mersennes. Thus the electromagnetic p-adic length scales associated with quarks, hadrons, and nuclear physics as well as with muon are in well defined sense also Mersenne length scales.

Particles are characterized by a collection of p-adic primes

It seems that is not correct to speak about particle as a space-time sheet characterized by single p-adic prime. Already p-adic mass calculations suggest that there are several sizes corresponding to space-time sheets at which particle feeds its gauge charges. p-Adic length scale hypothesis provides further insight: the length scale is more like the size of field body and possibly also de-localization volume of particle determining the p-adic mass scale in p-adic thermodynamics rather than the geometric size for the elementary particle.

What one can definitely say that each particle is characterized by a collection of p-adic primes and one of them characterizes the mass scale of the particle whereas other characterize its interactions. There are two possible interpretations and both of them allow to resolve objections against p-adic hierarchies of color and electro-weak physics.

1. These primes characterize the space-time sheets at which it feeds its gauge fluxes and particles can interact only via their common space-time sheets and are otherwise dark with respect to each other.
2. Number theoretical vision supports the notion of multi-p p-adicity and the idea that elementary particles correspond to infinite primes, integers, or perhaps even rationals [?, K105]. To infinite primes, integers, and rationals it is possible to associate a finite rational $q = m/n$ by a homomorphism. q defines an effective q-adic topology of space-time sheet consistent with p-adic topologies defined by the primes dividing m and n ($1/p$-adic topology is homeomorphic to p-adic topology). The largest prime dividing m determines the mass scale of the space-time sheet in p-adic thermodynamics. m and n are exchanged by super-symmetry and the primes dividing m (n) correspond to space-time sheets with positive (negative) time orientation. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by the exchange of particles characterized by divisors of m or n.

   The nice feature of this option is that single multi-p p-adic space-time sheet rather than a collection of them characterizes elementary particle. Concerning the description of interaction vertices as generalization of vertices of Feynman graphs (vertices as branchings of 3-surfaces) this option is decisively simpler than option 1) and is consistent with earlier number theoretic argument allowing to evaluate gravitational coupling strength [?, K105]. It is also easier to understand why the largest prime in the collection determines the mass scale of elementary particle.

Interestingly, these two options are not necessarily mutually exclusive: single multi-p p-adic space-time sheet could correspond to many-sheeted structure with respect to real topology.

What is the proper interpretation of p-adic length scales

One of the surprises of p-adic mass calculations was that for u and d quarks electromagnetic size corresponds to $k = 113$ which corresponds to the length scale of 2×10^{-14} m. This leads to the view that also hadrons and nuclei have this size in some sense. The charge radii of even largest nuclei without neutron halo are smaller than this.

1. If electromagnetic charges of quarks inside nucleons were separately de-localized in the scale $L(113)$, also the distributions of electromagnetic charges of nuclei would be non-trivial in surprisingly long length scale. Em charges would exhibit fractionality in this length scale and Rutherford scattering cross sections would be modified. The fact that the height of the Coulomb wall at $L(113)$ is lower than the observed heights of the Coulomb wall would lead to a paradox.

   This suggests that the p-adic length scale $L(113)$ does not characterize the geometric size of neither nucleons nor nuclei but to the size, perhaps height, of the electromagnetic field body associated with quark/hadron/nucleus.
2. If protons feed their electric em gauge fluxes to the same space-time sheet, there is an electromagnetic harmonic oscillator potential contributing to the nuclear energies. The Mersenne prime M_{127} as a characterizer of the field body of nucleus is natural and it also corresponds to the space-time sheet of electron.
3. For weak forces the size of the field body would be given by electro-weak length scale $L(89)$. The size scale would also correspond to the p-adic de-localization length scale of ordinary sized nucleons and nuclei.
4. It turns out that the identification of nuclear strong interactions in terms of dark QCD with large value of $\hbar$ and color length scale scaled up to $L_c \simeq 2^{11}L(107) \simeq .5 \times 10^{-11}$ m (!) predicts for the nuclei same electromagnetic sizes as in the conventional theory: scaled up sizes appear only in the dark sector and characterize the size of color field body so that paradoxes are avoided. There are also reasons to believe that dark quarks are dark also with respect to electromagnetic and weak interactions so that the sizes of corresponding field bodies are scaled up by a factor $1/v_0$.

The hypothesis that the collection of primes corresponds to multi-p p-adicity rather than collection of space-time sheets implies this. For this option various field bodies could form single field body in q-adic sense with superposed p-adic fractalities much like waves of shorter wavelength scale superposed on waves of longer wavelength scale. As noticed, this might be consistent with the existence of several p-adic field bodies with respect to real topology.

Field/magnetic bodies would represent the space-time correlate for the formation of bound states. It is even possible to think that bound state entanglement corresponds to the linking of magnetic flux tubes. The contributions of say color interactions between nucleons to the binding energy would be estimated using the field magnitudes at position of exotic quarks and the hypothesis is made that these intensities correlate with the shortest distance between dark quarks although the distance along the field body is of order L_c.

This picture finds experimental support. In the following all the scales are given as electron Compton scales also for scales shorter than electron scale $L_e(k) = \sqrt{5}L(k)$. Reader can calculate $L(k)$ using this formula. This is due a longstanding mis-identification of $L(k)$ with $L_e(k)$ and for the fact that recalculation of scales $L(k)$ is not practical.

1. Neutron proton scattering at low energies gives however surprisingly clear evidence for the presence of the p-adic length scales $L(109)$ ($k = 109$ is prime) and $L(113)$ in nuclear physics. The scattering lengths for s and p waves are $a_s = -2.37 \times 10^{-14}$ m and $a_t = 5.4 \times 10{-}15$ m [C138]. a_s is anomalously large and the standard explanation is that deuteron almost allows singlet wave bound state. The p-adic length scales $L(113)$ and $L(109)$ are by more than factor of 2 smaller than these scales. Interestingly, a_t is near to $L_e(109) = 2L_e(107) \simeq 5.0 \times 10^{-15}$ m. a_s is of same order of magnitude as $L_e(113) = 2 \times 10^{-14}$ m so that the interpretation in terms of the $k = 113$ space-time sheet is suggestive.

   If $L(k)$ is replaced with $L_e(k)$, there is a qualitative accordance with the assumption that in triplet state neutron and proton are glued by color bond together to form structure with size or order $L_e(109) = 2L_e(107)$. Does this mean that p-adically scaled up variants of $L_e(127)$ define fundamental length scales besides $L(k)$? Could they correspond to and algebraic extension of p-adic numbers involving $\sqrt{5}$ and therefore also Golden Mean?

2. Neutron halos at distance of about 2.5×10^{-14} m longer than even $L_e(113) = 2 \times 10^{-14}$ m are difficult to understand in the standard nuclear physics framework and provide support for the large value of L_c. They could be understood in terms of de-localization of quarks in the length scale $L_e(113)$ and color charges in the length scale of L_c. For instance, the nucleus in the center could be color charged and neutron halo would be analogous to a colored matter around the central halo.

What these considerations suggest is that $L_e(k) = \sqrt{5}L(k)$ could define another hierarchy of p-adic length scales perhaps naturally associated with causal diamonds and that electron Compton length just happens to co-incide with one of these length scales. A possible interpretation would be in terms of an algebraic extension allowing also to understand the role of Golden Mean in biology.

3.1.2 TGD Based View About Dark Matter

TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [K40].

1. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible as integer multiples of the ordinary Planch constant. A good guess is that the criticality condition reads as $Q_1 Q_2 \alpha \simeq 1$ where Q_i are gauge charges and α gauge coupling strength. This leads to universal properties of the large $\hbar$ phase. For instance, $\hbar$ is scaled in the transition to dark phase by a harmonic or subharmonic of parameter $1/v_0 \simeq 2^{11}$ which is essentially the ratio of CP_2 length scale and Planck length [K96, K40]. The criticality condition can be applied also to dark matter itself and entire hierarchy of dark matters is predicted corresponding to the spectrum of values of $\hbar$.

2. The particles of dark matter can also carry phase carry complex conformal weights but the net conformal weights for blocks of this kind of dark matter would be real. This implies macroscopic quantum coherence. It is not absolutely necessary that $\hbar$ is large for this phase.

3. From the point of view of nuclear physics application of this hypothesis is to QCD. The prediction is that the electromagnetic Compton sizes of dark quarks are scaled from $L(107)$ to about $2^{11}L(107) = L(129) = 2L(127) = (2/\sqrt{5})L_e(127)$, which is almost as long as Compton length of electron! The classical scattering cross sections are not changed but changes the geometric sizes of dark quarks, hadrons, and nuclei. The original hypothesis that ordinary valence quarks are dark whereas sea quarks correspond to ordinary value of $\hbar$ is taken as a starting point. In accordance with the earlier model, nucleons in atomic nuclei are assumed to be accompanied by color bonds connecting exotic quark and anti-quark characterized p-adic length scale $L(127)$ with ordinary value of $\hbar$ and having thus scaled down mass of order MeV. The strong binding would be due the color bonds having exotic quark and anti-quark at their ends.

4. Quantum classical correspondence suggests that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless. This hypothesis could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

   The basic implication of the new view is that the earlier view about nuclear physics applies now to dark nuclear physics and large parity breaking effects and contribution of Z^0 force to scattering and interaction energy are not anymore a nuisance.

5. For ordinary condensed matter quarks and leptons Z^0 charge are screened in electro-weak length scale whereas in dark matter $k = 89$ electro-weak space-time sheet have suffered a phase transition to a p-adic topology with a larger value of k. Gaussian Mersennes, in particular those associated with $k = 113, 151, 157, 163, 167$ are excellent candidates in this respect.

   In dark matter phase weak gauge fluxes could be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [K61].

3.1.3 The Identification Of Long Range Classical Weak Gauge Fields As Correlates For Dark Massless Weak Bosons

Long ranged electro-weak gauge fields are unavoidably present when the dimension D of the CP_2 projection of the space-time sheet is larger than 2. Classical color gauge fields are non-vanishing for all non-vacuum extremals. This poses deep interpretational problems. If ordinary quarks and leptons are assumed to carry weak charges feeded to larger space-time sheets within electro-weak length scale, large hadronic, nuclear, and atomic parity breaking effects, large contributions of the classical Z^0 force to Rutherford scattering, and strong isotopic effects, are expected. If weak charges are screened within electro-weak length scale, the question about the interpretation of long ranged classical weak fields remains.

During years I have discussed several solutions to these problems.

Option I: The trivial solution of the constraints is that Z^0 charges are neutralized at electro-weak length scale. The problem is that this option leaves open the interpretation of classical long ranged electro-weak gauge fields unavoidably present in all length scales when the dimension for the CP_2 projection of the space-time surface satisfies $D > 2$.

Option II: Second option involves several variants but the basic assumption is that nuclei or even quarks feed their Z^0 charges to a space-time sheet with size of order neutrino Compton length. The large parity breaking effects in hadronic, atomic, and nuclear length scales is not the only difficulty. The scattering of electrons, neutrons and protons in the classical long range Z^0 force contributes to the Rutherford cross section and it is very difficult to see how neutrino screening could make these effects small enough. Strong isotopic effects in condensed matter due to the classical Z^0 interaction energy are expected. It is far from clear whether all these constraints can be satisfied by any assumptions about the structure of topological condensate.

Option III: During 2005 third option solving the problems emerged based on the progress in the understanding of the basic mathematics behind TGD.

In ordinary phase the Z^0 charges of elementary particles are indeed neutralized in intermediate boson length scale so that the problems related to the parity breaking, the large contributions of classical Z^0 force to Rutherford scattering, and large isotopic effects in condensed matter, trivialize.

Classical electro-weak gauge fields in macroscopic length scales are identified as space-time correlates for the gauge fields created by dark matter, which corresponds to a macroscopically quantum coherent phase for which elementary particles possess complex conformal weights such that the net conformal weight of the system is real.

In this phase $U(2)_{ew}$ symmetry is not broken below the scaled up weak scale except for fermions so that gauge bosons are massless below this length scale whereas fermion masses are essentially the same as for ordinary matter. By charge screening gauge bosons look massive in length scales much longer than the relevant p-adic length scale. The large parity breaking effects in living matter (chiral selection for bio-molecules) support the view that dark matter is what makes living matter living.

Classical long ranged color gauge fields always present for non-vacuum extremals are interpreted as space-time correlates of gluon fields associated with dark copies of hadron physics. It seems that this picture is indeed what TGD predicts.

One cannot deny that the above scene is still somewhat unsatisfactory since it is difficult to understand why the classical weak fields present in say atomic nuclei would not couple to induced spinor fields and cause large parity breaking effects. The solution of this problem case after the realization that well-definedness of em charge for the modes of induced spinor field forces their modes to be localized at 2-D surfaces in the generic case. Induced W fields vanish at these surfaces and also Z^0 fields can vanish and naturally do so above weak scale proportional to h_{eff}. Therefore no large parity breaking effects come from fermionic sector for ordinary matter.

3.1.4 Dark Color Force As A Space-Time Correlate For The Strong Nuclear Force?

Color confinement suggests a basic application of the basic criteria for the transition to large $\hbar$ phase. The obvious guess is that valence quarks are dark [K42, K40]. Dark matter phase for quarks does not change the lowest order classical strong interaction cross sections but reduces dramatically higher order perturbative corrections and resolves the problems created by the large value of QCD coupling strength in the hadronic phase.

The challenge is to understand the strong binding solely in terms of dark QCD with large value of $\hbar$ reducing color coupling strength of valence quarks to $v_0 \simeq 2^{-11}$. The best way to introduce the basic ideas is as a series of not so frequently asked questions and answers.

Rubber band model of strong nuclear force as starting point

The first question is what is the vision for nuclear strong interaction that one can start from. The sticky toffee model of Chris Illert [C30] is based on the paradox created by the fact alpha particles can tunnel from the nucleus but that the reversal of this process in nuclear collisions does not occur. Illert proposes a classical model for the tunnelling of alpha particles from nucleus based on dynamical electromagnetic charge. Illert is forced to assume that virtual pions inside nuclei have considerably larger size than predicted by QCD and the model. Strikingly, the model favors fractional alpha particle charges at the nuclear surface. The TGD based interpretation would be based on the identification of the rubber bands of Illert as long color bonds having exotic light quark and anti-quark at their ends and connecting escaping alpha particle to the mother nucleus. The challenge is to give meaning to the attribute "exotic".

How the darkness of valence quarks can be consistent with the known sizes of nuclei?

The assumption about darkness of valence quarks in the sense of of large $\hbar$ ($\hbar_s = \hbar/v_0$) is very natural if one takes the basic criterion for darkness seriously. The obvious question is how the dark color force can bind the nucleons to nuclei of ordinary size if the strength of color force is v_0 and color sizes of valence quarks are about $L_e(129)$?

It seems also obvious that $L(107)$ in some sense defines the size for nucleons, and somehow this should be consistent with scaled up size scale $L(k_{eff} = 129)$ implied by the valence quarks with large $\hbar$. The proposal of [K42, K40] inspired by RHIC findings [C124] is that valence quarks are dark in the sense of having large value of $\hbar$ and thus correspond to $k_{eff} = 129$ whereas sea quarks correspond to ordinary value for $\hbar$ and give rise to the QCD size $\sim L(107)$ of nucleon.

If one assumes that the typical distances between sea quark space-time sheets of nucleons is obtained by scaling down the size scale of valence quarks, the size scale of nuclei comes out correctly.

Valence quarks and exotic quarks cannot be identical

The hypothesis is that nucleons contain or there are associated with them pairs of exotic quarks and flux tubes of color field bodies of size $\sim L(129)$ connecting the exotic quark and anti-quark in separate nuclei. Nucleons would be structures with the size of ordinary nucleus formed as densely packed structures of size $L(129)$ identifiable as the size of color magnetic body.

The masses of exotic quarks must be however small so that they must differ from valence quarks. The simplest possibility is that exotic quarks are not dark but p-adically scaled down versions of sea quarks with ordinary value of $\hbar$ having $k = 127$ so that masses are scaled down by a factor 2^{-10}.

Energetic considerations favor the option that exotic quarks associate with nucleons via the $k_{eff} = 111$ space-time sheets containing nucleons and dark quarks. Encouragingly, the assumption that nucleons topologically condense at the weak $k_{eff} = 111$ space-time sheet of size $L(111) \simeq 10^{-14}$ m of exotic quarks predicts essentially correctly the mass number of the highest known super-massive nucleus. Neutron halos are outside this radius and can be understood in terms color Coulombic binding by dark gluons. Tetraneutron can be identified as alpha particle containing two negatively charged color bonds.

What determines the binding energy per nucleon?

The binding energies per nucleon for $A \geq 4$ to not vary too much from 7 MeV but the lighter nuclei have anomalously small binding energies. The color bond defined by a color magnetic flux tube of length $\sim L(k = 127)$ or $\sim L(k_{eff} = 129)$ connecting exotic quark and anti-quark in separate nucleons with scaled down masses $m_q(dark) \sim x m_q$, with $x = 2^{-10}$ for option for $k = 127$, is a good candidate in this respect. Color magnetic spin-spin interaction would give the dominant contribution to the interaction energy as in the case of hadrons. This interaction energy is expected to depend on exotic quark pair only. The large zero point kinetic energy of light nuclei topologically condensed at $k_{eff} = 111$ space-time sheet having possible identification as the dark variant of $k = 89$ weak space-time sheet explains why the binding energies of D and ^{3}He are anomalously small.

What can one assume about the color bonds?

Can one allow only quark anti-quark type color bonds? Can one allow the bonds to be also electromagnetically charged as the earlier model for tetra-neutron suggests (tetra-neutron would be alpha particle containing two negatively charged color bonds so that the problems with the Fermi statistics are circumvented). Can one apply Fermi statistics simultaneously to exotic quarks and anti-quarks and dark valence quarks?

Option I: Assume that exotic and dark valence quarks are identical in the sense of Fermi statistics. This assumption sounds somewhat non-convincing but is favored by p-adic mass calculations supporting the view that the p-adic mass scale of hadronic quarks can vary. If this hypothesis holds true at least effectively, very few color bonds from a given nucleon are allowed by statistics and there are good reasons to argue that nucleons are arranged to highly tangled string like structures filling nuclear volume with two nucleons being connected by color bonds having of length of order $L(129)$. The organization into closed strings is also favored by the conservation of magnetic flux.

The notion of nuclear string is strongly supported by the resulting model explaining the nuclear binding energies per nucleon. It is essential that nucleons form what might be called nuclear strings rather than more general tangles. Attractive p-p and n-n bonds must correspond to colored ρ_0 type bonds with spin one and attractive p-n type bonds to color singlet pion type bonds. The quantitative estimates for the spin-spin interaction energy of the lightest nuclei lead to more precise estimates for the lengths of color bonds. The resulting net color quantum numbers must be compensated by dark gluon condensate, the existence of which is suggested by RHIC experiments [C124]. This option is strongly favored by the estimate of nuclear binding energies.

Option II: If Fermi statistics is not assumed to apply in the proposed way, then color magnetic flux tubes bonds between any pair of nucleons are possible. The identification of color isospin as strong isospin still effective removes color degree of freedom. As many as 8 color tubes can leave the nucleus if exotic quarks and anti-quarks are in the same orbital state and a cubic lattice like structure would become possible. This picture would be consistent with the idea that in ordinary field theory all particle pairs contribute to the interaction energy. The large scale of the magnetic flux tubes would suggest that the contributions cannot depend much on particle pair. The behavior of the binding energies favors strongly the idea of nuclear string and reduces this option to the first one.

What is the origin of strong force and strong isospin?

Here the answer is motivated by the geometry of CP_2 allowing to identify the holonomy group of electro-weak spinor connection as U(2) subgroup of color group. Strong isospin group SU(2) is identified as subgroup of isotropy group U(2) for space-time surfaces in a sub-theory defined by $M^4 \times S^2$, S^2 a homologically non-trivial geodesic sphere of CP_2 and second factor of $U(1) \times U(1)$ subgroup of the holonomies for the induced Abelian gauge fields corresponds to strong isospin component I_3. The extremely tight correlations between various classical fields lead to the hypothesis that the strong isospin identifiable as color isospin I_3 of exotic quarks at the ends of color bonds attached to a given nucleon is identical with the weak isospin of the nucleon. Note that this does not require that exotic and valence quarks are identical particles in the sense of Fermi statistics.

Does the model explain the strong spin orbit coupling ($L \cdot S$ force)? This force can be identified as an effect due to the motion of fermion string containing the effectively color charged nucleons in the color magnetic field $v \times E$ induced by the motion of string in the color electric field at the dark $k = 107$ space-time sheet.

How the phenomenological shell model with harmonic oscillator potential emerges?

Nucleus can be seen as a collection of of long color magnetic flux tubes glued to nucleons with the mediation of exotic quarks and anti-quarks. If nuclei form closed string, as one expects in the case of Fermi statistics constraint, also this string defines a closed string or possibly a collection of linked and knotted closed strings. If Fermi statistics constraint is not applied, the nuclear strings form a more complex knotted and linked tangle. The stringy space-time sheets would be the color magnetic flux tubes connecting exotic quarks belonging to different nucleons.

The color bonds between the nucleons are indeed strings connecting them and the averaged interaction between neighboring nucleons in the nuclear string gives in the lowest order approximation 3-D harmonic oscillator potential although strings have $D = 2$ transversal degrees of freedom. Even in the case that nucleons for nuclear strings and thus have only two bonds to neighbors the average force around equilibrium position is expected to be a harmonic force in a good approximation. The nuclear wave functions fix the restrictions of stringy wave functionals to the positions of nucleons at the nuclear strings. Using M-theory language, nucleons would represent branes connected by color magnetic flux tubes representing strings whose ends co-move with branes.

Which nuclei are the most stable ones and what is the origin of magic numbers?

$P = N$ closed strings correspond to energy minima and their deformations obtained by adding or subtracting nucleons in general correspond to smaller binding energy per nucleon. Thus the observed strong correlation between P and N finds a natural explanation unlike in the harmonic oscillator model. For large values of A the generation of dark gluon condensate and corresponding color Coulombic binding energy favors the surplus of neutrons and the generation of neutron halos. The model explains also the spectrum of light nuclei, in particular the absence of pp, nn, ppp, and nnn nuclei.

In the standard framework spin-orbit coupling explains the magic nuclei and color Coulomb force gives rise to this kind of force in the same ways as in atomic physics context. Besides the standard magic numbers there are also non-standard ones (such as $Z, N = 6, 12$) if the maximum of binding energy is taken as a definition of magic, there are also other magic numbers than the standard ones. Hence can consider also alternative explanations for magic numbers. The geometric view about nucleus suggests that the five Platonic regular solids might defined favor nuclear configurations and it indeed turns that they explain non-standard magic numbers for light nuclei.

New magic nuclei might be obtained by linking strings representing doubly magic nuclei. An entire hierarchy of linkings becomes possible and could explain the new magic numbers 14, 16, 30, 32 discovered for neutrons [C22]. Linking of the nuclear strings could be rather stable by Pauli Exclusion Principle. For instance, ^{16}O would corresponds to linked ^4He and ^{12}C nuclei. Higher magic numbers $28, 50, ...$ allow partitions to sums of lower magic numbers which encourages to consider the geometric interpretation as linked nuclei. p-Adic length scale hypothesis in turn suggest the existence of magic numbers coming as powers of 2^3.

What about the description of nuclear reactions?

The identification of nuclei as linked and knotted strings filling the nuclear volume for constant nuclear density leads to a topological description for the nuclear reactions with simplest reactions corresponding to fusion and fission of closed nuclear strings. The microscopic description is in terms of nucleon collisions in which exotic quarks and anti-quarks are re-shared between nucleons and also new pairs are created. The distinction to ordinary string model is that the topological reactions for strings can occur only when the points at which where they are attached to nucleons collide.

The old fashioned description of the nuclear strong force is based on the meson exchange picture. The perturbation theory based on the exchange of pions doesn't however make sense in practice. In the hadronic string model this description would be replaced by hadronic string diagrams. The description of nuclear scattering in terms of nuclear strings allows phenomenological interpretation in terms of stringy diagrams but color bonds between nucleons do not correspond to meson exchanges but are something genuinely new.

3.1.5 Tritium Beta Decay Anomaly

The proposed model explains the anomaly associated with the tritium beta decay. What has been observed [C80, C95] is that the spectrum intensity of electrons has a narrow bump near the endpoint energy. Also the maximum energy E_0 of electrons is shifted downwards.

I have considered two explanations for the anomaly. The original models are based on TGD variants of original models [C117, C103] involving belt of dark neutrinos or antineutrinos along the orbit of Earth. Only recently (towards the end of year 2008) I realized that nuclear string model provides much more elegant explanation of the anomaly and has also the potential to explain much more general anomalies [E26, C74, C116]. [E26].

3.1.6 Cold Fusion And Trojan Horse Mechanism

Cold fusion [C48] has not been taken seriously by the physics community but the situation has begun to change gradually. There is an increasing evidence for the occurrence of nuclear transmutations of heavier elements besides the production of ^4He and ^3H whereas the production rate of ^{3}He and neutrons is very low. These characteristics are not consistent with the standard nuclear physics predictions. Also Coulomb wall and the absence of gamma rays and the lack of a mechanism transferring nuclear energy to the electrolyte have been used as an argument against cold fusion.

An additional piece to the puzzle came when Ditmire *et al* [C67] observed that the spectrum of electron energies in laser induced explosions of ion clusters extends up to energies of order MeV (rather than 10^2 eV!): this suggests that strong interactions are involved.

The possibility of charged color bonds explaining tetra-neutron allows to construct a model explaining both the observations of Ditmire *et al* and cold fusion and nuclear transmutations. "Trojan horse mechanism" allows to circumvent the Coulomb wall, and explains various selection rules and the absence of gamma rays, and also provides a mechanism for the heating of electrolyte.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

3.2 Model For The Nucleus Based On Exotic Quarks

The challenge is to understand the strong binding solely in terms of the color bonds and large value of $\hbar$ for valence quarks reducing color coupling strength to v_0 and scaling there sizes to $L(107)/v_0 = L(129)$. There are many questions to be answered. How exotic quarks with scaled down masses differ from dark valence quarks? How the model can be consistent with the known nuclear radii of nuclei if valence quarks have Compton length of order $L(129)$?

3.2.1 The Notion Of Color Bond

The basic notion is that of color bond having exotic quark and anti-quark at its ends. Color bonds connecting nucleons make them effectively color charged so that nuclei can be regarded as color bound states of nucleons glued together using color bonds.

The motivation for the notion of color bond comes from the hypothesis that valence quarks are in large $\hbar$ phase, and also from the ideas inspired by the work of Chris Illert [C30] suggesting that long virtual pions act as "rubber bands" connecting nucleons to each other. There are indications that the quark distribution functions for the nucleons inside nuclei differ from those for free nucleons [C146, C54]. QCD based estimates show that color van der Waals force is not involved [C146]. The contribution of the quark pairs associated with color bonds is a possible explanation for this phenomenon.

3.2.2 Are The Quarks Associated With Color Bonds Dark Or P-Adically Scaled Down Quarks?

What seems clear is that color bonds with light quark and antiquark, to be referred as exotic quarks in the sequel, at their ends could explain strong nuclear force. Concerning the identification of the exotic quarks there are frustratingly many options. In lack of deeper understanding, the only manner to proceed is to try to make a detailed comparison of various alternatives in hope of identifying a unique internally consistent option.

The basic observation is that if four-momentum is conserved in the phase transition to the dark phase, the masses of quarks in large $\hbar$ phase should not differ from those in ordinary phase, which means that Compton lengths and p-adic length scale are scaled up by a factor $1/v_0$. This assumption explains elegantly cold fusion and many other anomalies [K42, K40]. The quarks at the ends of color bonds must however have scaled down masses to not affect too much the masses of nuclei. This option would also allow to identify valence and possibly also sea quarks as dark quarks in accordance with the general criterion for the transition to dark phase as proposed in the model for RHIC events [K40].

Exotic quarks must be light. Hence there should be some difference between exotic and valence quarks. This leaves two options to consider.

Are the exotic quarks p-adically scaled down versions of ordinary quarks with ordinary value of $\hbar$?

Exotic quarks could simply correspond to longer p-adic length scale, say M_{127} and thus having masses scaled down by a factor 2^{-10} but ordinary value of $\hbar$. One can also consider the possibility that they correspond to a QCD associated with M_{127} as proposed earlier. They could also correspond to their own weak length scale and weak bosons. This would resolve the objections against new elementary particles coming from the decay widths of intermediate gauge bosons even without assumption about the loss of asymptotic freedom implying that the QCD in question effectively exists only in finite length scale range.

p-Adic mass calculations indeed support the view to that hadronic quarks appear as several scaled up variants and there is no reason to assume that also scaled down variants could not appear. This hypothesis leads to correct order of magnitude estimates for the color magnetic spin-spin interaction energy.

For this option valence (and possibly also sea) quarks could be dark and have color sizes of order $L(k_{eff} = 129)$ as suggested by the criterion $\alpha_s Q_c^2 \simeq 1$ for color confinement as a transition to a dark phase.

Do exotic quarks correspond to large $\hbar$ and reduced c?

If valence quarks are dark one can wonder why not also exotic quarks are dark and whether there exists a mechanism reducing their masses by a factor v_0.

If one questions the assumption that $\hbar$ is a fundamental constant, sooner or later also the question "What about c?" pops up. There are indeed motivations for expecting that c has a discrete spectrum in a well-defined sense. TGD predicts an infinite variety of warped vacuum extremals defining embeddings of M^4 to $M^4 \times CP_2$ with $g_{tt} = \sqrt{1 - R^2\omega^2}, g_{ij} = -\delta_{ij}$, and if common M^4 time coordinate is used for them the maximal signal velocity is for them given by $c_\#/c = \sqrt{1 - R^2\omega^2}$.

Physically this means that the time taken for light to travel between point A and B depends on what space-time sheet the light travels even in the case that gravitational and gauge fields are absent. The fact that the analog of Bohr quantization occurs for the deformed vacuum extremals of Kähler action suggests that $c_\#$ has a discrete spectrum.

This inspires the question whether also light velocity c besides $\hbar$ is quantized in powers of v_0 so that the rest energies of dark quarks would be given by $E_0 = \hbar_s c_\#/L(k_{eff} = k+22) = \hbar c_\#/L(k)$ and scale down because of the scaling $c \rightarrow v_0 \times c$. A distinction between rest mass and rest energy should be made since rest mass is scaled up as $M \rightarrow M/v_0$. Compton time would be by a factor $1/v_0^2$ longer than the ordinary Compton time.

If c and $\hbar$ can scale up separately but in powers of v_0 (or its harmonics and sub-harmonics) it is possible to have a situation in which $\hbar c$ remains invariant because mass scale is reduced v_0 and $\hbar$ is increased by $1/v_0$. In the case of dark quarks this would mean that light would propagate with velocity $2^{-11}c$ along various space-time sheets associated with dark quarks.

This admittedly complex looking option would mean that valence quarks have large $\hbar$ but ordinary c and exotic quarks have large $\hbar$ but small c due to the warping of their space-time sheet in time direction.

3.2.3 Electro-Weak Properties Of Exotic And Dark Quarks

Are exotic quarks scaled down with respect to electromagnetic interactions?

The earlier models involving large $\hbar$ rely on the assumption that the transition to large $\hbar$ phase with respect to electromagnetic interactions occurs only under special conditions (models for cold fusion and structure of water represent basic examples). Hence valence quarks can be in large $\hbar$ phase only with respect to strong and possibly weak interactions.

1. For p-adically scaled down exotic quarks also the electromagnetic space-time sheet should correspond to scaled up value of k since $k = 113$ would give too large contribution to the quark mass. It is not clear whether both em and color space-time sheets can correspond to $k = 127$ or whether one must have $k_{em} = 131$.

2. For exotic quarks with large $\hbar$ and small c the situation can be different $k = 107$ contribution to quark mass is scaled down by v_0 factor: $m_q(dark) = v_0 m_q \sim .05$ MeV. Since $k = 113$ contributes a considerable fraction to hadron mass, one can argue that also the $k = 113$ contribution to the mass must be scaled down so that dark quarks would be also electromagnetically dark. If so, the size of $k = 113$ dark electromagnetic field body would be of order atomic size and nuclei would represent in their structure also atomic length scale.

Are exotic and dark quarks scaled down with respect to weak interactions?

What about darkness of exotic and dark quarks with respect to weak interactions? The qualitative behavior of the binding energies of $A \leq 4$ nuclei can be understood if they possess zero point kinetic energy associated with space-time sheet with size characterized by $L(k = 111 = 3\times 37) \simeq 10^{-14}$ m.

Also the maximal mass number of super-heavy nuclei without neutron halo is predicted correctly. $k_{eff} = 111$ happens to correspond to the scaled weak length scale M_{89} which raises the possibility that dark quarks correspond to large value of $\hbar$ with respect to weak interactions. This could be the case for dark valence quarks and both identifications of exotic quarks.

1. For $k = 127$ quarks with dark weak interactions no large parity breaking effects are induced neither below mass scale m_W.
2. For large $\hbar$-small c option the scale invariance of gauge interactions would mean that the masses of the corresponding weak bosons are of order 50 MeV but the weak interaction rates of are scaled down by a factor v_0^2 since the ratios m_q/m_W invariant under the transition to dark phase appear in the rates: this at energy scale smaller than $v_0 m_w$. This disfavors this option.

3.2.4 How The Statistics Of Exotic And Ordinary Quarks Relate To Each Other?

Exotic and ordinary quarks should be identical or in some sense effectively identical in order that nuclear string picture would result.

Can one regard exotic quarks and ordinary quarks as identical fermions?

The first guess would be that this is not the case. One must be however cautious. The fact that p-adically scaled up variants of quarks appear in the model of hadrons suggested by p-adic mass calculations, suggests that the scaled up versions must be regarded as identical fermions. Since also the scaling of $\hbar$ induces only a scaling up of length scale, one might argue that this conclusion holds true quite generally.

Identity is also favored by a physical argument. If identity holds true, Fermi statistics forces the nucleons to form closed nuclear strings to maximize their binding energies. The notion nuclear string explains nicely the behavior nuclear binding energies per nucleon and also suggests that linking and knotting could define mechanisms for nuclear binding.

Could dark quarks and ordinary quarks be only effectively identical?

The idea of regarding quarks and dark quarks as identical fermions does not sound convincing, and one can ask the idea could make sense in some effective sense only.

1. The effective identity follows from a model for matter antimatter symmetry assuming that ordinary quarks form strongly correlated pairs with dark anti-quarks so that nucleons would be accompanied by dark antinucleons and quarks and dark quarks would be effectively identical. This option looks however rather science fictive and involves un-necessarily strong assumption.
2. A weaker hypothesis is inspired by the model of topological condensation based on # (/worm-hole/ topological sum) contacts [?]. # contact can be modelled as a CP_2 type extremal with Euclidian signature of induced metric forming topological sum with the two space-time sheets having Minkowskian signature of induced metric. # contact is thus accompanied by two light-like 3-D causal horizons at which the metric determinant vanishes. These causal horizons carry of quantum numbers and are identified as partons. If the contact is passive in the sense that it mediates only gauge fluxes, the quantum numbers of the two partons cancel each other. This can be true also for four-momentum in the case that time orientations of the space-time sheets are opposite.

   This kind of # contacts between $k_{eff} = 129$ and $k = 127$ space-time sheets would force effective identity of $k = 127$ and $k_{eff} = 129$ quarks. The implication would be that in many-sheeted sense nucleons inside nuclei would have ordinary quantum numbers whereas in single sheeted point sense they would carry quantum numbers of quark or anti-quark.

3.3 Model Of Strong Nuclear Force Based On Color Bonds Between Exotic Quarks

In this section the color bond model of strong nuclear force is developed in more detail.

3.3.1 A Model For Color Bonds In Terms Of Color Flux Tubes

Simple model for color bond

Consider next a simple model for color bond.

1. The first guess would be that the color bond has quantum numbers of neutral pion so that also the pair of nucleons connected by a color bond would behave like a pion. This gives attractive color magnetic interaction energy and an attractive identification is as p-n bond.
2. Also the bonds with identical spins and identical color charges at the ends of the bond yield an attractive color magnetic spin-spin interaction energy. This kind of bonds would be responsible for p-p and n-n pairing. In this case color magnetic energy is however by a factor 1/3 smaller and could explain the non-existence of pp and nn bound states. An even number of neutral ρ type bonds could be allowed without anomalous contribution to the spin. High spin nuclei could contain many ρ type bonds so that antimatter would play important role in the physics of heavy nuclei.
3. A further generalization by allowing also electromagnetically charged color bonds with em quantum numbers of pion and ρ would explain tetra-neutron [C81, C25] as alpha particle (pnpn) with two π_- type color bonds. This would predict a rich variety of exotic nuclei. Long color bonds connecting quark and anti-quark attached to different nucleons would also allow to understand the observation of Chris Illert [C30] that the classical description of quantum tunnelling suggests that nucleons at the surface of nucleus have charges which are fractional.

This picture would suggest that the color isospin of the quark at the end of the bond equals to the weak isospin of the nucleon and is also identifiable as the strong isospin of the nucleon inside nucleus. To achieve an overall color neutrality the presence a dark gluon condensate compensating for the net color charge of colored bonds must be assumed. This could also compensate the net spin of the colored bonds.

The surplus of neutrons in nuclei would tend to create a non-vanishing color isospin which could be cancelled by the dark gluon condensate. The results of RHIC experiment [C124] can be understood in TGD framework as a generation of a highly tangled string like structure containing large number of p-p and n-n type bonds and thus also dark gluon condensate neutralizing the net color charge. This would suggest that in a good approximation the nuclei could be seen as tangled string like structures formed from protons and neutrons. If the distances between nuclei are indeed what standard nuclear physics suggests, kind of nuclear strings would be in question.

Simple model for color magnetic flux tubes

Color magnetic flux tubes carrying also color electric fields would define the color magnetic body of the nucleus having size of order $L(129)$. Dark quarks would have also weak and electromagnetic field bodies with sizes $L(111)$ and $L(135)$. The color magnetic body codes information about nucleus itself but also has independent degrees of freedom, in particular those associated with linking and knotting of the flux tubes (braiding plays a key role in the models of topological quantum computation [K5]).

Color flux tubes carry a non-trivial color magnetic flux and one can wonder whether the color flux tubes can end of whether they form closed circuits. Since CP_2 geometry allows homological magnetic charges, color magnetic flux tubes could have ends with quarks and anti-quark at them acting as sources of the color magnetic field. The model for binding energies however favors closed strings. In the general case the color magnetic flux tubes would have a complex sub-manifold of CP_2 with boundary as a CP_2 projection.

The spin-spin interaction energies depend crucially on the value of the color magnetic field strength experienced by the exotic quark at the end of color flux tube, and one can at least try make educated guesses about it. The conservation of the color magnetic flux gives the condition

$g_s B \propto 1/S$, where S is the area of the cross section of the tube. $S \geq L^2(107)$ is the first guess for the area if valence quarks are ordinary. $S \geq L^2(k_{eff} = 129)$ is the natural guess if valence quarks are dark.

The quantization of the color magnetic flux using the scaled up value of $\hbar$ would give $\int g_s B dS = n/v_0$ implying $g_s B \simeq n/v_0 S$. When applied to $S \sim L^2(107)$ the quantization condition would give quite too large estimate for the spin-spin interaction energy. For $S \sim L^2(129)$ the scale of the interaction energy would come out correctly. For $k = 127$ option $S \sim L^2(127)$ is forced by the quantization condition.

This observation favors strongly dark valence quarks for both options. The magnetic flux of exotic quarks would be fed to flux tubes of transverse area $\sim L^2(k)$, $k = 127$ or $k = 129$, coupling naturally with the color magnetic flux tubes of valence quarks with size $L(129)$.

A further constraint could come from the requirement that the flux tubes is such that locally the magnetic field looks like a dipole field. This would mean that the flux tube would become thicker at larger distances roughly as $S(r) \propto r^3$. An alternative restriction would come from the requirement that the energy of the color magnetic flux tube is same irrespective of its cross section at dark quark position. This would give $S \propto L$ where L is the length of the flux tube.

Quantum classical correspondence requires color bonds

Non-vacuum extremals are always accompanied by a non-vanishing classical electro-weak and color gauge fields. This is an obvious challenge for quantum classical correspondence. The presence of a suitable configuration of color bonds with dark quarks at their ends starting from nucleon gives hopes of resolving this interpretational problem. Dark quarks and anti-quarks would serve as sources of the color and weak electric gauge fluxes and quarks and nucleons would create the classical em field.

The requirement that classical Abelian gauge fluxes are equal to the quantum charges would pose very strong conditions on the physical states. For instance, quantization condition for Weinberg angle is expected to appear. The fact that classical fluxes are inversely proportional to the inverse of the corresponding gauge coupling strength $1/\alpha_i$ gives additional flexibility and with a proper choice of gauge coupling strengths the conditions might be satisfied and space-time description would also code for the values of gauge coupling strengths. Color bonds should be present in all length scales for non-vacuum extremals encouraging the hypothesis about the p-adic hierarchy of dark QCD type phases.

Identification of dark quarks and valence quarks as identical fermions forces the organization of nucleons to nuclear strings?

Quantum classical correspondence in strong form gives strong constraints on the construction. The model explaining the nuclear binding energies per nucleon strongly favors the option in which nucleons arrange to form closed nuclear strings. If dark quarks and ordinary valence quarks can be regarded as identical fermions this hypothesis follows as a prediction. Therefore this hypothesis, which admittedly looks ad hoc and might make sense only effectively (see the discussion below), deserves a detailed consideration.

Fermi statistics implies that the quark at the end of the color bond must be in a spin state which is different from the spin state of the nucleon (spin of d quark in the case of p=uud and u quark in the case of n) to allow local S-wave. For anti-quarks there are no constraints. Only d (u) quark with spin opposite to that of p (n) can be associated with p (n) end of the color bond. Hence at most five different bonds can begin from a given nucleon. In the case of proton $p_\downarrow$ they are give by $d_\uparrow \overline{d}_\downarrow$, $\overline{q}_\downarrow q_\uparrow$, $q = u, d$.

Only two bonds between given nuclei are possible as following examples demonstrate.

1. $p_\downarrow - n_\uparrow$: $d_\uparrow \overline{d}_\downarrow$, $\overline{u}_\downarrow u_\uparrow$.
2. $p_\downarrow - p_\uparrow$: $d_\uparrow \overline{d}_\uparrow$, $\overline{d}_\uparrow d_{\ uparrow}$.

The experimentation with the rules in case of neutral color bonds supports the view that although branchings are possible, they do not allow more than $A = Z + N$ bonds. One example is 6 nucleon state with p at center connected by 5 bonds to p+ 4n at periphery and an additional bond connecting peripheral p and n. This kind of configuration could be considered as one possible configuration in the case of ^{6}Li and ^{6}He. It would seem that there is always a closed string structure with A bonds maximizing the color magnetic binding energy. The allowance of also charged color bonds makes possible to understand tetra-neutron as alpha particle with two charged color bonds.

The fact that neutron number for nuclei tends to be larger than proton number implies that the number of n-n type ρ bonds for stringy configurations is higher than p-p type bonds so that net color isospin equal equal to $I_3 = -(A-2Z)$ is generated in case of stringy nuclei and is most naturally cancelled by a dark gluon condensate. Neutralizing gluon condensate allows neutron halo with a non-vanishing value of I_3.

3.3.2 About The Energetics Of Color Bonds

To build a more quantitative picture about the anatomy of the color bond it is necessary to consider its energetics. The assumption that in lowest order in $\hbar$ the binding energy transforms as rest energy under the p-adic scaling and scaling of $\hbar$ makes it easy to make order of magnitude estimates by scaling from the hadronic case.

Color field energy of the bond

At the microscopic level the harmonic oscillator description should correspond to the color energy associated with color bonds having u or d type quark and corresponding anti-quarks at their ends. For simplicity restrict the consideration in the sequel to electromagnetically neutral color bonds.

Besides spin-spin interaction energy and color Coulombic interaction energy there are contributions of color fields coded by the string tension $T_d = v_0 T$ of the color bond, where $T \simeq 1/\text{GeV}^2$ is hadronic string tension. The energy of string with given length remains invariant in the combined scaling of $\hbar$, string tension, and length L of the color bond represented by color magnetic flux tube (which contain also color electric fields).

1. The mass of the color bonds between valence quarks assumed to have $\hbar_s = \hbar/v_0$ of length $L = xL(129)$ are given by $M(107) \sim x \times \hbar/L(107) \sim x \times .5$ GeV and correspond naturally to the energy scale of hadronic strong interactions.
2. The rest energy of the color bonds between $k = 127$ quarks with ordinary value of $\hbar$ having length $L = xL(127)$ are given by $M(127) \sim x \times \hbar/L(127) = 2^{-10}M(107)$ so that the order order of magnitude is $x \times .5$ MeV.
3. The rest energy of the color bonds between $k_{eff} = 129$ dark quarks with $c_\# = v_0 c$ is given by the same expression. Note however that rest mass would be scaled up by a factor $1/v_0$.

The resulting picture seems to be in a dramatic conflict with the electromagnetic size of nucleus which favors the $L \sim L(107) < 2$ fm rather than $L \sim L(129)$ and which is smaller by a factor 2^{-11} and which favors also the notion of nuclear string. The resolution of the paradox is based on the notion of color magnetic body. Color bonds behave like color magnetic dipoles and bonds correspond to flux tubes of a topologically quantized dipole type color magnetic field having length of order $L(129) \simeq 5 \times 10^{-12}$ m connecting nucleons at distance $L < L(107)$.

Color magnetic spin-spin interaction energy, the structure of color bonds, and the size scale of the nucleus

Color magnetic spin-spin interaction allows to understand $\rho - \pi$ mass splitting in terms of color magnetic spin-spin interaction expected to give the dominating contribution to the nuclear binding energy. The quantitative formulation of this idea requiring consistency with p-adic mass calculations and with existing view about typical electromagnetic nuclear size scale fixed by the height of Coulomb wall leads to a rather unique picture about color magnetic bonds.

1. Questions

One can pose several questions helping to develop a detailed model for the structure of the color bond.

1. The contributions $k = 113$ and $k = 107$ space-time sheets to the mass squared are of same order of magnitude [K71]. The contributions to the mass squared add coherently inside a given

space-time sheet. This requires that nucleonic space-time sheet are not directly connected by join along boundaries bonds/flux tubes and the assumption that color bond connect dark quarks is consistent with this. This means that it makes sense to estimate contributions to the mass squared at single nucleon level.

2. The contribution of color magnetic spin-spin interaction to the mass squared of nucleon can be regarded as coming from $k = 107$ space-time sheets as p-adic contribution but with a large value of $\hbar$. If $k = 107$ contribution would vanish, only a positive contribution to mass would be possible since the real counterpart Δm_R^2 of p-adic Δm^2 is always positive whereas $(m^2 + \Delta m^2)_R < m_R^2$ can hold true.

3. What has been said about color magnetic body and color bonds applies also to electromagnetic field body characterized by $k = 113$. The usual electromagnetic size of nucleus is defined by the relative distances of nucleons in M^4 can be much smaller than $L(113)$ so that the prediction for Coulomb wall is not reduced to the Coulomb potential at distance $L(113)$. Nucleon mass could be seen as due to p-adic thermodynamics for mass squared (or rather, conformal weight) with the real counterpart of the temperature being determined by p-adic length scale $L(113)$.

4. The model inspired by p-adic mass calculations [K71] forced the conclusion that valence quarks have flux tubes between $k = 107$ and $k = 113$ space-time sheets possibly feeding color fluxes so that closed flux loops between the two space-time sheets result. The counter intuitive conclusion was that roughly half of quark mass is contributed by the $k = 113$ space-time sheet which is by a scale factor 8 larger than the color size of quarks. If valence quarks are dark, scaled up $k = 107$ space-time sheet having $k_{eff} = 129$ becomes the larger space-time sheet, and the situation would not look so counter-intuitive anymore.

5. How the ends of the color bonds are attached to the $k = 113$ nucleon space-time sheets? The simplest assumption is that color bonds correspond to color magnetic flux tubes of length scale $L(129)$ starting at or being closely associated with $k = 107$ space-time sheets of nucleons. Hence the contribution to the mass squared would come from scaled up $k_{eff} = 129$ space-time sheet and add coherently to the dominating p-adic $k = 107$ contribution to the mass squared of nucleon.

6. If exotic quarks are $k = 127$ quarks with ordinary value of $\hbar$, one encounters the problem how their contributions can add coherently with $k_{eff} = 129$ color contribution to reduce the rest energy of nucleus. One possibility allowed by the appearance of harmonics of v_0 is that $\hbar$ is scaled up by $1/(2v_0) \simeq 2^{10}$ so that space-time sheets have same size or that p-adic additivity of mass squared is possible for effective p-adic topologies which do not differ too much from each other.

2. Estimate for color magnetic spin-spin interaction energy

Suppose the scaling invariance in the sense that the binding energies transform in the lowest order just like rest masses so that one can estimate the color magnetic spin-spin splittings from the corresponding splittings for hadrons without any detailed modelling. This hypothesis is very attractive predicts for both options that the scale of color magnetic spin-spin splitting is 2^{-n} times lower than for $\pi - rho$ system, where $n = 10$ for $n = 127$ option and $n = 11$ for $k_{eff} = 129$ option. For scaled down spin-spin interaction energy for π type bond is $E \sim .4$ MeV for $k = 127$ and $\sim .2$ MeV for $k_{eff} = 11$, which would mean that the bond is shorter than scaled up length $L(\pi)$ of color bond between valence quarks of pion.

The further assumption that color magnetic spin-spin interaction energy behaves as $\alpha_s/m_q^2 L^3$, $L = x2^n L(\pi)$. This gives $E \simeq x^{-3}2^{-n}E(107)$. The value of x can be estimated from the requirement that the energy is of order few MeV. This gives $x \sim 10^{-1/3}$ for $k = 127$ option and $x \sim (20)^{-1/3}$ for $k_{eff} = 129$ option.

3.4 Model Of Strong Nuclear Force Based On Color Bonds Between Exotic Quarks

In this section the color bond model of strong nuclear force is developed in more detail.

3.4.1 A Model For Color Bonds In Terms Of Color Flux Tubes

Simple model for color bond

Consider next a simple model for color bond.

1. The first guess would be that the color bond has quantum numbers of neutral pion so that also the pair of nucleons connected by a color bond would behave like a pion. This gives attractive color magnetic interaction energy and an attractive identification is as p-n bond.
2. Also the bonds with identical spins and identical color charges at the ends of the bond yield an attractive color magnetic spin-spin interaction energy. This kind of bonds would be responsible for p-p and n-n pairing. In this case color magnetic energy is however by a factor 1/3 smaller and could explain the non-existence of pp and nn bound states. An even number of neutral ρ type bonds could be allowed without anomalous contribution to the spin. High spin nuclei could contain many ρ type bonds so that antimatter would play important role in the physics of heavy nuclei.
3. A further generalization by allowing also electromagnetically charged color bonds with em quantum numbers of pion and ρ would explain tetra-neutron [C81, C25] as alpha particle (pnpn) with two π_- type color bonds. This would predict a rich variety of exotic nuclei. Long color bonds connecting quark and anti-quark attached to different nucleons would also allow to understand the observation of Chris Illert [C30] that the classical description of quantum tunnelling suggests that nucleons at the surface of nucleus have charges which are fractional.

This picture would suggest that the color isospin of the quark at the end of the bond equals to the weak isospin of the nucleon and is also identifiable as the strong isospin of the nucleon inside nucleus. To achieve an overall color neutrality the presence a dark gluon condensate compensating for the net color charge of colored bonds must be assumed. This could also compensate the net spin of the colored bonds.

The surplus of neutrons in nuclei would tend to create a non-vanishing color isospin which could be cancelled by the dark gluon condensate. The results of RHIC experiment [C124] can be understood in TGD framework as a generation of a highly tangled string like structure containing large number of p-p and n-n type bonds and thus also dark gluon condensate neutralizing the net color charge. This would suggest that in a good approximation the nuclei could be seen as tangled string like structures formed from protons and neutrons. If the distances between nuclei are indeed what standard nuclear physics suggests, kind of nuclear strings would be in question.

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Color flux tubes carry a non-trivial color magnetic flux and one can wonder whether the color flux tubes can end of whether they form closed circuits. Since CP_2 geometry allows homological magnetic charges, color magnetic flux tubes could have ends with quarks and anti-quark at them acting as sources of the color magnetic field. The model for binding energies however favors closed strings. In the general case the color magnetic flux tubes would have a complex sub-manifold of CP_2 with boundary as a CP_2 projection.

The spin-spin interaction energies depend crucially on the value of the color magnetic field strength experienced by the exotic quark at the end of color flux tube, and one can at least try make educated guesses about it. The conservation of the color magnetic flux gives the condition $g_sB \propto 1/S$, where S is the area of the cross section of the tube. $S \geq L^2(107)$ is the first guess for the area if valence quarks are ordinary. $S \geq L^2(k_{eff} = 129)$ is the natural guess if valence quarks are dark.

The quantization of the color magnetic flux using the scaled up value of $\hbar$ would give $\int g_sBdS = n/v_0$ implying $g_sB \simeq n/v_0S$. When applied to $S \sim L^2(107)$ the quantization condition would give quite too large estimate for the spin-spin interaction energy. For $S \sim L^2(129)$ the scale of the interaction energy would come out correctly. For $k = 127$ option $S \sim L^2(127)$ is forced by the quantization condition.

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Color magnetic spin-spin interaction allows to understand $\rho - \pi$ mass splitting in terms of color magnetic spin-spin interaction expected to give the dominating contribution to the nuclear binding energy. The quantitative formulation of this idea requiring consistency with p-adic mass calculations and with existing view about typical electromagnetic nuclear size scale fixed by the height of Coulomb wall leads to a rather unique picture about color magnetic bonds.

1. Questions

One can pose several questions helping to develop a detailed model for the structure of the color bond.

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The further assumption that color magnetic spin-spin interaction energy behaves as $\alpha_s/m_q^2 L^3$, $L = x2^n L(\pi)$. This gives $E \simeq x^{-3}2^{-n}E(107)$. The value of x can be estimated from the requirement that the energy is of order few MeV. This gives $x \sim 10^{-1/3}$ for $k = 127$ option and $x \sim (20)^{-1/3}$ for $k_{eff} = 129$ option.

3.5 How The Color Bond Model Relates To The Ordinary Description Of Nuclear Strong Interactions?

How the notion of strong isospin emerges from the color bond model? What about shell model description based on harmonic oscillator potential? Does the model predict spin-orbit interaction? Is it possible to understand the general behavior of the nuclear binding energies, in particular the anomalously small binding energies of light nuclei? What about magic numbers? The following discussion tries to answer these questions.

3.5.1 How Strong Isospin Emerges?

The notion of strong isospin is a crucial piece of standard nuclear physics. Could it emerge naturally in the transition to the phase involving dark quarks? Could the transition to color confined phase mean a reduction of color group as isotropy group of CP_2 type extremals representing elementary particles to $U(2)$ identifiable as strong isospin group. Could $U(1)_Y \times U(1)_{I_3}$ or $U(1)_{I_3}$ be identifiable as the Abelian holonomy group of the classical color field responsible for the selection of a preferred direction of strong isospin?

This picture would not mean breaking of the color symmetry at the WCW level where it would rotate space-time surfaces in CP_2 like rigid bodies. Rather, the breaking would be analogous to the breaking of rotational symmetry of individual particles by particle interactions. Strong isospin would correspond to the isotropy group of the space-time surface and the preferred quantization direction to the holonomy group of the induced color gauge field. The topological condensation of quarks and gluons at hadronic and nuclear space-time surfaces would freeze the color rotational degrees of freedom apart from isotropies providing thus the appropriate description for the reduced color symmetries.

Mathematical support for the picture from classical TGD

There is mathematical support for the proposed view and closely relating to the long-standing interpretational problems of TGD.

1. CP_2 holonomy group is identifiable as U(2) subgroup of color group and well as electro-weak gauge group. Hitherto the possible physical meaning of this connection has remained poorly understood. $U(2)$ subgroup as as isotropies of space-time surfaces with $D = 2$-dimensional CP_2 projection, which belongs to a homologically non-trivial geodesic sphere S^2, and defines a sub-theory for which all induced gauge fields are Abelian and a natural selection of a preferred strong isospin direction occurs. Thus one might identify strong isospin symmetry as the $SU(2)$ subgroup of color group acting as the isotropy group of the space-time surface and strong isospin would not correspond to the group of isometries but to space-time isotropies.
2. Color isospin component of gluon field, em field and Z^0 field which corresponds to weak isospin, are proportional to each other for solutions having 2-dimensional CP_2 projection. In fact, both Z^0 and I_3 component of gluon field are proportional to the induced Kähler form with a positive coefficient. If the proposed quantum classical correspondence for color bonds holds true, this means that the signs of these charges are indeed correlated also for nucleon and quark/ anti-quark. The ratios of these charges are fixed for the extremals for which CP_2 projection is homologically non-trivial geodesic sphere S^2.
3. It is far from clear whether the classical Z^0 field can vanish for any non-vacuum extremals. If this is not the case, dark weak bosons would be unavoidable and strong isospin could be identifiable as color isospin and dark weak isospin. The predicted parity breaking effects need not be easily detectable since dark quarks would be indeed dark matter. An open question is whether some kind of duality holds true in the sense that either color field or vectorial part of Z^0 field could be used to describe the nuclear interaction. This duality brings in mind the $SO(4) \leftrightarrow SU(3)$ duality motivated by the number theoretical vision [K102, K107].
4. The minimal form of the quantum classical correspondence is that at least the signs of the I_3 and Y components of the color electric flux correlate with the dark quark at the end of color bond and the signs of the Z^0 field and Kähler field correlate with the sign of weak isospin and weak hyper-charge of nucleon. A stronger condition is that these classical gauge fluxes are identical with a proper choice of the values of gauge coupling strengths and that in the case of color fluxes the quark at the end of the bond determines the color gauge fluxes in the bond whereas electromagnetic would distribute freely between the bonds.

Correlation between weak isospin and color isospin

The weakest assumption motivated by this picture would be that the sign of color isospin correlates with the sign of weak isospin so that the quarks at the ends of color bonds starting from nucleon would have color isospin equal to the weak isospin of the nucleon:

$$I_{3,s} = I_{3,w} = I_{3,c} \ .$$

This assumption would allow to interpret the attractive strong interaction between nucleons in terms of color magnetic interaction. p-n bond would be neutral π_0 type color singlet bonds. n-n and p-p bonds would have spin ± 1 and color isospin equal to strong iso-spin of $\rho_{\pm}$. Note that QCD type color singlet states invariant under $I_3 \rightarrow -I_3$ would not be possible. Color magnetic interaction mediated by the pion type color bond would be attractive for p and n since color isospins would be opposite sign but repulsive for pp and nn since color isospins would have same sign. The ρ type color bond with identical spins and color isospins I_3 would generate attractive interaction between identical nucleons. The color magnetic spin-spin interaction energy would be 3 times larger for π type bond so that the formation of deuterium as bound state of p and n and absence of pp and nn bound states might be understood.

It is not possible to exclude charged color bonds, and as will be found, their presence provides an elegant explanation for tetra-neutron [C81, C25].

3.5.2 How To Understand The Emergence Of Harmonic Oscillator Potential And Spin-Orbit Interaction?

Shell model based on harmonic oscillator potential and spin-orbit interaction provide rather satisfactory model of nuclei explaining among other things magic numbers.

Harmonic oscillator potential as a phenomenological description

It would be a mistake to interpret nuclear harmonic oscillator potential in terms Coulomb potential for the I_3 component of the classical gluon field having color isospin as its source. Interaction energy would have correct sign only for proton+quark/ anti-quark or neutron+quark/ anti-quark at the end of the color bond so that only neutrons or protons would experience an attractive force.

Rather, the harmonic oscillator potential codes for the presence of color Coulombic and color magnetic interaction energies and is thus only a phenomenological notion. Harmonic oscillator potential emerges indeed naturally since the nucleus can be regarded as a collection of nucleons connected by color flux tubes acting rather literally as strings. The expansion the interaction energy around equilibrium position naturally gives a collection of harmonic oscillators. The average force experience by a nucleon is expected to be radial and this justifies the introduction of external harmonic oscillator potential depending on A via the oscillator frequency.

At the deeper level the system could be seen as a tangle formed by bosonic strings represented by magnetic flux tubes connecting $k = 111$ space-time sheets containing dark quarks closely associated with nucleons. The oscillations of nucleons in harmonic oscillator potential induce the motion of dark quark space-time sheets play the role of branes in turn inducing motion of the ends of flux tubes fix the boundary values for the vibrations of the flux tubes. The average force experienced by nucleons around equilibrium configuration is expected to define radial harmonic force. This holds true even in the case of nuclear string.

In this picture $k = 111$ space-time sheets could contain the nucleons of even heaviest nuclei if the nucleon size is taken to be $2L_e(107)/3 \simeq 1.5$ fm. The prediction for the highest possible mass number without neutron halo, which is at radius $2.5 \times L_e(111)$, would be $A = 296$ assuming that nuclear radius is $R = 1.4$ fm. $A = 298$ is the mass number of the heaviest known superheavy nucleus [C109] so that the prediction can be regarded as a victory of the model.

Could conformal invariance play a key role in nuclear physics?

The behavior the binding energies of $A \leq 4$ nucleons strongly suggest that nucleons are arranged to closed string like structure and have thus only two color bonds to the neighboring nucleons in the nuclear string. The thickness of the string at the positions of fermions defines the length scale cutoff defining the minimal volume taken by a single localized fermion characterized by given p-adic prime.

The conformal invariance for the sections of the string defined by color bonds is should allow a deeper formulation of the model in terms of conformal field theory. The harmonic oscillator spectrum for single particle states could be interpreted in terms of stringy mass squared formula $M^2 = M_0^2 + m_1^2 n$ which gives in good approximation

$$M = m_0 + \frac{m_1^2}{2M_0}n \ . \tag{3.5.1}$$

The force constant would be determined by M_0 which would be equal to nucleon mass.

Presumably this would bring to the mind of M-theorist nucleus as a system of A branes connected by strings. The restriction of the wave functional of the string consisting of portions connecting nucleons to each other at the junction points would be induced by the wave functions of nucleons. The bosonic excitations of the color magnetic strings would contribute to color magnetic energy of the string characterized by its string tension. This energy scale might be considerably smaller than the fermionic energy scale determined by the color magnetic spin-spin interaction.

Dark color force as the origin of spin-orbit interaction?

The deviation of the magic numbers associated with protons ($Z = 2, 8, 20, 28, 40, 82$) and neutrons ($A - Z = 2, 8, 20, 28, 50, 82, 126$) from the predictions of harmonic oscillator model provided the motivation for the introduction of the spin orbit interaction V_{L-S} [C146] with the following general form

$$V_{L-S}(r) = \bar{L}\cdot\bar{S}\frac{1}{r}(\frac{dV_s}{dr} + \frac{dV_I}{dr}\bar{\tau}_1\cdot\bar{\tau}_2) \ . \tag{3.5.2}$$

The interaction implies the splitting of (j,l,s) eigen states so that states $j, l = j \pm \frac{1}{2}$ have different energies. If the energy splitting is large enough, some states belonging to a higher shell come down and combine with the states of the lower shell to form a new shell with a larger magic number. This is what should happen for both proton and neutron single particle states.

The origin of spin-orbit interaction would be the classical color field created by the color isospin in p-p and n-n color bonds and dark gluons compensating the color charge. Spin-orbit interaction results in the atomic physics context from the motion of electrons in the electric field of the nucleus. The moving particle experiences in its rest frame a magnetic field $\overline{B} = \overline{v}\times\overline{E}$, which in the spherically symmetric case can by little manipulations can be cast into the form

$$\overline{B} = \frac{\overline{p}}{m}\times\frac{\overline{r}}{r}\frac{dV}{dr} = \overline{L}\frac{1}{m}\frac{1}{r}\frac{dV}{dr} \ .$$

The interaction energy is given by

$$E = -\overline{\mu}\cdot\overline{B} = -\frac{ge}{2m^2}\overline{S}\cdot\overline{L}\times\frac{1}{r}\frac{dV}{dr} \ . \tag{3.5.3}$$

Here magnetic magnetic moment is expressed in terms of spin using the standard definitions. g denotes Lande factor and equals in good approximation to $g = 2$ for point like fermion.

Classical color field can be assumed to contain only I_3 component and be derivable from spherically symmetric potential. In the recent case the color bonds moving made from two quarks and moving with nuclear string experience the force.

The color magnetic moments of the quark and anti-quark are of same sign in for both ρ and π type bond so that the isospin component of the net color magnetic moment can be written as

$$\overline{\mu}_c = g\frac{g_s}{m_q(dark)}I_3\overline{S} \ . \tag{3.5.4}$$

Here g_s denotes color coupling constant, g is the Lander factor equal to $g = 2$ in ideal case, and m is mass parameter. Since the color bond is color magnetic flux tube attached from its ends to dark quarks it seems that the mass parameter $m_q(dark)$ in the magnetic moment is that of dark quark and should be $m_q(dark) = v_0 m_q$.

An additional factor of 2 is present because both quark and anti-quark of the bond give same contribution to the color moment of the bond. I_3 equals to the strong isospin of the nucleon to which the quark is attached and spin is opposite to the spin of this quark so that a complete correlation with the quantum numbers of the second nucleon results and one can effectively assign the spin orbit interaction with nucleons. The net interaction energy is small for spin paired states. The sign of the interaction is same for both neutrons and protons.

Using the general form of the spin orbit interaction potential in the non-relativistic limit, one can cast the $L-S$ interaction term in a the form

$$V_{L-S}(r) = \frac{16\pi\mu_c}{m_q(dark)}\bar{L}\cdot\bar{S}\frac{1}{r}\frac{dV_{I_3}}{dr} \quad . \tag{3.5.5}$$

In the first order perturbation theory the energy change for (j,l,s) eigen state with $l=j+\epsilon\frac{1}{2}$, $\epsilon=\pm 1$ and spherically symmetric electromagnetic gauge potential $V(r)$ [B28] given by

$$\begin{aligned} \Delta E(j,l=j+\epsilon\frac{1}{2}) &= \frac{4g_s^2}{m_q^2(dark)L^3}(N-P)c(l)\left[\epsilon(j+\frac{1}{2})+1\right] \quad , \\ c(l) &= -\frac{4\pi L^3}{g_s(N-P)}\langle l|\frac{1}{r}\frac{dV_{I_3}}{dr}|l\rangle \quad . \end{aligned} \tag{3.5.6}$$

The coefficient $g_s/4\pi$ and factor $N-P$ have been extracted from the color gauge potential in the expression of $a(l)$ to get a more kinematical expression. $N-P$-proportionality is expected since the system has net nuclear color isospin proportional to $N-P$ neutralized by dark gluons which can be thought of as creating the potential in which the nuclear string moves. The constant $c(l)$ contains information about the detailed distribution of the color isospin. $c(l)$ depends also on the details of the model (the behavior of single particle radial wave function $R_{n,l}(r)$ in case of wave mechanical model and now on its analog defined by the wave function of nucleon induced by nuclear string). R denotes the nuclear charge radius.

The general order of magnitude of L is $L\sim L_e(129)$. What comes in mind first is the scaling $L\sim v_0^{-1}R_0$, $R_0\sim(3/5)\times L_e(107)\simeq 1.5\times 10^{-15}$ m. This is not consistent with the fact that for light nuclei with $A\leq 4$ L decreases with A but conforms with the fact that spin-spin interaction energies which are very sensitive to L can depend only slightly on A so that L must be more or less independent on A. Assume $g_s^2/4\pi=.1$ and $m_q=m_u\sim .1$ GeV, $g=1$ in the formula for the color magnetic moment. By using $2\pi/L_e(107)\simeq .5$ GeV these assumptions lead to the estimate

$$\begin{aligned} \Delta E(j,l=j+\epsilon\frac{1}{2}) &= \frac{4g_s^2}{m_q^2L^3(107)}(\frac{5}{3})^3\times v_0\times(N-P)\times c(l)\times\left[\epsilon(j+\frac{1}{2})+1\right] \\ &\simeq (\epsilon(j+\frac{1}{2})+1)\times(N-P)\times c(l)\times 2.9\ \ MeV \quad . \end{aligned} \tag{3.5.7}$$

The splitting is predicted to be same for protons and neutrons and also the magnitude looks reasonable. If the dark gluons are at the center and create a potential which is gradually screened by the dark quark pairs, the sign of the spin-orbit interaction term is correct meaning that the contribution to binding energy is positive for $j+1/2$ state. In the case of neutron halo the unscreened remainder of the dark gluon color charge would define $1/r$ potential at the halo possibly responsible for the stability.

This estimate should be compared to the general estimate for the energy scale in the harmonic oscillator model given by $\omega_0\simeq 41\cdot A^{-1/3}$ MeV [C146] so that the general orders of magnitude make sense.

3.5.3 Binding Energies And Stability Of Light Nuclei

Some examples are in order to see whether the proposed picture might have something to do with reality.

(A, Z)	(2, 1)	(3, 1)	(3, 2)	(4, 2)
E_B/MeV	1.111	2.826	2.572	7.0720

Table 3.1: The binding energies per nucleon for the lightest nuclei.

Binding energies of light nuclei

The estimate for the binding energies of light nuclei is based on the following assumptions.

1. Neglect the contribution of the string tension and dark gluon condensate to the binding energy.
2. Suppose that the number of bonds equals to A for $A \leq 4$ nuclei and that the bonds are arranged to maximize color magnetic spin-spin interaction energy. A possible interpretation is in terms of a closed color magnetic flux tube connecting nucleons. The presence of close color magnetic flux tubes is necessary unless one allows homological color magnetic monopoles. This option favors the maximization of the number of n-p type bonds since their spin-spin interaction energy is 3 times higher than that for p-p and n-n type bonds. This is just a working hypothesis and would mean that nuclei could be seen as nuclear strings.

   The alternative interpretation is that the number bonds per nucleon is constant so that the binding energy would not depend on nucleon. The number of bonds could be quite large. Scaling the c quark mass of about 4 GeV gives gives dark mass of about 2 MeV so that two dark generations might be possible. For two dark quark generations 8+8 different quarks can appear at the ends of color flux tubes and 64 different color bonds are in principle possible (which brings in mind the idea of nuclear genetic code and TGD proposal for quantum computation utilizing braided flux tubes!). Also in this case the bond energy can depend on whether p or n is question for $P \neq N$ nuclei since p-p and n-n bonds have smaller bind energy than p-n type bonds.
3. Assume that the nucleons are topologically condensed at $k = 111$ space-time sheet with zero point kinetic energy

$$E_0(A) \sim \frac{3n}{2}\frac{\pi^2}{Am_pL^2(111)} \equiv \frac{n}{A} \times E_0(A=1) \ ,$$

   where n is a numerical factor and $E_0(A=1) \simeq 23$ MeV. Let ΔE denote the color magnetic spin-spin interaction energy per nucleon for π type bond. The zero point kinetic energy is largest for $A \leq 3$ and explains why the binding energy is so small. For $n = 1$ the zero point kinetic energy would be 5.8 MeV for $A = 4$, 7.7 MeV for $A = 3$, and 11.5 MeV for $A = 2$.

With these assumptions the binding energy per bond can be written for $A \leq 4$ as

$$E = r \times \Delta E - \frac{nE_0(p)}{A^2} \ ,$$

where Δ denotes the color magnetic spin-spin interaction energy per bond. The parameter r codes for the fact that color magnetic spin-spin interaction energy depends on whether p-p or n-n type bond is in question. The values of r are $r(^4He) = 1$, $r(^3He) = 7/9$, $r(^2H) = 1$.

Estimates for n and Δ can be deduced from the binding energies of ^2H and ^{3}He. The result is $n = 1.0296$ and $\Delta E = 7.03$ MeV. The prediction for ^{4}He biding energy is 6.71 MeV which is slightly smaller than the actual energy 7.07 MeV. The value of the binding energy per nucleon is in the range 7.4-8.8 MeV for heavier nuclei which compares favorably with the prediction 7.66 MeV at the limit $A \rightarrow \infty$. The generation of dark gluon condensate and color Coulomb energy per nucleon increasing with the number of nucleons could explain the discrepancy.

Why certain light nuclei do not exist?

The model should also explain why some light nuclei do not exist. In the case of proton rich nuclei electromagnetic Coulomb interaction acts as un-stabilizer. For heavy nuclei with non-vanishing value of $P-N$ the positive contribution of dark gluons to the energy tends to in-stabilize the nuclei. The color Coulombic interaction energy is expected to behave as $(N-P)^2$ whereas the energy of dark gluons behaves as $|N-P|$. Hence one expects that for some critical value of $|N-P|$ color Coulombic interaction is able to compensate the contribution of dark gluon energy. One the other hand, the larger number of nn type bonds tends reduced the color magnetic spin-spin interaction energy.

1. Coulomb repulsion for pp is estimated to be.76 MeV from ^{3}He -^{3}H mass difference whereas the color magnetic binding energy would be $E_D/3 = .74$ MeV from the fact that the energy of ρ type bond is 1/3 from that for π type bond. Hence pp bound state would not be possible. The fact that nn bound state does not exist, suggests that the energy of the color neutralizing dark gluon overcomes the color Coulombic interaction energy of dark gluon and dark quarks and spin-spin interaction energy of ρ_0 type bond.
2. For ppp and nnn protons cannot be in S wave. The color magnetic bond energy per nucleon would be predicted to be $E_D = 2.233$ MeV whereas a rough order of magnitude estimate for Coulombic repulsion as

$$E_{em} = Z(Z-1) \times \left[E_B(^3H) - E_B(^3He)\right] = Z(Z-1) \times .76 \ \ MeV$$

gives $E_{em} \simeq 4.56$ MeV so that ppp bound state is not possible. nnn bound state would not be possible because three dark gluons would not be able to create high enough color Coulomb interaction energy E_c which together with color magnetic spin-spin interaction energy E_D would compensate their own negative contribution $3E_g$:

$$3E_g > E_D + E_c \ \ .$$

3. For pppp and nnnn Fermi statistics forces two nucleons to higher partial waves so that the states are not stable. Tetraneutron need not correspond to nnnn state in TGD framework but has more natural interpretation as an alpha particle containing two negatively charged dark quark pairs.

3.5.4 Strong Correlation Between Proton And Neutron Numbers And Magic Numbers

The estimates for the binding energies suggest that nucleons arrange into closed nuclear strings in which nucleons are connected by long color magnetics with one dark quark anti-quark pair per nucleon. Nuclear string approach allows to understand the strong correlation between proton and neutron numbers as well as magic numbers.

Strong correlation between Z and N

$N = Z$ nuclei with maximal color magnetic spin-spin interaction energy arranged into closed nuclear strings contain only colored π type bonds between p and n and should be especially stable. The question is how to create minimum energy configurations with $N \neq Z$.

1. If only stringy configurations are allowed, the removal of the proton would create ρ type n-n bond and lead to a reduction of binding energy per nucleon. This would predict that (Z, Z) type isotopes correspond to maxima of binding energy per nucleon. The increase of the Coulombic energy disfavors the removal of neutrons and addition of protons.
2. For a given closed string structure one can always link any given proton by $\overline{u}u$ bond to neutron and by $\overline{d}d$ bonds to two protons (same for neutron). The addition of only neutron to a branch from proton gives nuclei (Z, N=Z+k), $k = 1, ..., Z$, having only π type bonds. In a similar manner nuclei with $(Z+k, Z)$, $k = 1, .., Z$, containing only π type bonds are obtained. This mechanism would predict isotopes in the ranges (Z, Z)-(Z, 2Z) and (Z, Z)-(2Z, Z) with the same strong binding energy per nucleon apart from increase of the binding energy caused by the generation of dark gluon condensate which in the case of protons seems to be overcome by Coulomb repulsion. Very many of these isotopes are not observed so that this mechanism is not favored.

Consider how this picture compares with experimental facts.

1. Most $Z = N$ with $Z \leq 29$ nuclei exist and are stable against strong decays but can decay weakly. The interpretation for the absence of $Z > 29$ $Z = N$ nuclei would be in terms of Coulomb repulsion. Binding energy per nucleon is usually maximum for $N = Z$ or $N = Z+1$ for nuclei lighter than Si. The tendency $N > Z$ for heavier nuclei could be perhaps understood in terms of the color Coulombic interaction energy of dark gluon condensate with color charges in n-n type color bonds. This would allow also to understand why for $Z = 20$ all isotopes with $(Z = 20, N > 20)$ have higher binding energy per nucleon than $(Z = 20, N = 20)$ isotope in conflict with the idea that doubly magic nucleus should have a maximal binding energy.

   The addition of neutrons to ^{40}Ca nucleus, besides increasing the binding energy per nucleon, also decreases the charge radius of the nucleus contrary to the expectation that the radius of the nucleus should be proportional to $A^{1/3}$ [C146]. A possible interpretation is in terms of the color Coulombic interaction energy due to the generation of dark gluon condensate, the presence of which reduces the equilibrium charge radius of the nucleus.

2. ^{8}Be having $(Z, N) = (4, 4)$ decaying by alpha emission (to two alpha particles) is an exception to the rule. The binding energy per nucleon 7.0603 MeV of Be is slightly lower than the binding energy 7.0720 MeV of alpha particle and the pinching of the Be string to form two alpha strings could be a possible topological decay mechanism.

Magic nuclei in shell model and TGD context

Spin-spin pairing for identical nucleons in the harmonic oscillator potential is an essential element of the harmonic oscillator model explaining among other things shell structure and lowest magic numbers 2, 8, 20 but failing for higher magic numbers 28, 50, 82, 126 (the prediction is 2, 8, 20 and 40, 68, 82, 122). Spin-orbit coupling [C142] reproduces effectively the desired shell structure by drawing some states of the higher shell to the lower shell, and it is indeed possible to reproduce the magic numbers in this manner for 3-D harmonic oscillator model.

This picture works nicely if magic nuclei are identified as nuclei which have exceptionally high abundances. ^{28}Fe, the most abundant element, is however an exception to the rule since neither Z nor N are magic in this case. The standard explanation for the stable nuclei of this kind is as endpoints of radioactive series. This explanation does not however remove the problem of understanding their large binding energy, which is after all what matters.

The surprise of recent years has been that even for neutron rich unstable nuclei 28 appears as a magic number for unstable neutrons in very neutron rich nuclei such as Si(14, 28) [C22] so that the notion of magic number does not seem to be so dependent on spin-orbit interactions with the nuclear environment as believed. Also new magic numbers such as N=14, 16, 30, 32 have been discovered in the neutron sector [C22]. Already the stable isotope Mg(12, 14) has larger binding energy per nucleon than doubly magic Mg(12, 12) and could be perhaps understood in terms of dark gluons. ^{56}Fe and ^{58}Fe correspond to N=30 and 32. The linking of two N=8 magic nuclei would give N=16 and various linkings of N=14 and N=16 nuclei would reduce the stability N = 28, 30, 32 magic nuclei to the stability of their building blocks. Perhaps these findings could provide motivations for considering whether the stringy picture might provide an alternative approach to understanding of the magic numbers.

1. The identification of magic nuclei as minima of binding energy predicts new magic numbers

The identification of the magic nuclei as minima of the binding energy as function of Z and N provides an alternative definition for magic numbers but this would predict among other things that also $Z = N = 4, 6, 12$ also correspond to doubly magic nuclei in the sense that $E_b(^8Be) = 7.0603)$, $E_b(^{12}C) = 7.677$ MeV and $E_B(^{24}Mg) = 8.2526$ are maxima for the binding energy per nucleon as a function of Z and N. For higher nuclei addition of neutrons to a doubly magic nucleus typically increases the binding energy up to some critical number of added neutrons (the generation of the dark gluon condensate would explain this in TGD framework). The maximum for the excitation energy of the first excitation seems to be the definition of magic in the shell model.

2. Platonic solids and magic numbers

The TGD picture suggest that light magic nuclei could have a different, purely geometric, interpretation in terms of five regular Platonic solids. $Z = N = 4, 6, 8, 12, 20$ could correspond to tetrahedron, octahedron (6 vertices), hexahedron (8 vertices), dodecahedron (12 vertices), and icosahedron (20) vertices. Each vertex would contain a bonded neutron and proton in the case of doubly magic nucleus. This model would predict correctly all the maxima of the binding energy per nucleon for $Z, N \leq 20$.

3. p-Adic length scale hypothesis and magic numbers

$Z = N = 8$ could be also interpreted as a maximal number of nucleons which $k = 109$ space-time sheet associated with dark quarks can contain. p-Adic length scale hypothesis would suggest that strings with length coming as p-adic length scale $L_e(k)$ are especially stable. Strings with thickness $L_e(109)$ would correspond to Z=N=2 for length $L = L_e(109)$, $L_e(k = 109 + 2n)$ would correspond to $Z = 2^{n+1}$ explaining $N = 2, 8, 16, 32$.

4. Could the linking of magic nuclei produce new magic nuclei?

Nuclear strings can become knotted and linked with fermion statistics guaranteeing that the links cannot be destroyed by a 3-dimensional topological transition.

An interesting question is whether the magic numbers $N = 14, 16, 30, 32$ could be interpreted in terms of lower level magic numbers: 14=8+6, 16=8+8, 30=16+40, 32=16+16. This would make sense if $k = 111$ space-time sheets containing $Z, N \leq 4, 6, 8$ neutrons and protons define basic nucleon clusters forming closed nuclear strings. The linking these structures could give rise to higher magic nuclei whose stability would reduce that of the building blocks, and it would be possible to interpret magic number $Z, N = 28 = 20 + 8$ as linked lower level magic nuclei.

The partitions 28=20+8, 50=20+2+28 = 20+2+8+20, 82=50+2+28, 126=50+50+20+6=82+28+8+8 inspire the question whether higher doubly magic nuclei and their deformations could correspond to linked lower level magic nuclei so that a linking hierarchy would result.

Could the transition to the electromagnetically dark matter cause the absence of higher shells?

Spin orbit coupling explains the failure of the shell model as an explanation of the magic numbers. Transition to electromagnetic dark matter at critical charge number $Z = 12$ suggests an alternative explanation for the failure in the case of protons. The phase transition of Pd nuclei (Z=46) to electromagnetically dark nuclear phase inducing in turn the transition of D nuclei to dark matter phase has been proposed as an explanation for cold fusion [K40].

On basis of $Z^2\alpha_{em} \simeq 1$ criterion $Z = 12$ would correspond to the critical value for the nuclear charge causing this transition. One can argue that due to the Fermi statistics nuclear shells behave as weakly interacting units and the transition occurs for the first time for $Z = 20$ nucleus, which corresponds to Ca, one of the most important ions biologically and neurophysiologically. These necessarily completely filled structures would become structural units of nuclei at electromagnetically dark level.

An alternative interpretation is that the criterion to dark matter phase applies only to a pair of two systems and reads thus $Z_1Z_2\alpha_{em} \simeq 1$ implying that only the nuclei $Z, N \geq 40$ can perform the transition to the dark phase (what this really means is an interesting question). This would explain why Pd with $Z = 46$ has so special role in cold fusion.

Interestingly, the number of protons at $n = 2$ shell of harmonic oscillator is $Z = 12$ and thus corresponds to a critical value for em charge above which a transition to an electromagnetic dark matter phase increasing the size of the electromagnetic $k = 113$ space-time sheet of nucleus by a factor $\simeq 2^{11}$ could occur. This could explain why $n = 2$ represents the highest allowed harmonic oscillator shell with higher level structures consisting of clusters of $n < 3$ shells. Neutrons halos could however allow higher shells.

Could only the hadronic space-time sheet be scaled up for light nuclei?

The model discussed in this chapter is based on guess work and leaves a lot of room for different scenarios. One of them emerged only after a couple of months finishing the work with this chapter.

1. Is only the $\hbar$ associated with hadronic space-time sheet large?

The surprising and poorly understood conclusion from the p-adic mass calculations was that the p-adic primes characterizing light quarks u, d, s satisfy $k_q < 107$, where $k = 107$ characterizes hadronic space-time sheet [K71].

1. The interpretation of $k = 107$ space-time sheet as a hadronic space-time sheet implies that quarks topologically condense at this space-time sheet so that $k = 107$ cannot belong to the collection of primes characterizing quark.
2. Since hadron is expected to be larger than quark, quark space-time sheets should satisfy $k_q < 107$ unless $\hbar$ is large for the hadronic space-time sheet so that one has $k_{eff} = 107 + 22 = 129$. This would predict two kinds of hadrons. Low energy hadrons consists of u, d, and s quarks with $k_q < 107$ so that hadronic space-time sheet must correspond to $k_{eff} = 129$ and large value of $\hbar$. One can speak of confined phase. This allows also $k = 127$ light variants of quarks appearing in the model of atomic nucleus. The hadrons consisting of c, t, b and the p-adically scaled up variants of u, d, s having $k_q > 107$, $\hbar$ has its ordinary value in accordance with the idea about asymptotic freedom and the view that the states in question correspond to short-lived resonances.

This picture is very elegant but would mean that it would be light *hadron* rather than quark which should have large $\hbar$ and scaled up Compton length. This does not affect appreciably the model of atomic nucleus since the crucial length scales $L_e(127)$ and $L_e(129)$ are still present.

2. Under what conditions quarks correspond to large $\hbar$ phase?

What creates worries is that the scaling up of $k = 113$ quark space-time sheets of quarks forms an essential ingredient of condensed matter applications [K42] assuming also that these scaled up space-time sheets couple to scaled up $k = 113$ variants of weak bosons. Thus one must ask under what conditions $k = 113$ quarks, and more generally, all quarks can make a transition to a dark phase accompanying a simultaneous transition of hadron to a doubly dark phase.

The criterion for the transition to a large $\hbar$ phase at the level of valence quarks would require that the criticality criterion is satisfied at $k = 111$ space-time sheet and would be expressible as $Z^2\alpha_{em} = 1$ or some variant of this condition discussed above.

The scaled up $k = 127$ quark would correspond to $k = 149$, the thickness of the lipid layer of cell membrane. The scaled up hadron would correspond to $k = 151$, the thickness of cell membrane. This would mean that already the magnetic bodies of hadrons would have size of cell membrane thickness so that the formation of macroscopic quantum phases would be a necessity since the average distance between hadrons is much smaller than their Compton length.

3.5.5 A Remark About Stringy Description Of Strong Reactions

If nucleons are arranged into possibly linked and knotted closed nuclear strings, nuclear reactions could be described in terms of basic string diagrams for closed nuclear strings.

The simplest fusion/fission reactions $A_1 + A_2 \leftrightarrow (A_1 + A_2)$, $A_i > 2$, could correspond to reactions in which the $k = 111$ dark space-time sheets fuse or decay and re-distribution of dark quarks and anti-quarks between nucleons occurs so that system can form a new nucleus or decay to a new nuclei. This also means re-organizes the linking and knotting of the color flux tubes.

The reactions $p/n + A \rightarrow ..$ would involve the topological condensation of the nucleon to $k = 111$ space-time sheet after which it can receive quark anti-quark pair, which can be also created by dark gluon emission followed by annihilation to a dark quark pair.

3.5.6 Nuclear Strings And DNA Strands

Nuclear strings consisting of protons and neutrons bring in mind bit arrays. Their dark mirror counterparts in turn brings in mind the structure of DNA double strand. This idea does not look so weird once one fully accepts the hierarchies associated with TGD. The hierarchy of space-time sheets quantified by p-adic fractality, the hierarchy of infinite primes representable as a repeated second quantization of a super-symmetric arithmetic quantum field theory, the self hierarchy predicted by TGD inspired theory of consciousness, the Jones inclusion hierarchy for von Neumann factors of type II_1 appearing in quantum TGD and allowing to formulate what might be called

Feynman rules for cognition, and the hierarchy of dark matters would all reflect the same reflective hierarchy.

The experience with DNA suggests that nuclear strings could form coiled tight double helices for which only transversal degrees of freedom would appear as collective degrees of freedom. DNA allows a hierarchy of coilings and DNA molecules can also link and this could happen also now. Nuclei as collections of linked nuclear strings could perhaps be said to code the electromagnetic and color field bodies and it is difficult to avoid the idea that DNA would code in the same manner field bodies at which matter condenses to form much larger structures. The hierarchy of dark matters would give rise to a hierarchy of this kind of codings.

The linking and knotting of string like structures is the key element in the model of topological quantum computation and the large value of $\hbar$ for dark matter makes it ideal for this purpose. I have already earlier proposed a model of DNA based topological quantum computation inspired by some strange numerical co-incidences [K5]. If dark matter is the essence of intelligent and intentional life at the level of molecular physics, it is difficult to see how it could not serve a similar role even at the level of elementary particle physics and provide kind of zoomed up "cognitive" representation for the ordinary matter.

The precise dark-visible correspondence might fail at the level of nuclei and nucleons because the lifetimes of the scaled down dark matter nucleons and nuclei are different from those of ordinary nucleons if dark matter is dark also with respect to weak interactions. The weak interaction rates in the lowest order are scaled up by the presence of $1/m_W^4$ factors by a factor 2^{-44} so that weak interactions are not so weak anymore. If dark electron and neutrino have their ordinary masses, dark proton and neutron would be stable. If also they appear as scaled down versions situation changes, but only a small change of the mass ratio of dark proton and neutron can make the weak decay of free dark neutron impossible kinematically and the one-to-one correspondence would make sense for stable nuclei. The beta decays of dark nuclei could however as a third order process with a considerable rate and change dramatically the weak decay rates of dark nuclei.

3.6 Neutron Halos, Tetra-Neutron, And "Sticky Toffee Model Of" Nucleus

Neutron halos and tetra neutron represent two poorly understood features of nuclear physics which all have been seen as suggesting the existence of an unknown long range force or forces.

3.6.1 Tetraneutron

There is evidence for the existence of tetra-neutrons [C81]. Standard theory does not support their existence [C25] so that the evidence for them came as a complete experimental surprise. Tetra-neutrons are believed to consist of 4 neutrons. In particular their lifetime, which is about 100 nanoseconds, is almost an eternity in the natural time scale of nuclear physics. The reason why the existing theory of nuclear force does not allow tetra-neutrons relates to Fermi statistics: the second pair of neutrons is necessarily in a highly energetic state so that a bound state is not possible.

Exotic quarks and charged color bonds provide perhaps the most natural explanation for tetra-neutron in TGD framework. In the model discussed hitherto only electromagnetically neutral color bonds have been considered but one can consider also charged color bonds in analogy allowing instead of neutral π and ρ also their charged companions. This would make possible to construct from two protons and neutrons the analog of alpha particle by replacing two neutral color bonds with negatively charged bonds so that one would have two $\overline{u}d$ p-n bonds and two $\overline{u}u$ p-n bonds. Statistics difficulty would be circumvented and the state would decay to four neutrons via W boson exchange between quark of charged p-n bonds and protons. The model suggests the existence of also neutral variant of deuteron.

One can consider two options according to whether the exotic quarks have large $\hbar$ but small c (Option II) or whether they are just p-adically scaled up quarks with $k = 127$ (Option I). I have considered earlier a model analogous to option II but based on the hypothesis about existence of scaled down variant of QCD associated with Mersenne prime M_{127}. The so called lepto-hadron physics would also be associated with M_{127} and involve colored excitations of leptons [K115] which might also represent dark matter: in this case dark valence leptons with color would correspond to $keff = 149$, which happens to correspond to the thickness of the lipid layer of cell membrane.

The notion of many-sheeted space-time predicts the possibility of fractal scaled up/down versions of QCD which, by the loss of asymptotic freedom, exist only in certain length scale range and energy range. Thus the prediction does not lead to contradictions elementary particle physics limits for the number of colored elementary particles. The scaled up dark variants of QCD like theory allow to circumvent these problems even when asymptotic freedom is assumed.

In particular, pions and other mesons could exist for $k = 127$ option as scaled down versions having much smaller masses. This lead to the earlier model of tetra-neutron as an ordinary alpha particle bound with two exotic pions with negative charges and having very small masses. This state looks like tetra-neutron and decays to neutrons weakly. The statistics problem is thus circumvented and the model makes precise quantitative predictions.

3.6.2 The Formation Of Neutron Halo And TGD

One counter argument against TGD inspired nuclear model is the short range of the nuclear forces: the introduction of the p-adic length scale $L(113) \simeq 1.6E^{-14}$ m is in conflict with this classical wisdom. There exists however direct evidence for the proposed length scale besides the evidence from the p-n low energy scattering. Some light nuclei such as ^8He, ^{11}Li and ^{11}Be possess neutron halo with radius of size $\sim 2.5E^{-14}$ m [C133]. The width of the halo is rather large if the usual nuclear length scale is used as unit and the neutrons in the halo seem to behave as free particles. The short range of the nuclear forces makes it rather difficult to understand the formation of the neutron halo although the existing models can circumvent this difficulty. The proposed picture of the nucleus suggests a rather simple model for the halo.

For ordinary nuclei the densities of nucleons tend to be concentrated near the center of the nucleus. One can however consider the possibility of adding nucleons in vicinity of the boundary of the $k = 111$ space-time sheet associated with the nucleus itself. The binding force would be color interaction between the color charges of color bonds and neutralizing color charge of colored gluons in the center (or in halo itself). Neutron halo would define a separate nucleus in the sense that states could be constructed by starting from the ground state. Halo would correspond to a quantum de-localized cluster of size of alpha particle.

The case ^{11}Be provides support for the theory. Standard shell model suggests that six neutrons of ^{11}Be fill completely $1s_{\frac{1}{2}}$ and $1p_{\frac{3}{2}}$ states while $1p_{\frac{1}{2}}$ state holds one neutron so that ^{11}Be ground state has $J^{\pi} = \frac{1}{2}^-$ whereas experimentally ground state is known to have $J^{\pi} = \frac{1}{2}^+$. The system can be regarded as $^{10}Be +$ halo neutron. The first guess is that the state could be simply of the following form

$$|0^+\rangle \times |2s_{1/2}\rangle \ . \tag{3.6.1}$$

Color force would stabilize this state. A more general state is a superposition of higher $ns_{1/2}$ states in order to achieve more sharp localization near boundary. This increases the kinetic energy of the neutron and the small binding energy of the halo neutron about 2.5 MeV implies that the kinetic energy should be of order $5 - 6$ MeV. For instance, in the model described in [C130] the halo neutron property and correct spin-parity for ^{11}Be can be realized if the state is superposition of form

$$\begin{aligned} |^{11}Be\rangle &= a|0^+\rangle \times |2s_{1/2}\rangle + ba|2^+\rangle \times |21d_{5/2}\rangle \ , \\ a &\simeq .74 \ , \\ b &\simeq .63 \ . \end{aligned} \tag{3.6.2}$$

The correlation between the coreandhalo neutron is necessary in the model of Otsuka [C130] to produce bound $1/2^+$ state. The halo neutron must also rotate.

The second example is provided by two-neutron halo nuclei, such as ^{11}Li and ^{12}Be, which do not bind single neutron but bind two neutrons. This looks mysterious since free neutrons do not allow bound states. A possible explanation is that the increase of the color Coulomb energy of neutron color bonds with at least N-P dark gluons makes possible binding of neutron halo to the center nucleus. The situation would be analogous to the formation of planetary system. Order of magnitude estimate for color Coulomb energy of halo neutron is $E \sim (N-P)\alpha_s/L(113) \simeq (N-P) \times .8$ MeV. For $N-P=3$ the binding energy would be about 2.3 MeV and smaller than the experimental estimate 2.5 MeV. For $N-P=4$ this gives 3.2 MeV and larger than 2.5 MeV so that there is some room for the reduction of binding energy by the contribution from kinetic energy.

3.7 Tritium Beta Decay Anomaly

The determination of neutrino mass from the beta decay of tritium leads to a tachyonic mass squared [C80, C95]. I have considered several alternative explanations for this long standing anomaly.

1. ^{3}He nucleus resulting in the decay could be fake (tritium nucleus with one positively charged color bond making it to look like ^{3}He). The idea that slightly smaller mass of the fake ^{3}He might explain the anomaly: it however turned out that the model cannot explain the variation of the anomaly from experiment to experiment.
2. Much later I realized that also the initial ^3H nucleus could be fake (^{3}He nucleus with one negatively charged color bond). It turned out that fake tritium option can explain all aspects of the anomaly and also other anomalies related to radioactive and alpha decays of nuclei.
3. The alternative based on the assumption of dark neutrino or antineutrino belt surrounding Earth's orbit and explain satisfactorily several aspects of the anomaly but fails in its simplest form to explain the dependence of the anomaly on experiment. Since the fake tritium scenario is based only on the basic assumptions of the nuclear string model [L4], [L4] and brings in only new values of kinematical parameters it is definitely favored.

3.7.1 Tritium Beta Decay Anomaly

A brief summary of experimental data before going to the detailed models is in order.

Is neutrino tachyonic?

Nuclear beta decay allows in principle to determine the value of the neutrino mass since the energy distribution function for electrons is sensitive to neutrino mass at the boundary of the kinematically allowed region corresponding to the situation in which final neutrino energy goes to zero [C120].

The most useful quantity for measuring the neutrino mass is the so called Kurie plot for the function

$$\begin{aligned} K(E) &\equiv \left[\frac{d\Gamma/dE}{pEF(Z,E)}\right]^{1/2} \sim (E_\nu k_\nu)^{1/2} = \left[E_\nu\sqrt{E_\nu^2 - m(\nu)^2}\right]^{1/2} \quad , \\ E_\nu &= E_0 - E \ \ , \ \ E_0 = M_i - M_f - m(\nu) \ . \end{aligned} \tag{3.7.1}$$

Here E denotes electron energy and E_0 is its upper bound from energy and momentum conservation (for a configuration in which final state nucleon is at rest). Mass shell condition lowers the upper bound to $E \leq E_0 - m(\nu)$. For $m(\nu) = 0$ Kurie plot is straight line near its endpoint. For $m(\nu) > 0$ the end point is shifted to $E_0 - m(\nu)$ and $K(E)$ behaves as $m(\nu)^{1/2}k_\nu^{1/2}$ near the end point.

The problem is that the determination of $m(\nu)$ from this parameterization in tritium beta decay experiments gives a negative mass squared varies and is $m(\nu)^2 = -147 \pm 68 \pm 41$ eV^2 according to [C120] ! This behavior means that the derivative of $K(E)$ is infinite at the end point E_0 and $K(E)$ increases much faster near end point than it should. One can quite safely argue that tachyonicity gives only an ad hoc parameterization for the change of the shape of the function K deriving from some unidentified physical effect: in particular, the value of the tachyonic mass must correspond to a parameter related to new physics and need not have anything to do with neutrino mass.

More detailed experimental data

The results of Troitsk and Mainz experiments can be taken as constraints of the model. In Troitsk experiments [C80] gas phase tritium is used whereas in Mainz experiments [C95] liquid tritium film is used.

Troitsk experiments are described in [C80]. In 1944 Troitsk experiment, the enhancement of the spectrum intensity was found to begin roughly at $V_b \simeq 7.6$ eV below E_0. The conclusion was that the rise of the spectrum intensity below 18,300 eV with respect to the standard model prediction takes place (this is illustrated in **Fig.** 4 of [C80]). No bump was claimed in this paper. In the analysis of 1996 experiment Troitsk group however concluded that the trapping of electrons gives rise to the enrichment of the low energy spectrum intensity of electrons and that when takes this effect into account, a narrow bump results.

Figure 4 of [C80] demonstrates that spectrum intensity is below the theoretical value near the endpoint (right from the bump). In [C80] the reduction of the spectrum intensity was assumed to be due to non-vanishing neutrino mass in [C80]. The determination of $m(\nu)$ from the data near the end point assuming that beta decay is in question [C80] gives $m(\nu) \sim 5$ eV.

The data can be parameterized by a parameter V_b which in the model context can be interpreted as repulsive interaction energy of antineutrinos with condensed matter suggested to explain the bump. Accordingly, the parameterization of $K(E)$ near the end point is

$$K(E) \sim (E - E_0)\theta(E - E_0) \rightarrow (E - E_0)\theta(E - E_0 + V_b) \ .$$

The end point is shifted to energy $E_\nu = V_b$ and $K(E)$ drops from the value V_b to zero at at this energy.

The values of V_b deduced from Troitsk and Mainz experiments are in the range $5 - 100$ eV. The value of V_b observed in Troitsk experiments using gas phase tritium [C80] was of order 10 eV. In Mainz experiment [C95] tritium film was used and the excess of counts around energy $V_b \simeq 100$ eV below E_0 was observed.

There is also a time variation involved with the value of V_b. In 1944 experiment [C80] the bump was roughly $V_b \simeq 7.6$ eV below E_0. In 1996 experiment [C80] the value of V_b was found to be $V_b \simeq 12.3$ eV [C95]. Time variation was observed also in the Mainz experiment. In "Neutrino 98" conference an oscillatory time variation for the position of the peak with a period of 1/2 years in the amplitude was reported by Troitsk group.

3.7.2 Could TGD Based Exotic Nuclear Physics Explain The Anomaly?

Nuclear string model explains tetra-neutron as alpha particle with two negatively charged color bonds. This inspires the question whether some fraction of decays could correspond to the decays of tritium to fake ^{3}He (tritium with one positively charged color bond) or fake tritium (^{3}He with one negatively charged color bond) to ^{3}He.

Could the decays of tritium decay to fake ^{3}He explain the anomaly?

Consider first the fake ^{3}He option. Tritium (pnn) would decay with some rate to a fake ^{3}He, call it $^3\mathrm{He}_f$, which is actually tritium nucleus containing one positively charged color bond and possessing mass slightly different than that of ^{3}He (ppn).

1. In this kind of situation the expression for the function $K(E,k)$ differs from $K(stand)$ since the upper bound E_0 for the maximal electron energy is modified:

$$\begin{aligned} E_0 &\rightarrow E_1 = M(^3\mathrm{H}) - M(^3\mathrm{He}_f) - m_\mu = M(^3\mathrm{H}) - M(^3\mathrm{He}) + \Delta M - m_\mu \ , \\ \Delta M &= M(^3\mathrm{He}) - M(^3\mathrm{He}_f) \ . \end{aligned} \quad (3.7.2)$$

Depending on whether $^3\mathrm{He}_f$ is heavier/lighter than ^{3}He E_0 decreases/decreases. From $V_b \in [5 - 100]$ eV and from the TGD based prediction order $m(\overline{\nu}) \sim .27$ eV one can conclude that ΔM should be in the range 10-200 eV.

2. In the lowest approximation $K(E)$ can be written as

$$K(E) = K_0(E, E_1, k))\theta(E_1 - E) \simeq (E_1 - E)\theta(E_1 - E) \ . \tag{3.7.3}$$

   Here $\theta(x)$ denotes step function and $K_0(E, E_0, k)$ corresponds to the massless antineutrino.

3. If a fraction p of the final state nuclei correspond to a fake ^{3}He the function $K(E)$ deduced from data is a linear combination of functions K(E, ^{3}He) and K(E, $^3\mathrm{He}_f$) and given by

$$\begin{aligned} K(E) &= (1-p)K(E,^3\mathrm{He}) + pK(E,^3\mathrm{He}_f) \\ &\simeq (1-p)(E_0 - E)\theta(E_0 - E) + p(E_1 - E)\theta(E_1 - E) \end{aligned} \tag{3.7.4}$$

   in the approximation $m_\nu = 0$.
   For $m(^3\mathrm{He}_f) < m(^3\mathrm{He})$ one has $E_1 > E_0$ giving

$$K(E) = (E_0 - E)\theta(E_0 - E) + p(E_1 - E_0)\theta(E_1 - E)\theta(E - E_0) \ . \tag{3.7.5}$$

   $K(E, E_0)$ is shifted upwards by a constant term $p\Delta M$ in the region $E_0 > E$. At $E = E_0$ the derivative of $K(E)$ is infinite which corresponds to the divergence of the derivative of square root function in the simpler parameterization using tachyonic mass. The prediction of the model is the presence of a tail corresponding to the region $E_0 < E < E_1$.

4. The model does not as such explain the bump near the end point of the spectrum. The decay $^3\mathrm{H} \rightarrow ^3\mathrm{He}_f$ can be interpreted in terms of an exotic weak decay $d \rightarrow u + W^-$ of the exotic d quark at the end of color bond connecting nucleons inside ^3H. The rate for these interactions cannot differ too much from that for ordinary weak interactions and W boson must transform to its ordinary variant before the decay $W \rightarrow e + \overline{\nu}$. Either the weak decay at quark level or the phase transition could take place with a considerable rate only for low enough virtual W boson energies, say for energies for which the Compton length of massless W boson correspond to the size scale of color flux tubes predicted to be much longer than nuclear size. Is so the anomaly would be absent for higher energies and a bump would result.

5. The value of $K(E)$ at $E = E_0$ is $V_b \equiv p(E_1 - E_0)$. The variation of the fraction p could explain the observed dependence of V_b on experiment as well as its time variation. It is however difficult to understand how p could vary.

Could the decays of fake tritium to ^{3}He explain the anomaly?

Second option is that fraction p of the tritium nuclei are fake and correspond to ^{3}He nuclei with one negatively charged color bond.

1. By repeating the previous calculation exactly the same expression for $K(E)$ in the approximation $m_\nu = 0$ but with the replacement

$$\Delta M = M(^3\mathrm{He}) - M(^3\mathrm{He}_f) \quad \rightarrow \quad M(^3\mathrm{H}_f) - M(^3\mathrm{H}) \ . \tag{3.7.6}$$

2. In this case it is possible to understand the variations in the shape of $K(E)$ if the fraction of $^3\mathrm{H}_f$ varies in time and from experiment to experiment. A possible mechanism inducing this variation is a transition inducing the transformation $^3\mathrm{H}_f \rightarrow ^3\mathrm{H}$ by an exotic weak decay $d + p \rightarrow u + n$, where u and d correspond to the quarks at the ends of color flux tubes. This kind of transition could be induced by the absorption of X-rays, say artificial X-rays or X-rays from Sun. The inverse of this process in Sun could generate X rays which induce this process in resonant manner at the surface of Earth.

3. The well-known poorly understood X-ray bursts from Sun during solar flares in the wavelength range 1-8 A [C5] corresponds to energies in the range 1.6-12.4 keV, 3 octaves in good approximation. This radiation could be partly due to transitions between ordinary and exotic states of nuclei rather than brehmstrahlung resulting in the acceleration of charged particles to relativistic energies. The energy range suggests the presence of three p-adic length scales: nuclear string model indeed predicts several p-adic length scales for color bonds corresponding to different mass scales for quarks at the ends of the bonds [L4] , [L4]. This energy range is considerably above the energy range $5-100$ eV and suggests the range $[4\times 10^{-4}, 6\times 10^{-2}]$ for the values of p. The existence of these excitations would mean a new branch of low energy nuclear physics, which might be dubbed X-ray nuclear physics. The energy scale of for the excitation energies of exotic nuclei could corresponds to Coulomb interaction energy $\alpha_{em}m$, where m is mass scale of the exotic quark. This means energy scale of 10 keV for MeV mass scale.

4. The approximately 1/2 year period of the temporal variation would naturally correspond to the $1/R^2$ dependence of the intensity of X-ray radiation from Sun. There is evidence that the period is few hours longer than 1/2 years which supports the view that the origin of periodicity is not purely geometric but relates to the dynamics of X-ray radiation from Sun. Note that for 2 hours one would have $\Delta T/T \simeq 2^{-11}$, which defines a fundamental constant in TGD Universe and is also near to the electron proton mass ratio.

5. All nuclei could appear as similar anomalous variants. Since both weak and strong decay rates are sensitive to the binding energy, it is possible to test this prediction by finding whether nuclear decay rates show anomalous time variation.

6. The model could explain also other anomalies of radioactive reaction rates including the findings of Shnoll [E26] , [E26] and the unexplained fluctuations in the decay rates of ^{32}Si and ^{226}Ra reported quite recently [C74] and correlating with $1/R^2$, R distance between Earth and Sun. ^{226}Ra decays by alpha emission but the sensitive dependence of alpha decay rate on binding energy means that the temporal variation of the fraction of fake ^{226}Ra isotopes could explain the variation of the decay rates. The intensity of the X-ray radiation from Sun is proportional to $1/R^2$ so that the correlation of the fluctuation with distance would emerge naturally.

7. Also a dip in the decay rates of ^{54}Mn coincident with a peak in proton and X-ray fluxes during solar flare [C116] has been observed: the proposal is that neutrino flux from Sun is also enhanced during the solar flare and induces the effect. A peak in X-ray flux is a more natural explanation in TGD framework.

8. The model predicts interaction between atomic physics and nuclear physics, which might be of relevance in biology. For instance, the transitions between exotic and ordinary variants of nuclei could yield X-rays inducing atomic transitions or ionization. The wave length range 1-8 Angstroms for anomalous X-rays corresponds to the range $Z \in [11, 30]$ for ionization energies. The biologically important ions Na^+, Mg^{++}, P^-, Cl^-, K^+, Ca^{++} have $Z = (11, 15, 17, 19, 20)$. I have proposed that Na^+, Cl^-, K^+ (fermions) are actually bosonic exotic ions forming Bose-Einstein condensates at magnetic flux tubes [K88]. The exchange of W bosons between neutral Ne and A(rgon) atoms (bosons) could yield exotic bosonic variants of Na^+ (perhaps even Mg^{++}, which is boson also as ordinary ion) and Cl^- ions. Similar exchange between A atoms could yield exotic bosonic variants of Cl^- and K^+ (and even Ca^{++}, which is also boson as ordinary variant). This hypothesis is testable by measuring the nuclear weights of these ions. X-rays from Sun are not present during night time and this could relate to the night-day cycle of living organisms. Note that magnetic bodies are of size scale of Earth and even larger so that the exotic ions inside them could be subject to intense X-ray radiation. X-rays could also be dark X-rays with large Planck constant and thus with much lower frequency than ordinary X-rays so that control could be possible.

3.7.3 The Model Based On Dark Neutrinos

A common origin of the tritium beta decay anomaly was independently suggested by several groups (see [C117]): a broad spike or bump like excess of counts centered $5-100$ eV below the end point energy E_0. In [C117] it was suggested that a repulsive interaction of antineutrinos with condensed matter with interaction energy of order $V_b \simeq 5 - 100$ eV could explain the bump.

It has been pointed out by Stevenson [C103] that the process in which neutrinos are absorbed from a background of electron neutrinos

$$\nu_e +^3 \mathrm{H} \rightarrow^3 \mathrm{He} + e^-$$

leads to electrons in the anomalous endpoint region. This gives an essentially constant addition to the region $E_0 - E_F < E < E_0$. The density of cosmic neutrino background is however far too small to give the required large background density of order $1/m(\nu)^3$.

The earlier -wrong- hypothesis that nuclei are Z^0 charged are consistent with both options described above as explanations of the anomaly. One can modify these models to apply also in the new framework. The problem of these models is that one is forced to make ad hoc assumptions about dynamics in long length scales. They might make sense in TGD Universe but would require experimental justification. These models in their simplest form fail also to explain the dependence of V_b on experiment and fail to provide provide insights about more general time variations of nuclear decay rates.

Neutrino belt or antineutrino belt?

The model corresponding to mechanism of [C117] is that the belt consists of dark antineutrinos and the repulsive interaction energy of antineutrino with the these neutrinos explains the anomaly. The model based on dark neutrinos assumes that Earth's orbit is surrounded by a belt of dark neutrinos and that the mechanism proposed in [C103] could be at work. The periodic variation of the dark neutrino density along the orbit of Earth around Sun could also explain the periodic variations of the bump.

1. The first mechanism corresponds to that suggested in [C117]. The antineutrino emitted in the beta decay can transform to a dark neutrino by mixing and experiences a repulsive Z^0 force which effectively shifts the electron energy spectrum downwards. In this case the repulsive interaction energy V_b of dark anti-neutrinos with the dark antineutrinos of the solar belt would replace ΔM in the previous formula:

$$E_0 = M(^3\mathrm{H}) - M(^3\mathrm{He}) - m(\nu) \rightarrow M(^3\mathrm{H}) - M(^3\mathrm{He}) - V_b - m(\nu_d) \ . \tag{3.7.7}$$

2. Second option corresponds to the mechanism proposed in [C103]. Dark neutrino transforms to ordinary one and induces by ordinary W exchange ordinary tritium beta decay. In this case the Fermi energy E_F of dark neutrino determines the width of the bump and one has $V_b = E_F$:

$$E_0 = M(^3\mathrm{H}) - M(^3\mathrm{He}) - m(\nu) \rightarrow M(^3\mathrm{H}) - M(^3\mathrm{He}) - E_F + m(\nu_d) \ . \tag{3.7.8}$$

The rate of the process would be given by the standard model and only the density of dark neutrinos and the ratio $M^2(\nu, \nu(dark))/M^2(\nu)$ appear as free parameters.

Notice that these models are simpler than the original models which assumed that the interaction of neutrinos with condensed matter carrying Z^0 charge is involved. The explanation for the dependence of V_b on experiment poses a difficulty for both models. For the antineutrino belt the repulsive interaction energy is proportional to the density of antineutrinos. For neutrino belt V_b corresponds to the Fermi energy proportional to the density of neutrinos. In both cases large variation of V_b requires a large variation of the density of antineutrinos (neutrinos) of the belt in the scale smaller than Earth size. This does not look too plausible.

Can one understand time variation of V_b?

The periodic variation of the density of neutrinos or antineutrinos in the belt should induce the variation of V_b. The ordering of the two models trying to explain this variation reflects the evolution of the general ideas about quantum TGD.

1. First model

The value of the period and the fact that maximum shift occurs when Earth is near to its position nearest to Sun suggests that the physics of solar system must be involved somehow. The simplest explanation is that gravitational acceleration tends to drive dark neutrinos (antineutrinos) as near as possible to Sun inside the belt. In thermal equilibrium with temperature T the Boltzmann factor

$$exp(-\frac{V_{gr}}{T}) = exp(-\frac{GMm(\nu_d)}{rT}) \tag{3.7.9}$$

for the dark neutrino would determine the density profile of dark neutrinos along the belt as function of the distance r to the Sun.

The existence of the dark neutrino belt conforms with the model of for the formation of solar system from dark matter with a gigantic value of Planck constant discussed in [K96, K40]. The model indeed assumes that the dark matter is located at space-time sheet surrounding the orbit of Earth. The requirement that dark neutrino density is few neutrinos per atomic volume in the belt leads to a lower bound for the mass of the belt:

$$M(belt) \simeq m(\nu_d)\frac{Vol(belt)}{a^3} > 10^{-11}M(Sun) \quad (a \simeq 10^{-10} \text{ meters}) \ . \tag{3.7.10}$$

Here it is assumed that the dark neutrino mass is same as neutrino mass, which of course is an un-necessarily strong assumption. If the belt is at rest, the time period for the variation of the tritium beta decay anomaly is exactly half year. The period seems to be few hours longer than one half year (as reported in Neutrino98 conference in Tokyo by Lobashev *et al*) [C80], which suggests that belt rotates slowly relative to Earth in the same direction as Earth.

2. Second model

The model for radioactive decay rate anomalies requires that neutrinos and Earth move respect to each other and that the density of neutrinos in the laboratory volume varies along the orbit.

1. Assume first that ordinary quantum mechanics applies and neutrinos are ordinary. The simplest expectation from Equivalence Principle assuming that neutrinos and Earth move independently along geodesic lines is that the velocity is same for Earth and neutrinos. No effect results even if the density of neutrinos along the orbit varies.
2. Suppose that the neutrinos are dark in the sense of having gigantic gravitational Planck constant and are in a macroscopically quantum coherent phase de-localized along the entire orbit and described by a wave function (also neutrino Cooper pairs can be considered). If the neutrino ring is exactly circular as Bohr orbit picture suggests and contains Earth's orbit, the thickness of the ring must be at least $d = a - b$, where a and b are major and minor axis. Exact rotational symmetry implies that dark neutrinos are characterized by a phase factor characterizing the angular momentum eigen state in question (the unit of the quantized angular momentum is now very large). Thus neutrino density depends only on the transversal coordinates of the tube and vanishes at the boundary of the tube. Since the Earth's orbit is ellipse, the transversal variation of the neutrino density inside the tube induces periodic variations of the neutrino density in the detector and could explain the effects on radioactive decay rates.

Although the model might explain the time variation of V_b it does not provide any obvious explanation for beta decay rates in general and fails to explain the variation of the alpha decay rate of ^{226}Ra nor the correlation of decay rates with solar flares. Hence it is clear that the model involving only the notion of nuclear string is favored.

3.7.4 Some Other Apparent Anomalies Made Possible By Dark Neutrinos

The appearance of dark neutrinos in the final states of beta decays allow to imagine also some other apparent anomalies.

Apparent anomaly in the inverse beta decay

For the antineutrino belt option one can consider also the possibility of an apparent anomaly in the inverse beta decay in which positron and neutrino are emitted but only electron observed. The apparent anomaly would result from the absorption of a dark antineutrino with repulsive Z^0 interaction energy with condensed matter.

In this case the value of E_0 increases

$$E_0 = M_i - M_f - m(\nu) \rightarrow \hat{E}_0 = M_i - M_f + m(\nu_d) + V_b \ , \quad (3.7.11)$$

which means that positron spectrum extends above the kinematic limit if V_b has the value predicted by the explanation of tritium beta decay anomaly.

A second anomalous situation results if the emitted neutrino transforms to a dark neutrino with negative binding energy. In this case the value of E_0 would change as

$$E_0 \rightarrow \hat{E}_0 = M_i - M_f - m(\nu_d) + V_b \ . \quad (3.7.12)$$

Apparently neutrinoless beta decay and double beta decay

Neutrinoless double beta decay (NDB) is certainly one of the most significant nuclear physics processes from the point of view of unified theories (the popular article of New Scientist [E11] provides a good view of NDB and the recent rather exciting experimental situation). In the standard physics framework NDB can occur only if neutrinos are Majorana neutrinos so that neutrino number is conserved only modulo 2 meaning that neutrino and antineutrino are one and the same particle. Since no antineutrinos are emitted in the NDB, the total energy of the two electrons is larger than in the normal double beta decay, and serves as an experimental signature of the process.

There are several collaborations studying NDB. The team formed by Hans Klapdor-Kleingrothaus and colleagues from the Max Planck Institute for Nuclear Physics in Heidelberg have been studying this process since 1990 in Gran Sasso laboratory. The decays studied are decays of Germanium-76 isotope known to be one of the few isotopes undergoing ordinary double beta decay transforming it into Selenium. The energy of the emitted two electrons is absorbed by the surrounding Ge atoms. The total energy which is larger for NDB decay serves as a signature of the process.

Three years ago came the first paper of the Heidelberg group reporting the observation of 15 NDB decays [C76]. The analysis of the experiments however received a very critical response from colleagues. The Kurchatov Institute quitted the collaboration at 2001 and represented its own analysis with the conclusion that the data do not support NDB. Three years later Heidelberg group represented 14 new candidates for NDB and a new analysis [C77]. It is now admitted that the team is not obviously wrong but that there are still doubts whether the background radioactivity has been handled correctly.

In TGD Universe neutrinos are Dirac neutrinos and NDB is not possible. The possibility of dark neutrinos however allow to consider the possibility of apparently neutrinoless beta decay and double beta decay.

What would happen that the ordinary neutrino emitted in the beta decay of proton transforms into a dark neutrino by mixing. The dark neutrino would not be observed so that apparently neutrinoless beta decay would be in question. Dark neutrino has a negative interaction energy with condensed matter assuming that the explanation of tritium beta decay anomaly is correct so that electron would have an anomalously high energy. The process cannot occur if the negative energy states of the Fermi sea are filled as indeed suggested by energetic considerations.

The generalization of this process would be double beta decay involving strong interaction between decaying neutrons mediated by color bond between them and the transformation of second neutrino to dark neutrino with negative energy so that the electrons would have anomalously high energy. The same objection applies to this process as to the apparently neutrinoless beta decay.

3.8 Cold Fusion And Trojan Horse Mechanism

The model for cold fusion has developed gradually as the understanding of quantum TGD and many-sheeted space-time has developed. Trojan horse mechanism has served as the connecting thread between various models. The last step of progress relates to the new vision about nuclear physics but it is still impossible to fix the model completely unless one poses the condition of minimality and the requirement that single mechanism is behind various anomalies.

3.8.1 Exotic Quarks And Charged Color Bonds As A Common Denominator Of Anomalous Phenomena

There should exist a common denominator for anomalous behavior of water, cold fusion, the findings of Ditmire suggesting cold fusion, sono-fusion, exotic chemistries, strange properties of living matter including chiral selection, and also phenomena like low compressibility of condensed matter which standard physicist would not be worried about.

It seems that compression inducing the generation of charged color bonds between nucleons and leading to a formation of super-nuclei with atomic distances between building blocks might be the sought for common denominator. For super nuclei the repulsive weak interactions between exotic quark and anti-quark belonging to the two bonded nuclei would compensate the attractive color force so that a stable configuration of atomic size would result. Note that the weak coupling strength would be actually strong by the general criterion for transition to the large $\hbar$ phase.

The charging of color bonds would occur via W boson exchange between exotic and valence quarks with exotic W boson transforming to ordinary W via mixing.

The alternative option is a phase transition of nuclei transforming $k = 113$ em space-time sheets of valence quarks to em dark space-time sheets with a large value of $\hbar$ suggested for heavier nuclei by the general criteria. This phase transition could be avoided if the criticality forces surplus protons to transfer the electromagnetic charge of valence quarks to color bonds so that the situation reduces to the first option. In this picture standard nuclear physics would remain almost untouched and nothing new expect exotic quarks and charged color bonds is introduced.

The following examples suggest that this general picture indeed might unify a large class of phenomena.

1. The super-nuclei formed by the dark protons of water would be a basic example about this phenomenon. The occurrence of the process is plausible if also nucleons possess or can generate closed loops with exotic quark and anti-quark at the ends of the loop belonging to the same nucleon. The fact that these protons are dark with respect to electromagnetic interactions suggests that the charge of protons is transferred to the color bonds so that the outcome is a nuclear string formed from neutrons connected by positively charged color bonds. Darkness with respect to weak interactions suggests that valence quarks are doubly dark. This would mean that the p-adic length scale of color bonds would correspond to $k_{eff} = 107+2\times 22 = 151$ for $\hbar_s = n^2\hbar/v_0^2$, $n = 1$. This corresponds to the thickness of cell membrane so that the structure of water would contain information about the basic biological length scale.
2. In condensed matter the super-nuclei would form at some critical pressure when weakly charged color bonds between neighboring nuclei become possible and compensate the attractive color force. This would explain the low compressibility of condensed matter.
3. Bio-polymers in vivo might correspond to super-nuclei connected by charged color bonds whose weak charges would explain the large parity breaking involve with chiral selection. Hydrogen bond might be a basic example of a charged color bond. It could be that the value of integer n in $\hbar_s = n\hbar/v_0$ is $n = 3$ in living matter and $n = 1$ in ordinary condensed matter.

   Trojan horse mechanism might work also at the level of chemistry making possible to circumvent electronic Coulomb wall and might be an essential characteristic of the catalytic action. Note that Pd is also a powerful catalyst. $n = 1$ might however distinguish it from bio-catalysts. In separate context I have dubbed this mechanism as “Houdini effect”.

The reported occurrence of nuclear transmutations [C33, C150] such as $^{23}Na +^{16} O \rightarrow^{39} K$ in living matter allowing growing cells to regenerate elements K, Mg, Ca, or Fe, could be understood as fusion of neighboring nuclei connected by charged color bond which becomes neutral by W emission so that collapse to single nucleus results in absence of the repulsive weak force. Perhaps it is someday possible to produce metabolic energy by bio-fusion or perhaps Nature has already discovered the trick!

4. In cold fusion the nuclei of target D and Pd would combine to form super-nuclei connected by charged color bonds. This would explain why the heavy loading of Pd nuclei with D (for a review of loading process see [C47]) does not generate enormous pressures. Cold fusion would occur in some critical interval of loadings allowing ordinary and exotic nuclei to transform to each other. The transfer of the em charge of D to the color bond connecting D and Pd would make D effectively nn state. Together with the fact that the color bond would have length of order atomic radius would mean that the Coulomb wall of Pd and D is not felt by beam nuclei and Trojan horse mechanism would become possible. The prediction is that Coulomb wall disappears only only when deuterium or tritium target is used. If nuclei can transform to dark em phase cold fusion could occur for arbitrary target nuclei. That it is observed only for D and possibly H does not support this option.

   If valence quarks are doubly dark, their magnetic bodies have size of order $L(151) = 10$ nm, which is also the size scale of the nano-scaled Pd particles, color force would become long ranged. In sono-luminescence and son-fusion and also in nuclear transmutations similar formation of super-nuclei would occur and the collapse of super-nucleus to single nucleus could occur by the proposed mechanism.

5. In the experiments of Ditmire *et al* laser pulse induces very dense phase of Xenon atoms having $Z = 54$ which is heated to energies in which electron energies extend to MeV region and expands rapidly. $Z = 54$ means that Xe satisfies the most stringent condition of criticality for the transition to electromagnetic large $\hbar$ phase. This transition does not occur if protons feed the surplus em charge to the color bonds so that Xe nuclei also weakly charged. Assume that some fraction of Xe is in this kind of phase. The compression of Xe gas by laser pulse compresses Xe super-nuclei. If the connecting charged color bonds emit their em and weak charge by emission of W boson the super-nuclei collapse to single nucleus and nuclear fusion reactions become possible. The repulsive weak force becoming manifest in the compression generates brehmstrahlung heating the system and induces a violent explosion much like in sono-fusion.

In the sequel the experiments Ditmire *et al* and cold fusion are discussed in detail using this model.

Chapter 4

Nuclear String Hypothesis

4.1 Introduction

Nuclear string hypothesis [K103] is one of the most dramatic almost-predictions of TGD [K90]. The hypothesis in its original form assumes that nucleons inside nucleus organize to closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests. The presence of exotic light mesons in nuclei has been proposed also by Illert [C30] based on evidence for charge fractionization effects in nuclear decays.

4.1.1 $A > 4$ Nuclei As Nuclear Strings Consisting Of $A \leq 4$ Nuclei

In the sequel a more refined version of nuclear string hypothesis is developed.

1. The first refinement of the hypothesis is that ^4He nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings instead of nucleons which in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number of ^4He nuclei is maximal. One can hope that even also weak decay characteristics could be reduced to those for $A < 4$ nuclei using this hypothesis.

2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings and that the addition of neutrons tends to reduce Coulomb energy per string length by increasing the length of the nuclear string implying increase binding energy and stabilization of the nucleus. This picture does not explain the variation of binding energy per nucleon and its maximum appearing for ^{56}Fe.

3. In TGD framework tetra-neutron [C81, C25] is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants [K103]. For heavier nuclei tetra-neutron is needed as an additional building brick and the local maxima of binding energy E_B per nucleon as function of neutron number are consistent with the presence of tetra-neutrons. The additivity of magic numbers $2, 8, 20, 28, 50, 82, 126$ predicted by nuclear string hypothesis is also consistent with experimental facts and new magic numbers are predicted [C142, C22].

4.1.2 Bose-Einstein Condensation Of Color Bonds As A Mechanism Of Nuclear Binding

The attempt to understand the variation of the nuclear binding energy and its maximum for Fe leads to a quantitative model of nuclei lighter than Fe as color bound Bose-Einstein condensates of ^4He nuclei or rather, of pion like colored states associated with color flux tubes connecting ^4He nuclei. The crucial element of the model is that color contribution to the binding energy is proportional to n^2 where n is the number of color bonds. Fermi statistics explains the reduction of E_B for the nuclei heavier than Fe. Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand ^4He and lighter nuclei as strings formed from nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$ nuclei, $A = 4$ nuclei and $A < 4$ nuclei are thus involved. The binding energies of also lighter nuclei are predicted surprisingly accurately by applying simple p-adic scaling to the parameters of model for the electromagnetic and color binding energies in heavier nuclei.

4.1.3 Giant Dipole Resonance As De-Coherence Of Bose-Einstein Condensate Of Color Bonds

Giant (dipole) resonances [C4, C56, C93] , and so called pygmy resonances [C123, C91] interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei provide a unique test for the model. The key observation is that the splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy due to the n^2 dependence of the total binding energy. For ^4He de-coherence the model predicts singlet line at 12.74 MeV and triplet (25.48, 27.30,29.12) MeV at ~ 27 MeV spanning 4 MeV wide range which is of the same order as the width of the giant dipole resonance for nuclei with full shells.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in a surprisingly good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet (7.520,8.4600) MeV at ~ 8 MeV is predicted. At least the prediction for the position is correct.

4.1.4 Dark Nuclear Strings As Analogs Of As Analogs Of DNA-, RNA- And Amino-Acid Sequences And Baryonic Realization Of Genetic Code

One biological speculation [K114] inspired by the dark matter hierarchy is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of dark nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of amino-acids coded by a given number of codons are predicted correctly. Hence it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

4.2 Some Variants Of The Nuclear String Hypothesis

The basic assumptions of the nuclear string model could be made stronger in several testable ways. One can make several alternative hypothesis.

4.2.1 Could Linking Of Nuclear Strings Give Rise To Heavier Stable Nuclei?

Nuclear strings (Z_1, N_1) and (Z_2, N_2) could link to form larger nuclei $(Z_1 + Z_2, N_1 + N_2)$. If one can neglect the interactions between linked nuclei, the properties of the resulting nuclei should be determined by those of composites. Linking should however be the confining interaction forbidding the decay of the stable composite. The objection against this option is that it is difficult to characterize the constraint that strings are not allowed to touch and there is no good reason forbidding the touching.

The basic prediction would be that if the nuclei (Z_1, N_1) and (Z_2, N_2) which are stable, very long-lived, or possess exceptionally large binding energy then also the nucleus $(Z_1 + Z_2, N_1 + N_2)$ has this property. If the linked nuclear strings are essentially free then the expectation is that the half-life of a composite of unstable nuclei is that of the shorter lived nucleus. This kind of regularity would have been probably observed long time ago.

4.2.2 Nuclear Strings As Connected Sums Of Shorter NuclearStrings?

Nuclear strings can form connected sum of the shorter nuclear strings. Connected sum means that one deletes very short portions of nuclear string A and B and connects the resulting ends of string A and B together. In other words: A is inserted inside B or vice versa or A and B are cut to open strings and connected and closed again. This outcome would result when A and B touch each other at some point. If touching occurs at several points more complex fusion of nuclei to a larger nucleus to a composite occurs with piece of A followed by a piece of B followed... For this option there is a non-trivial interaction between strings and the properties of nuclei need not be simply additive but one might still hope that stable nuclei fuse to form stable nuclei. In particular, the prediction for the half-life based on binding by linking does not hold true anymore.

Classical picture would suggest that the two strings cannot rotate with respect to each other unless they correspond to rather simple symmetric configurations: this applies also to linked strings. If so then the relative angular momentum L of nuclear strings vanishes and total angular momentum J of the resulting nucleus satisfies $|J_1 - J_2| \leq J \leq J_1 + J_2$.

4.2.3 Is Knotting Of Nuclear Strings Possible?

One can consider also the knotting of nuclear strings as a mechanism giving rise to exotic excitations of nuclear. Knots decompose to prime knots so that kind of prime nuclei identified in terms of prime knots might appear. Fractal thinking suggests an analogy with the poorly understood phenomenon of protein folding. It is known that proteins always end up to a unique highly folded configuration and one might think that also nuclear ground states correspond to unique configurations to which quantum system (also proteins would be such if dark matter is present) ends up via quantum tunnelling unlike classical system which would stick into some valley representing a state of higher energy. The spin glass degeneracy suggests an fractal landscape of ground state configurations characterized by knotting and possibly also linking.

4.3 Could Nuclear Strings Be Connected Sums Of Alpha Strings And Lighter Nuclear Strings?

The attempt to kill the composite string model leads to a stronger formulation in which nuclear string consists of alpha particles plus a minimum number of lighter nuclei. To test the basic predictions of the model I have used the rather old tables of [C137] for binding energies of stable and long-lived isotopes and more modern tables [C12] for basic data about isotopes known recently.

4.3.1 Does The Notion Of Elementary Nucleus Make Sense?

The simplest formulation of the model assumes some minimal set of *stable* "elementary nuclei" from which more complex *stable* nuclei can be constructed.

1. If heavier nuclei are formed by *linking* then alpha particle $^4He = (Z, N) = (2, 2)$ suggests itself as the lightest stable composite allowing interpretation as a closed string. For connected sum option even single nucleon n or p can appear as a composite. This option turns out to be the more plausible one.

2. In the model based on linking $^6Li = (3, 3)$ and $^7Li = (3, 4)$ would also act as "elementary nuclei" as well as $^9Be = (4, 5)$ and $^{10}Be = (4, 6)$. For the model based on connected sum these nuclei might be regarded as composites $^6Li = (3, 3) = (2, 2) + (1, 1)$, $^7Li = (3, 4) = (2, 2) + (1, 2)$, $^9Be = (4, 5) = 2 \times (2, 2) + (0, 1)$ and $^{10}Be = (4, 6) = (2, 2) + 2 \times (1, 2)$. The study of binding energies supports the connected sum option.

3. ^{10}B has total nuclear spin $J = 3$ and $^{10}B = (5, 5) = (3, 3) + (2, 2) =^6 Li +^4 He$ makes sense if the composites can be in relative $L = 2$ state (^6Li has $J = 1$ and ^4He has $J = 0$). ^{11}B has $J = 3/2$ so that $^{11}B = (5, 6) = (3, 4) + (2, 2) =^7 Li +^4 He$ makes sense because ^7Li has $J = 3/2$. For the model based on disjoint linking also 10^B would be also regarded as "elementary nucleus". This asymmetry disfavors the model based on linking.

4.3.2 Stable Nuclei Need Not Fuse To Form Stable Nuclei

The question is whether the simplest model predicts stable nuclei which do not exist. In particular, are the linked ^4He composites stable? The simplest case corresponds to $^8B = (4, 4) =^4 He +^4 He$ which is not stable against alpha decay. Thus stable nuclei need not fuse to form stable nuclei. On the other hand, the very instability against alpha decay suggests that ^4B can be indeed regarded as composite of two alpha particles. A good explanation for the instability against alpha decay is the exceptionally large binding energy $E = 7.07$ MeV per nucleon of alpha particle. The fact that the binding energy per nucleon for ^8Be is also exceptionally large and equal to 7.06 MeV $< E_B(^4He)$ supports the interpretation as a composite of alpha particles.

For heavier nuclei binding energy per nucleon increases and has maximum 8.78 MeV for Fe. This encourages to consider the possibility that alpha particle acts as a fundamental composite of nuclear strings with minimum number of lighter isotopes guaranteeing correct neutron number. Indeed, the decomposition to a maximum number of alpha particles allows a qualitative understanding of binding energies assuming that additional contribution not larger than 1.8 MeV per nucleon is present.

The nuclei ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S, ^{36}A, and ^{40}Ca are lightest stable isotopes of form $(Z, Z) = n \times^4 He$, $n = 3, ..., 10$, for which E_B is larger than for ^4He. For the first four nuclei E_B has a local maximum as function of N. For the remaining the maximum of E_B is obtained for $(Z, Z + 1)$. $^{44}Ti = (22, 22)$ does not exist as a long-lived isotope whereas ^{45}Ti does. The addition of neutron could increase E_B by increasing the length of nuclear string and thus reducing the Coulomb interaction energy per nucleon. This mechanism would provide an explanation also for neutron halos [C133].

Also the fact that stable nuclei in general have $N \geq Z$ supports the view that $N = Z$ state corresponds to string consisting of alpha particles and that $N > Z$ states are obtained by adding something between. $N < Z$ states would necessarily contain at least one stable nucleus lighter than ^4He with smaller binding energy. ^3He is the only possible candidate as the only stable nucleus with $N < Z$. ($E_B(^2H) = 1.11$ MeV and $E_B(^3He) = 2.57$ MeV). Individual nucleons are also possible in principle but not favored. This together with increase of Coulomb interaction energy per nucleon due to the greater density of em charge per string length would explain their smaller binding energy and instability.

4.3.3 Formula For Binding Energy Per Nucleon As A Test For The-Model

The study of ^8B inspires the hypothesis that the total binding energy for the nucleus (Z_1+Z_2, N_1+N_2) is in the first approximation the sum of total binding energies of composites so that one would have for the binding energy per nucleon the prediction

$$E_B = \frac{A_1}{A_1 + A_2} \times E_{B_1} + \frac{A_2}{A_1 + A_2} \times E_{B_2}$$

in the case of 2-nucleus composite. The generalization to N-nucleus composite would be

$$E_B = \sum_k \frac{A_k}{\sum_r A_r} \times E_{B_k} \quad .$$

This prediction would apply also to the unstable composites. The increase of binding energy with the increase of nuclear weight indeed suggests a decomposition of nuclear string to a sequence alpha strings plus some minimum number of shorter strings.

The first objection is that for both Li, B, and Be which all having two stable isotopes, the lighter stable isotope has a slightly smaller binding energy contrary to the expectation based on additivity of the total binding energy. This can be however understood in terms of the reduction of Coulomb energy per string length resulting in the addition of neutron (protons have larger average distance along nuclear string along mediating the electric flux). The reduction of Coulomb energy per unit length of nuclear string could also partially explain why one has $E_B > E_B(^4He)$ for heavier nuclei.

The composition $^6Li = (3,3) = (2,2) + (1,1)$ predicts $E_B \simeq 5.0$ MeV not too far from 5.3 MeV. The decomposition $^7Li = (3,4) = (2,2) + (1,2)$ predicts $E_B = 5.2$ MeV to be compared with 5.6 MeV so that the agreement is satisfactory. The decomposition $^8Be = (4,4) = 2\times\ ^4He$ predicts $E_B = 7.07$ MeV to be compared with the experimental value 7.06 MeV. ^9Be and ^{10}Be have $E_B = 6.46$ MeV and $E_B = 6.50$ MeV. The fact that binding energy slightly increases in addition of neutron can be understood since the addition of neutrons to ^8Be reduces the Coulomb interaction energy per unit length. Also neutron spin pairing reduces E_B. The additive formula for E_B is satisfied with an accuracy better than 1 MeV also for ^{10}B and ^{11}B.

4.3.4 Decay Characteristics And Binding Energies As Signatures Of The Decomposition Of Nuclear String

One might hope of reducing the weak decay characteristics to those of shortest unstable nuclear strings appearing in the decomposition. Alternatively, one could deduce the decomposition from the weak decay characteristics and binding energy using the previous formulas. The picture of nucleus as a string of alpha particles plus minimum number of lighter nuclei ^3He having $E_B = 2.57$ MeV, ^3H unstable against beta decay with half-life of 12.26 years and having $E_B = 2.83$ MeV, and ^2H having $E_B = 1.1$ MeV gives hopes of modelling weak decays in terms of decays for these light composites.

1. β^- decay could be seen as a signature for the presence of ^3H string and alpha decay as a signature for the presence of ^4He string.
2. β^+ decay might be interpreted as a signature for the presence of ^3He string which decays to ^3H (the mass of ^3H is only.018 MeV higher than that of ^3He). For instance, $^8B = (5,3) = (3,2) + (2,1) = {}^5Li +^3 He$ suffers β^+ decay to $^8Be = (4,4)$ which in turn decays by alpha emission which suggests the re-arrangement to $(3,2) + (1,2) \rightarrow (2,2) + (2,2)$ maximizing binding energy.
3. Also individual nucleons can appear in the decomposition and give rise to β^- and possible also β^+ decays.

4.3.5 Are Magic Numbers Additive?

The magic numbers $2, 8, 20, 28, 50, 82, 126$ [C142] for protons and neutrons are usually regarded as a support for the harmonic oscillator model. There are also other possible explanations for magic nuclei and there are deviations from the naïve predictions. One can also consider several different criteria for what it is to be magic. Binding energy is the most natural criterion but need not always mean stability. For instance $^8B = (4,4) =^4 He +^4 He$ has high binding energy but is unstable against alpha decay.

Nuclear string model suggests that the fusion of magic nuclear strings by connected sum yields new kind of highly stable nuclei so that also (Z_1+Z_2, N_1+N_2) is a magic nucleus if (Z_i, N_i) is such. One has $N = 28 = 20 + 8$, $50 = 28 + 20 + 2$, and $N = 82 = 50 + 28 + 2 \times 2$. Also other magic numbers are predicted. There is evidence for them [C22] .

1. $^{16}O = (8,8)$ and $^{40}Ca = (20,20)$ corresponds to doubly magic nuclei and $^{60}Ni = (28,32) = (20,20) + (8,8) +^4 n$ has a local maximum of binding energy as function of neutron number. This is not true for ^{56}Ni so that the idea of magic nucleus in neutron sector is not supported by this case. The explanation would be in terms of the reduction of E_B due to the reduction of Coulomb energy per string length as neutrons are added.
2. Also $^{80}Kr = (36,44) = (36,36) +^4 n = (20,20) + (8,8) + (8,8) +^4 n$ corresponds to a local maximum of binding energy per nucleon as also does $^{84}Kr =^{80} Kr +^4 n$ containing two tetra-neutrons. Note however that $^{88}Zr = (40,48)$ is not a stable isotope although it can be regarded as a composite of doubly magic nucleus and of two tetra-neutrons.

4.3.6 Stable Nuclei As Composites Of Lighter Nuclei And Necessity Of Tetra-Neutron?

The obvious test is to look whether stable nuclei can be constructed as composites of lighter ones. In particular, one can check whether tetra-neutron ^4n interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants is necessary for the understanding of heavier nuclei.

1. $^{48}Ca = (20,28)$ with half-life $> 2 \times 10^{16}$ years has neutron excess of 8 units and the only reasonable interpretation seems to be as a composite of the lightest stable Ca isotope $Ca(20,20)$, which is doubly magic nucleus and two tetra-neutrons: $^{48}Ca = (20,28) =^{40} Ca + 2 \times^4 n$.
2. The next problematic nucleus is ^{49}Ti.

   i) $^{49}Ti = (22,27)$ having neutron excess of 5 one cannot be expressed as a composite of lighter nuclei unless one assumes non-vanishing and large relative angular momentum for the composites. For $^{50}Ti = (22,28)$ no decomposition can be found. The presence of tetra-neutron would reduce the situation to $^{49}Ti = (22,27) =^{45} Ti +^4 n$. Note that ^{45}Ti is the lightest Ti isotope with relatively long half-life of 3.10 hours so that the addition of tetra-neutron would stabilize the system since Coulomb energy per length of string would be reduced.

   ii) ^{48}Ti could not involve tetra-neutron by this criterion. It indeed allows decomposition to standard nuclei is also possible as $^{48}Ti = (22,26) =^{41} K +^7 Li$.

   iii) The heaviest stable Ti isotope would have the decomposition $^{50}Ti =^{46} Ti +^4 n$, where ^{46}Ti is the lightest stable Ti isotope.
3. The heavier stable nuclei $^{50+k}V = (23, 27+k)$, $k = 0,1$, $^{52+k}Cr = (24, 28+k)$, $k = 0,1,2$, $^{55}Mn = (25,30)$ and $^{56+k}Fe = (26, 30+k)$, $k = 0,1,2$ would have similar interpretation. The stable isotopes $^{50}Cr = (24,26)$ and $^{54}Fe = (26,28)$ would not contain tetra-neutron. Also for heavier nuclei both kinds of stable states appear and tetra-neutron would explain this.
4. $^{112}Sn = (50,62) = (50,50) + 3 \times^4 n$, ^{116}Sn, ^{120}Sn, and ^{124}Sn are local maxima of E_B as a function of neutron number and the interpretation in terms of tetra-neutrons looks rather natural. Note that $Z = 50$ is a magic number.

Nuclear string model looks surprisingly promising and it would be interesting to compare systematically the predictions for E_B with its actual values and look whether the beta decays could be understood in terms of those of composites lighter than ^4He.

4.3.7 What Are The Building Blocks Of Nuclear Strings?

One can also consider several options for the more detailed structure of nuclear strings. The original model assumed that proton and neutron are basic building blocks but this model is too simple.

Option Ia)

A more detailed work in attempt to understand binding energies led to the idea that there is fractal structure involved. At the highest level the building blocks of nuclear strings are $A \leq 4$ nuclei. These nuclei in turn would be constructed as short nuclear strings of ordinary nucleons.

The basic objection against the model is the experimental absence of stable $n-n$ bound state analogous to deuteron favored by lacking Coulomb repulsion and attractive electromagnetic spin-spin interaction in spin 1 state. Same applies to tri-neutron states and possibly also tetra-neutron state. There has been however speculation about the existence of di-neutron and poly-neutron states [C2, C9].

The standard explanation is that strong force couples to strong isospin and that the repulsive strong force in nn and pp states makes bound states of this kind impossible. This force, if really present, should correspond to shorter length scale than the isospin independent forces in the model under consideration. In space-time description these forces would correspond to forces mediated between nucleons along the space-time sheet of the nucleus whereas exotic color forces would be mediated along the color magnetic flux tubes having much longer length scale. Even for this option one cannot exclude exotic di-neutron obtained from deuteron by allowing color bond to carry negative em charge. Since em charges $0, 1, -1$ are possible for color bonds, a nucleus with mass number $A > 2$ extends to a multiplet containing $3A$ exotic charge states.

Option Ib)

One might ask whether it is possible to get rid of isospin dependent strong forces and exotic charge states in the proposed framework. One can indeed consider also other explanations for the absence of genuine poly-neutrons.

1. The formation of negatively charged bonds with neutrons replaced by protons would minimize both nuclear mass and Coulomb energy although binding energy per nucleon would be reduced and the increase of neutron number in heavy nuclei would be only apparent.

2. The strongest hypothesis is that mass minimization forces protons and negatively charged color bonds to serve as the basic building bricks of all nuclei. If this were the case, deuteron would be a di-proton having negatively charged color bond. The total binding energy would be only $2.222 - 1.293 = .9290$ MeV. Di-neutron would be impossible for this option since only one color bond can be present in this state.

The small mass difference $m(^3He) - m(^3H) = .018$ MeV would have a natural interpretation as Coulomb interaction energy. Tri-neutron would be allowed. alpha particle would consist of four protons and two negatively charged color bonds and the actual binding energy per nucleon would be by $(m_n - m_p)/2$ smaller than believed. Tetra-neutron would also consist of four protons and the binding energy per nucleon would be smaller by $m_n - m_p$ than what obtains in the standard model of nucleus. Beta decays would be basically beta decays of exotic quarks associated with color bonds.

Note that the mere assumption that the di-neutrons appearing inside nuclei have protons as building bricks means a rather large apparent binding energy this might explain why di-neutrons have not been detected. An interesting question is whether also higher n-deuteron states than ^4He consisting of strings of deuteron nuclei and other $A \leq 3$ nuclei could exist and play some role in the nuclear physics of $Z \neq N$ nuclei.

If protons are the basic building bricks, the binding energy per nucleon is replaced in the calculations with its actual value

$$E_B \quad \rightarrow \quad E_B - \frac{N}{A}\Delta m \ , \ \ \Delta m = m_n - m_p = 1.2930 \ \ MeV \ . \tag{4.3.1}$$

This replacement does not affect at all the parameters of the of $Z = 2n$ nuclei identified as ^4He strings.

One can of course consider also the option that nuclei containing ordinary neutrons are possible but that are unstable against beta decay to nuclei containing only protons and negatively charged bonds. This would suggest that di-neutron exists but is not appreciably produced in nuclear reactions and has not been therefore detected.

Options IIa) and IIb)

It is not clear whether the fermions at the ends of color bonds are exotic quarks or leptons. Lepto-pion (or electro-pion) hypothesis [K115] was inspired by the anomalous e^+e^- production in heavy ion collisions near Coulomb wall and states that electro-pions which are bound states of colored excitations of electrons with ground state mass 1.062 MeV are responsible for the effect. The model predicts that also other charged leptons have color excitations and give rise to exotic counterpart of QCD.

Also μ and τ should possess colored excitations. About fifteen years after this prediction was made, direct experimental evidence for these states finally emerges [C107, C108]. The mass of the new particle, which is either scalar or pseudo-scalar, is 214.4 MeV whereas muon mass is 105.6 MeV. The mass is about 1.5 per cent higher than two times muon mass. The most natural TGD inspired interpretation is as a pion like bound state of colored excitations of muon completely analogous to lepto-pion (or rather, electro-pion) [K115].

One cannot exclude the possibility that the fermion and anti-fermion at the ends of color flux tubes connecting nucleons are actually colored leptons although the working hypothesis is that they are exotic quark and anti-quark. One can of course also turn around the argument: could it be that lepto-pions are "leptonuclei", that is bound states of ordinary leptons bound by color flux tubes for a QCD in length scale considerably shorter than the p-adic length scale of lepton.

Scaling argument applied to ordinary pion mass suggests that the masses of exotic quarks at the ends of color bonds are considerably below MeV scale. One can however consider the possibility that colored electrons with mass of ordinary electron are in question in which case color bonds identifiable as colored variants of electro-pions could be assumed to contribute in the first guess the mass $m(\pi) = 1.062$ MeV per each nucleon for $A > 2$ nuclei. This implies the general replacement

$$\begin{aligned} E_B &\rightarrow E_B + m(\pi_L) - \frac{N}{A}\Delta m \ \text{ for } \ A > 2 \ , \\ E_B &\rightarrow E_B + \frac{m(\pi_L)}{2} - \frac{N}{A}\Delta m \ \text{ for } \ A = 2 \ . \end{aligned} \tag{4.3.2}$$

This option will be referred to as option IIb). One can also consider the option IIa) in which nucleons are ordinary but lepto-pion mass $m(\pi_L) = 1.062$ MeV gives the mass associated with color bond.

These options are equivalent for $N = Z = 2n$ nuclei with $A > 4$ but for $A \leq 4$ nuclei assumed to form nucleon string they options differ.

4.4 Light Nuclei As Color Bound Bose-Einstein Condensates Of ^4He Nuclei

The attempt to understand the variation of nuclear binding energy and its maximum for Fe leads to a model of nuclei lighter than Fe as color bound Bose-Einstein condensates of ^4He nuclei or meson-like structures associated with them. Fractal scaling argument allows to understand ^4He itself as analogous state formed from nucleons.

4.4.1 How To Explain The Maximum Of E_B For Iron?

The simplest model predicts that the binding energy per nucleon equals to $E_B(^4He)$ for all $Z = N = 2n$ nuclei. The actual binding energy grows slowly, has a maximum at ^{52}Fe, and then begins to decrease but remains above $E_B(^4He)$. The following values give representative examples for $Z = N$ nuclei.

For nuclei heavier than Fe there are no long-lived $Z = N = 2n$ isotopes and the natural reason would be alpha decay to ^{52}Fe. If tetra-neutron is what TGD suggests it to be one can guess that tetra-neutron mass is very nearly equal to the mass of the alpha particle. This would allow to regard states $N = Z + 4n$ as states as analogous to unstable states $N_1 = Z_1 = Z + 2n$ consisting of alpha particles. This gives estimate for E_B for unstable $N = Z$ states. For $^{256}Fm = (100, 156)$ one has $E_B = 7.433$ MeV which is still above $E_B(^4He) = 7.0720$ MeV. The challenge is to understand the variation of the binding energy per nucleon and its maximum for Fe.

nucleus	^4He	^8Be	^{40}Ca	^52Fe
E_B/MeV	7.0720	7.0603	8.5504	8.6104

Table 4.1: Representative examples of binding energy

4.4.2 Scaled Up QCD With Bose-Einstein Condensate Of ^4He Nuclei Explains The Growth Of E_B

The first thing to come in mind is that repulsive Coulomb contribution would cause the variation of the binding energy. Since alpha particles are building blocks for $Z = N$ nuclei, ^8Be provides a test for this idea. If the difference between binding energies per nucleon for ^8Be and ^4He were due to Coulomb repulsion alone, one would have $E_c = E_B(^4He) - E_B(^8Be) = .0117$ MeV, which is of order $\alpha_{em}/L(127)$. This would conform with the idea that flux tubes mediating em interaction have length of order electron Compton length. Long flux tubes would provide the mechanism minimizing Coulomb energy. A more realistic interpretation consistent with this mechanism would be that Coulomb and color interaction energies compensate each other: this can of course occur to some degree but it seems safe to assume that Coulomb contribution is small.

The basic question is how one could understand the behavior of E_B if its variation corresponds to that for color binding energy per nucleon. The natural scale of energy is MeV and this conforms with the fact that the range of variation for color binding energy associated with $L(127)$ QCD is about 1.5 MeV. By a naïve scaling the value of M_{127} pion mass is by a factor $2^{(127-107)/2} = 10^{-3}$ times smaller than that of ordinary pion and thus.14 MeV. The scaling of QCD Λ is a more reliable estimate for the binding energy scale and gives a slightly larger value but of the same order of magnitude. The total variation of E_B is large in the natural energy scale of M_{127} QCD and suggests strong non-linear effects.

In the absence of other contributions em and color contributions to E_B cancel for ^8Be. If color and Coulomb contributions on total binding energy depend roughly linearly on the number of ^4He nuclei, the cancellation to E_B should occur in a good approximation also for them. This does not happen which means that color contribution to E_B is in lowest approximation linear in n meaning n^2-dependence of the total color binding energy. This non-linear behavior suggests strongly the presence of Bose-Einstein condensate of ^4He nuclei or structures associated with them. The most natural candidates are the meson like colored strings connecting ^4He nuclei together.

The additivity of n color magnetic (and/or electric) fluxes would imply that classical field energy is n^2-fold. This does not yet imply same for binding energy unless the value of α_s is negative which it can be below confinement length scale. An alternative interpretation could be in terms of color magnetic interaction energy. The number of quarks and anti-quarks would be proportional to n as would be also the color magnetic flux so that n^2- proportionality would result also in this manner.

If the addition of single alpha particle corresponds to an addition of a constant color contribution E_s to E_B (the color binding energy per nucleon, not the total binding energy!) one has $E_B(^{52}Fe) = E_B(^4He)+13E_s$ giving $E_s = .1834$ MeV, which conforms with the order of magnitude estimate given by M_{127} QCD.

The task is to find whether this picture could explain the behavior of E_B. The simplest formula for $E_B(Z = N = 2n)$ would be given by

$$E_B(n) = -\frac{n(n-1)}{L(A)n}k_s + nE_s \ . \tag{4.4.1}$$

Here the first term corresponds to the Coulomb interaction energy of n ^4He nuclei proportional to $n(n-1)$ and inversely proportional to the length $L(A)$ of nuclear string. Second term is color binding energy per nucleon proportional to n.

The simplest assumption is that each ^4He corresponds always to same length of nuclear string so that one has $L \propto A$ and one can write

$$E_B(n) = E_B(^4He) - \frac{n(n-1)}{n^2}E_c + nE_s \ . \tag{4.4.2}$$

The value of $E_B(^8Be) \simeq E_B(^4He)$ $(n = 2)$ gives for the unit of Coulomb energy

$$E_c = 4E_s + 2[E_B(^4He) - E_B(^8Be)] \simeq 4E_s \ . \tag{4.4.3}$$

The general formula for the binding energy reads as

$$\begin{aligned} E_B(n) &= E_B(^4He) - 2\frac{n(n-1)}{n^2}[E_B(^4He) - E_B(^8Be)] \\ &+ [-4\frac{n(n-1)}{n^2} + n]E_s \ . \end{aligned} \tag{4.4.4}$$

The condition that $E_B(^{52}Fe)$ $(n = 13)$ comes out correctly gives

$$E_s = \frac{13}{121}(E_B(^{52}Fe) - E_B(^4He)) + \frac{13 \times 24}{121}[E_B(^4He) - E_B(^8Be)] \ . \tag{4.4.5}$$

This gives $E_s \simeq .1955$ MeV which conforms with M_{127} QCD estimate. For the E_c one obtains $E_c = 1.6104$ MeV and for Coulomb energy of ^4He nuclei in ^8Be one obtains $E = E_c/2 = .8052$ MeV. The order of magnitude is consistent with the mass difference of proton and neutron. The scale suggests that electromagnetic flux tubes are shorter than color flux tubes and correspond to the secondary p-adic length scale $L(2,61) = L(127)/2^{5/2}$ associated with Mersenne prime M_{61}. The scaling factor for the energy scale would be $2^{5/2} \simeq 5.657$.

The calculations have been carried out without assuming which are actual composites of ^4He nuclei (neutrons and protons plus neutral color bonds or protons and neutral and negatively charged color bonds) and assuming the masses of color bonds are negligible. As a matter fact, the mass of color bond does not affect the estimates if one uses only nuclei heavier than ^4He to estimate the parameters. The estimates above however involve ^4He so that small change on the parameters is induced.

4.4.3 Why E_B Decreases For Heavier Nuclei?

The prediction that E_B increases as $(A/4)^2$ for $Z = N$ nuclei is unrealistic since E_B decreases slowly for $A \geq 52$ nuclei. Fermi statistics provides a convincing explanation assuming that fermions move in an effective harmonic oscillator potential due to the string tension whereas free nucleon model predicts too large size for the nucleus. The splitting of the Bose-Einstein condensate to pieces is second explanation that one can imagine but fails at the level of details.

Fermi statistics as a reason for the reduction of the binding energy

The failure of the model is at least partially due to the neglect of the Fermi statistics. For the lighter nuclei description as many boson state with few fermions is expected to work. As the length of nuclear string grows in fixed nuclear volume, the probability of self intersection increases and Fermi statistics forces the wave function for stringy configurations to wiggle which reduces binding energy.

1. For the estimation purposes consider $A = 256$ nucleus ^{256}Mv having $Z = 101$ and $E_B = 7.4241$ MeV. Assume that this unstable nucleus is nearly equivalent with a nucleus consisting of $n = 64$ ^4He nuclei $(Z = N)$. Assuming single color condensate this would give the color contribution

$$E_s^{tot} = (Z/2)^2 \times E_s = 64^2 \times E_s$$

with color contribution to E_B equal to $(Z/2)E_s \simeq 12.51$ MeV.

2. Suppose that color binding energy is canceled by the energy of nucleon identified as kinetic energy in the case of free nucleon model and as harmonic oscillator energy in the case of harmonic oscillator model.

3. The number of states with a given principal quantum number n for both free nucleons in a spherical box and harmonic oscillator model is by spherical symmetry $2n^2$ and the number of protons/neutrons for a full shell nuclei behaves as $N_1 \simeq 2n_{max}^3/3$. The estimate for the average energy per nucleon is given in the two cases as

$$\begin{aligned} \langle E\rangle_H &= 2^{-4/3} \times N^{1/3} E_0 \ , \ E_0 = \omega_0 \ , \\ \langle E\rangle_F &= \frac{2}{5}(\frac{3}{2})^{5/3} N^{2/3} E_0 \ , \ E_0 = \frac{\pi^2}{2m_p L^2} \ . \end{aligned} \tag{4.4.6}$$

   Harmonic oscillator energy $\langle E\rangle_H$ increases as $N^{1/3}$ and $\langle E\rangle_F$ as $N^{2/3}$. Neither of these cannot win the contribution of the color binding energy increasing as N.

4. Equating this energy with the total color binding energy gives an estimate for E_0 as

$$\begin{aligned} E_0 &= (2/3)^{1/3} \times Z^{-4/3} \times (Z/2)^2 \times E_s \ , \\ E_0 &= \frac{5}{4}(\frac{2}{3})^{5/3} \times Z^{-5/3} \times (Z/2)^2 \times E_s \ , \\ E_s &= .1955 \ MeV \ . \end{aligned} \tag{4.4.7}$$

   The first case corresponds to harmonic oscillator model and second to free nucleon model.

5. For the harmonic oscillator model one obtains the estimate $E_0 = \hbar\omega_0 \simeq 2.73 \ MeV$. The general estimate for the energy scale in the harmonic oscillator model given by $\omega_0 \simeq 41 \cdot A^{-1/3}$ MeV [C146] giving $\omega_0 = 6.5$ MeV for $A = 256$ (this estimate implies that harmonic oscillator energy per nucleon is approximately constant and would suggest that string tension tends to reduce as the length of string increases). Harmonic oscillator potential would have roughly twice too strong strength but the order of magnitude is correct. Color contribution to the binding energy might relate the reduction of the oscillator strength in TGD framework.

6. Free nucleon model gives the estimate $E_0 = .0626$ MeV. For the size of a $A = 256$ nucleus one obtains $L \simeq 3.8L(113) \simeq 76$ fm. This is by one order of magnitude larger that the size predicted by the standard formula $r = r_0 A^{1/3}$, $r_0 = 1.25$ fm and 8 fm for $A = 256$.

   Harmonic oscillator picture is clearly favored and string tension explains the origin of the harmonic oscillator potential. Harmonic oscillator picture is expected to emerge at the limit of heavy nuclei for which nuclear string more or less fills the nuclear volume whereas for light nuclei the description in terms of bosonic ^4He nuclei should make sense. For heavy nuclei Fermi statistics at nuclear level would begin to be visible and excite vibrational modes of the nuclear string mapped to the excited states of harmonic oscillator in the shell model description.

Could upper limit for the size of ^4He Bose-Einstein condensate explain the maximum of binding energy per nucleon?

One can imagine also an alternative explanation for why E_B to decrease after $A = 52$. One might that $A = 52$ represents the largest ^4He Bose-Einstein condensate and that for heavier nuclei Bose-Einstein condensate de-coheres into two parts. Bose-Einstein condensate of $n = 13$ ^4He nuclei would the best that one can achieve.

This could explain the reduction of the binding energy and also the emergence of tetra-neutrons as well as the instability of $Z = N$ nuclei heavier than ^{52}Fe. A number theoretical interpretation related to the p-adic length scale hypothesis suggests also itself: as the size of the tangled nuclear string becomes larger than the next p-adic length scale, Bose-Einstein condensate might lose its coherence and split into two.

If one assumes that ^4He Bose-Einstein condensate has an upper size corresponding to $n = 13$, the prediction is that after $A = 52$ second Bose-Einstein condensate begins to form. E_B is obtained as the average

$$E_B(Z,N) = \frac{52}{A} E_B(^{52}Fe) + \frac{A-52}{A} E_B(^{A-52}X(Z,N)) \ .$$

The derivative

$$dE_B/dA = (52/A)[-E_B(^{52}Fe) + E_B(^{A-52}X)] + \frac{A-52}{A} dE_B(^{A-52}X(Z,N))/dA$$

is first negative but its sign must change since the nuclei consisting of two copies of ^{52}Fe) condensates have same E_B as ^{52}Fe). This is an un-physical result. This does not exclude the splitting of Bose-Einstein condensate but the dominant contribution to the reduction of E_B must be due to Fermi statistics.

4.5 What QCD Binds Nucleons To $A \leq 4$ Nuclei?

The obvious question is whether scaled variant(s) of color force could bind nucleons to form $A \leq 4$ nuclei which in turn bind to form heavier nuclei. Since the binding energy scale for ^3He is much smaller than for ^4He one might consider the possibility that the p-adic length scale for QCD associated with ^4He is different from that for $A < 4$ nuclei.

4.5.1 The QCD Associated With Nuclei Lighter Than ^4He

It would be nice if one could understand the binding energies of also $A \leq 4$ nuclei in terms of a scaled variant of QCD applied at the level of nucleons. Here one has several options to test.

Various options to consider

Assume that neutral color bonds have negligible fermion masses at their ends: this is expected if the exotic quarks appear at the ends of color bonds and by the naïve scaling of pion mass. One can also consider the possibility that the p-adic temperature for the quarks satisfies $T = 1/n \leq 1/2$ so that quarks would be massless in excellent approximation. $T = 1/n < 1$ holds true for gauge bosons and one might argue that color bonds as bosonic particles indeed have $T < 1$.

Option Ia): Building bricks are ordinary nucleons.

Option IIa): Building blocks are protons and neutral and negatively charged color bonds. This means the replacement $E_B \rightarrow E_B - \Delta m$ for $A > 2$ nuclei and $E_B \rightarrow E_B - \Delta m/2$ for $A = 2$ with $\Delta m = n_n - m_p = 1.2930$ MeV.

Options Ib and IIb are obtained by assuming that the masses of fermions at the ends of color bonds are non-negligible. Electro-pion mass $m(\pi_L) = 1.062$ MeV is a good candidate for the mass of the color bond. Option Ia allow 3 per cent accuracy for the predicted binding energies. Option IIb works satisfactorily but the errors are below 22 per cent only.

Ordinary nucleons and massless color bonds

It turns out that for the option Ia), ordinary nucleons and massless color bonds, is the most plausible candidate for $A < 4$ QCD is the secondary p-adic length scale $L_e(2,59)$ associated with prime $p \simeq 2^k$, $k = 59$ with $k_{eff} = 2 \times 59 = 118$. The proper scaling of the electromagnetic p-adic length scale corresponds to a scaling factor 2^3 meaning that one has $k_{eff} = 122 \rightarrow k_{eff} - 6 = 116 = 4 \times 29$ corresponding to $L_e(4,29)$.

1. Direct p-adic scaling of the parameters

E_s would be scaled up p-adically by a factor $2^{(127-118)/2} = 2^{9/2}$. E_c would be scaled up by a factor $2^{(122-116)/2} = 2^3$. There is also a scaling of E_c by a factor $1/4$ due to the reduction of charge unit and scaling of both E_c and E_s by a factor $1/4$ since the basic units are now nucleons. This gives

$$\hat{E}_s \ = \ 2^{5/2} E_s = 1.1056 \ \ MeV \ \ , \ \ \hat{E}_c = 2^{-1} E_c = .8056 \ \ MeV \ \ . \tag{4.5.1}$$

The value of electromagnetic energy unit is quite reasonable.

nucleus	^2H	^3H	^3He
$E_B(exp)/MeV$	1.111	2.826	2.572
$E_B(pred_1)/MeV$	1.106	3.317	3.138
$E_B(pred_2)/MeV$	.942	2.826	2.647

Table 4.2: Predictions for the binding energy of the lightest nuclei

The basic formula for the binding energy reads now

$$E_B = -\frac{(n(p)(n(p)-1))}{A^2}\hat{E}_c + n\hat{E}_s \ , \qquad (4.5.2)$$

where $n(p)$ is the number of protons $n = A$ holds true for $A > 2$. For deuteron one has $n = 1$ since deuteron has only single color bond. This delicacy is a crucial prediction and the model fails to work without it.

This gives

$$E_B(^2H) = \hat{E}_s \ , \ E_B(^3H) = 3\hat{E}_s \ , \ E_B(^3He) = -\frac{2}{9}\hat{E}_c + 3\hat{E}_s \ . \qquad (4.5.3)$$

The predictions are given by the third row of **Table 4.2** The predicted values given are too large by about 15 per cent in the worst case.

The reduction of the value of α_s in the p-adic scaling would improve the situation. The requirement that $E_B(^3H)$ comes out correctly predicts a reduction factor.8520 for α_s. The predictions are given in the fourth row of **Table 4.2**. Errors are below 15 per cent.
The discrepancy is 15 per cent for ^2H. By a small scaling of E_c the fit for ^3He can be made perfect. Agreement is rather good but requires that conventional strong force transmitted along nuclear space-time sheet is present and makes *nn* and *pp* states unstable. Isospin dependent strong interaction energy would be only .17 MeV in isospin singlet state which suggests that a large cancelation between scalar and vector contributions occurs. *pnn* and *ppn* could be regarded as Dn and Dp states with no strong force between D and nucleon. The contribution of isospin dependent strong force to E_B is scaled down by a factor 2/3 in $A = 3$ states from that for deuteron and is almost negligible. This option seems to allow an almost perfect fit of the binding energies. Note that one cannot exclude exotic nn-state obtained from deuteron by giving color bond negative em charge.

Other options

Consider next other options.

1. *Option IIb*

For option IIb) the basic building bricks are protons and $m(\pi) = 1.062$ is assumed. The basic objection against this option is that for protons as constituents *real* binding energies satisfy $E_B(^3He) < E_B(^3H)$ whereas Coulombic repulsion would suggest $E_B(^3He) > E_B(^3H)$ unless magnetic spin-spin interaction effects affect the situation. One can however look how good a fit one can obtain in this manner.

As found, the predictions of direct scaling are too large for $E_B(^3H)$ and $E_B(^3He)$ (slight reduction of α_s cures the situation). Since the actual binding energy increases by $m(\pi_L)-(2/3)(m_n-m_p)$ for ^3H and by $m(\pi_L)-(1/3)(m_n-m_p)$ for ^3He, it is clear that the assumption that lepto-pion mass is of order 1 MeV improves the fit. The results are given by **Table 4.3**.
Here $E_B(pred)$ corresponds to the effective value of binding energy assuming that nuclei effectively consist of ordinary protons and neutrons. The discrepancies are below 22 percent.

What is troublesome that neither the scaling of α_s nor modification of E_c improves the situation for ^2H and ^3H. Moreover, magnetic spin-spin interaction energy for deuteron is expected to reduce $E_B(pred)$ further in triplet state. Thus option IIb) does not look promising.

nucleus	^2H	^3H	^3He
$E_B(exp)/MeV$	1.111	2.826	2.572
$E_B(pred)/MeV$	.875	3.117	2.507

Table 4.3: Predictions for the binding energy of lightest nuclei: Option IIb

nucleus	^2H	^3H	^3He
$E_B(act)/MeV$	1.642	3.880	3.634
$E_B(pred)/MeV$	1.3322	3.997	3.743

Table 4.4: Binding energies of the lightest nuclei: Option Ib.

2. *Option Ib)*

For option Ib) with $m(\pi) = 1.062$ MeV and ordinary nucleons the actual binding $E_B(act)$ energy increases by $m(\pi)$ for $A = 3$ nuclei and by $m(\pi)/2$ for deuteron. Direct scaling gives a reasonably good fit for the p-adic length scale $L_e(9,13)$ with $k_{eff} = 117$ meaning $\sqrt{2}$ scaling of E_s. For deuteron the predicted E_B is too low by 30 per cent. One might argue that isospin dependent strong force between nucleons becomes important in this p-adic length scale and reduces deuteron binding energy by 30 per cent. This option is not un-necessary complex as compared to the option Ia).

For option IIa) with $m(\pi) = 0$ and protons as building blocks the fit gets worse for $A = 3$ nuclei.

4.5.2 The QCE Associated With ^4He

^4He must somehow differ from $A \leq 3$ nucleons. If one takes the argument based on isospin dependence strong force seriously, the reasonable looking conclusion would be that ^4He is at the space-time sheet of nucleons a bound state of two deuterons which induce no isospin dependent strong nuclear force. One could regard the system also as a closed string of four nucleons such that neighboring p and n form strong iso-spin singlets. The previous treatment applies as such.

For ^4He option Ia) with a direct scaling would predict $E_B(^4He) < 4 \times \hat{E}_s = 3.720$ MeV which is by a factor of order 2 too small. The natural explanation would be that for ^4He both color and em field body correspond to the p-adic length scale $L_e(4,29)$ ($k_{eff} = 116$) so that E_s would increase by a factor of 2 to 1.860 MeV. Somewhat surprisingly, $A \leq 3$ nuclei would have "color field bodies" by a factor 2 larger than ^4He.

1. For option Ia) this would predict $E_B(^4He) = 7.32867$ MeV to be compared with the real value 7.0720 MeV. A reduction of α_s by 3.5 per cent would explain the discrepancy. That α_s decreases in the transition sequence $k_{eff} = 127 \rightarrow 118 \rightarrow 116$ which is consistent with the general vision about evolution of color coupling strength.
2. If one assumes option Ib) with $m(\pi) = 1.062$ MeV the actual binding energy increases to 8.13 MeV. The strong binding energy of deuteron units would give an additional.15 MeV binding energy per nucleon so that one would have $E_B(^4He) = 7.47$ MeV so that 10 per cent accuracy is achieved. Obviously this option does not work so well as Ia).
3. If one assumes option IIb), the actual binding energy would increase by .415 MeV to 7.4827 MeV which would make fit somewhat poorer. A small reduction of E_c could allow to achieve a perfect fit.

4.5.3 What About Tetra-Neutron?

One can estimate the value of $E_B(^4n)$ from binding energies of nuclei (Z,N) and $(Z,N+4)$ $(A = Z + N)$ as

(Z,N)	(26, 26)(^{52}Fe)	(50, 70)(^{120}Sn)	(82, 124) (^{206}Pb)
$E_B(^4n)/MeV$	6.280	7.3916	5.8031

Table 4.5: Estimate for the binding energy of tetraneutron

k_{eff}	2×59	4×29
$E_B(act)(^4n)/MeV$	3.7680	
$E_{B,app}(4n)/MeV$	4.4135	8.1825

Table 4.6: Another estimate for the binding energy of tetraneutron

$$E_B(^4n) = \frac{A+4}{4}[E_B(A+4) - \frac{A}{A+4}E_B(A)] \ .$$

In **Table 4.5** there are some estimate for $E_B(^4n)$.

The prediction of the above model would be $E(^4n) = 4\hat{E}_s = 3.760$ MeV for $\hat{E}_s = .940$ MeV associated with $A < 4$ nuclei and $k_{eff} = 118 = 2\times 59$ associated with $A < 4$ nuclei. For $k_{eff} = 116$ associated with ^4He $E_s(^4n) = E_s(^4He) = 1.82$ MeV the prediction would be 7.28 MeV. 14 percent reduction of α_s would give the estimated value for of E_s for ^{52}Fe.

If tetra-neutron is ppnn bound state with two negatively charged color bonds, this estimate is not quite correct since the actual binding energy per nucleon is $E_B(^4He) - (m_n - m_p)/2$. This implies a small correction $E_B(A+4) \rightarrow E_B(A+4) - 2(m_n - m_p)/(A+4)$. The correction is negligible.

One can make also a direct estimate of ^4n binding energy assuming tetra-neutron to be ppnn bound state. If the masses of charged color bonds do not differ appreciably from those of neutral bonds (as the p-adic scaling of $\pi + -\pi^0$ mass difference of about 4.9 MeV strongly suggests) then model Ia) with $E_s = E_B(^3H)/3$ implies that the actual binding energy $E_B(^4n) = 4E_s = E_B(^3H)/3$ (see **Table 4.6**). The apparent binding energy is $E_{B,app} = E_B(^4n) + (m_n - m_p)/2$. Binding energy differs dramatically from what one can imagine in more conventional models of strong interactions in which even the existence of tetra-neutron is highly questionable.
The higher binding energy per nucleon for tetra-neutron might directly relate to the neutron richness of heavy nuclei in accordance with the vision that Coulomb energy is what disfavors proton rich nuclei.

According to [C115], tetra-neutron might have been observed in the decay $^8He \rightarrow ^4He + ^4n$ and the accepted value for the mass of ^8He isotope gives the upper bound of $E(^4n) < 3.1$ MeV, which is one half of the estimate. One can of course consider the possibility that free tetra-neutron corresponds to $L_e(2,59)$ and nuclear tetra-neutron corresponds to the length scale $L_e(4,29)$ of ^4He. Also light quarks appear as several p-adically scaled up variants in the TGD based model for low-lying hadrons and there is also evidence that neutrinos appear in several scales.

4.5.4 What Could Be The General Mass Formula?

In the proposed model nucleus consists of $A \leq 4$ nuclei. Concerning the details of the model there are several questions to be answered. Do $A \leq 3$ nuclei and $A = 4$ nuclei ^4He and tetra-neutron form separate nuclear strings carrying their own color magnetic fields as the different p-adic length scale for the corresponding "color magnetic bodies" would suggest? Or do they combine by a connected sum operation to single closed string? Is there single Bose-Einstein condensate or several ones.

Certainly the Bose-Einstein condensates associated with nucleons forming $A < 4$ nuclei are separate from those for $A = 4$ nuclei. The behavior of E_B in turn can be understood if ^4He nuclei and tetra-neutrons form separate Bose-Einstein condensates. For $Z > N$ nuclei poly-protons constructed as exotic charge states of stable $A \leq 4$ nuclei could give rise to the proton excess.

Before continuing it is appropriate to list the apparent binding energies for poly-neutrons and poly-protons.

poly-neutron	n	^2n	^3n	^4n
$E_{B,app}/MeV$	0	$E_B(^2H) + \frac{\Delta}{2}$	$E_B(^3H) + \frac{2\Delta}{3}$	$E_B(^4He) + \frac{\Delta}{2}$
poly-proton	p	^2p	^3p	^4p
$E_{B,app}/MeV$	0	$E_B(^2H) - \frac{\Delta}{2}$	$E_B(^3He) - \frac{\Delta}{3}$	$E_B(^4He) - \frac{\Delta}{2}$

Table 4.7: Apparent binding energies for poly-neutrons and poly-protons

For heavier nuclei $E_{B,app}(^4n)$ is smaller than $E_B(^4He) + (m_p - m_n)/2$.

The first guess for the general formula for the binding energy for nucleus (Z, N) is obtained by assuming that for maximum number of ^4He nuclei and tetra-neutrons/tetra-protons identified as ^4H nuclei with 2 negatively/positively charged color bonds are present.

1. $N \geq Z$ nuclei

Even-Z nuclei with $N \geq Z$ can be expressed as $(Z = 2n, N = 2(n + k) + m)$, $m = 0, 1, 2$ or 3. For $Z \leq 26$ (only single Bose-Einstein condensate) this gives for the apparent binding energy per nucleon (assuming that all neutrons are indeed neutrons) the formula

$$\begin{aligned} E_B(2n, 2(n+k)+m) &= \frac{n}{A}E_B(^4He) + \frac{k}{A}E_{B,app}(^4n) + \frac{1}{A}E_{B,app}(^mn) \\ &+ \frac{n^2+k^2}{n+k}E_s - \frac{Z(Z-1)}{A^2}E_c \ . \end{aligned} \tag{4.5.4}$$

The situation for the odd-Z nuclei $(Z, N) = (2n + 1, 2(n + k) + m)$ can be reduced to that for even-Z nuclei if one can assume that the $(2n + 1)^{th}$ proton combines with 2 neutrons to form ^3He nucleus so that one has still $2(k-1)+m$ neutrons combining to $A \leq 4$ poly-neutrons in above described manner.

2. $Z \geq N$ nuclei

For the nuclei having $Z > N$ the formation of a maximal number of ^4He nuclei leaves k excess protons. For long-lived nuclei $k \leq 2$ is satisfied. One could think of decomposing the excess protons to exotic variants of $A \leq 4$ nuclei by assuming that some charged bonds carry positive charge with an obvious generalization of the above formula.

The only differences with respect to a nucleus with neutron excess would be that the apparent binding energy is smaller than the actual one and positive charge would give rise to Coulomb interaction energy reducing the binding energy (but only very slightly). The change of the binding energy in the subtraction of single neutron from $Z = N = 2n$ nucleus is predicted to be approximately $\Delta E_B = -E_B(^4He)/A$. In the case of ^{32}S this predicts $\Delta E_B = .2209$ MeV. The real value is .2110 MeV. The fact that the general order of magnitude for the change of the binding energy as Z or N changes by one unit supports the proposed picture.

4.5.5 Nuclear Strings And Cold Fusion

To summarize, option Ia) assuming that strong isospin dependent force acts on the nuclear space-time sheet and binds pn pairs to singlets such that the strong binding energy is very nearly zero in singlet state by the cancelation of scalar and vector contributions, is the most promising one. It predicts the existence of exotic di-, tri-, and tetra-neutron like particles and even negatively charged exotics obtained from $^2H,^3H,^3He$, and ^4He by adding negatively charged color bond. For instance, ^3H extends to a multiplet with em charges $1, 0, -1, -2$. Of course, heavy nuclei with proton neutron excess could actually be such nuclei.

The exotic states are stable under beta decay for $m(\pi) < m_e$. The simplest neutral exotic nucleus corresponds to exotic deuteron with single negatively charged color bond. Using this as target it would be possible to achieve cold fusion since Coulomb wall would be absent. The empirical evidence for cold fusion thus supports the prediction of exotic charged states.

Signatures of cold fusion

In the following the consideration is restricted to cold fusion in which two deuterium nuclei react strongly since this is the basic reaction type studied.

In hot fusion there are three reaction types:

1. $D + D \rightarrow^4 He + \gamma$ $(23.8MeV)$
2. $D + D \rightarrow^3 He + n$
3. $D + D \rightarrow^3 H + p$.

The rate for the process 1) predicted by standard nuclear physics is more than 10^{-3} times lower than for the processes 2) and 3) [C48]. The reason is that the emission of the gamma ray involves the relatively weak electromagnetic interaction whereas the latter two processes are strong.

The most obvious objection against cold fusion is that the Coulomb wall between the nuclei makes the mentioned processes extremely improbable at room temperature. Of course, this alone implies that one should not apply the rules of hot fusion to cold fusion. Cold fusion indeed differs from hot fusion in several other aspects.

1. No gamma rays are seen.
2. The flux of energetic neutrons is much lower than expected on basis of the heat production rate an by interpolating hot fusion physics to the recent case.

These signatures can also be (and have been!) used to claim that no real fusion process occurs. It has however become clear that the isotopes of Helium and also some tritium accumulate to the Pd target during the reaction and already now prototype reactors for which the output energy exceeds input energy have been built and commercial applications are under development. Therefore the situation has turned around. The rules of standard physics do not apply so that some new nuclear physics must be involved and it has become an exciting intellectual challenge to understand what is happening. A representative example of this attitude and an enjoyable analysis of the counter arguments against fold fusion is provided by the article "Energy transfer in cold fusion and sono-luminescence" of Julian Schwinger [C113]. This article should be contrasted with the ultra-skeptical article "ESP and Cold Fusion: parallels in pseudoscience" of V. J. [C151] [C151].

Cold fusion has also other features, which serve as valuable constraints for the model building.

1. Cold fusion is not a bulk phenomenon. It seems that fusion occurs most effectively in nano-particles of Pd and the development of the required nano-technology has made possible to produce fusion energy in controlled manner. Concerning applications this is a good news since there is no fear that the process could run out of control.
2. The ratio x of D atoms to Pd atoms in Pd particle must lie the critical range $[.85, .90]$ for the production of ^4He to occur [D55]. This explains the poor repeatability of the earlier experiments and also the fact that fusion occurred sporadically.
3. Also the transmutations of Pd nuclei are observed [C112].

Below a list of questions that any theory of cold fusion should be able to answer.

1. Why cold fusion is not a bulk phenomenon?
2. Why cold fusion of the light nuclei seems to occur only above the critical value $x \simeq .85$ of D concentration?
3. How fusing nuclei are able to effectively circumvent the Coulomb wall?
4. How the energy is transferred from nuclear degrees of freedom to much longer condensed matter degrees of freedom?
5. Why gamma rays are not produced, why the flux of high energy neutrons is so low and why the production of ^4He dominates (also some tritium is produced)?
6. How nuclear transmutations are possible?

Could exotic deuterium make cold fusion possible?

One model of cold fusion has been already discussed in [K103] and the recent model is very similar to that. The basic idea is that only the neutrons of incoming and target nuclei can interact strongly, that is their space-time sheets can fuse. One might hope that neutral deuterium having single negatively charged color bond could allow to realize this mechanism.

1. Suppose that part of the deuterium in Pd catalyst corresponds to exotic deuterium with neutral nuclei so that cold fusion would occur between neutral exotic D nuclei in the target and charged incoming D nuclei and Coulomb wall in the nuclear scale would be absent.
2. The exotic variant of the ordinary $D + D$ reaction yields final states in which ^4He, ^3He and ^3H are replaced with their exotic counterparts with charge lowered by one unit. In particular, exotic ^3H is neutral and there is no Coulomb wall hindering its fusion with Pd nuclei so that nuclear transmutations can occur.

Why the neutron and gamma fluxes are low might be understood if for some reason only exotic ^3H is produced, that is the production of charged final state nuclei is suppressed. The explanation relies on Coulomb wall at the nucleon level.

1. Initial state contains one charged and one neutral color bond and final state $A = 3$ or $A = 4$ color bonds. Additional neutral color bonds must be created in the reaction (one for the production $A = 3$ final states and two for $A = 4$ final state). The process involves the creation of neural fermion pairs. The emission of one exotic gluon per bond decaying to a neutral pair is necessary to achieve this. This requires that nucleon space-time sheets fuse together. Exotic D certainly belongs to the final state nucleus since charged color bond is not expected to be split in the process.
2. The process necessarily involves a temporary fusion of nucleon space-time sheets. One can understand the selection rules if only neutron space-time sheets can fuse appreciably so that only ^3H would be produced. Here Coulomb wall at nucleon level should enter into the game.
3. Protonic space-time sheets have the same positive sign of charge always so that there is a Coulomb wall between them. This explains why the reactions producing exotic ^4He do not occur appreciably. If the quark/antiquark at the neutron end of the color bond of ordinary D has positive charge, there is Coulomb attraction between proton and corresponding negatively charged quark. Thus energy minimization implies that the neutron space-time sheet of ordinary D has positive net charge and Coulomb repulsion prevents it from fusing with the proton space-time sheet of target D. The desired selection rules would thus be due to Coulomb wall at the nucleon level.

About the phase transition transforming ordinary deuterium to exotic deuterium

The exotic deuterium at the surface of Pd target seems to form patches (for a detailed summary see [K103]). This suggests that a condensed matter phase transition involving also nuclei is involved. A possible mechanism giving rise to this kind of phase would be a local phase transition in the Pd target involving both D and Pd. In [K103] it was suggested that deuterium nuclei transform in this phase transition to "ordinary" di-neutrons connected by a charged color bond to Pd nuclei. In the recent case di-neutron could be replaced by neutral D.

The phase transition transforming neutral color bond to a negatively charged one would certainly involve the emission of W^+ boson, which must be exotic in the sense that its Compton length is of order atomic size so that it could be treated as a massless particle and the rate for the process would be of the same order of magnitude as for electro-magnetic processes. One can imagine two options.

1. Exotic W^+ boson emission generates a positively charged color bond between Pd nucleus and exotic deuteron as in the previous model.
2. The exchange of exotic W^+ bosons between ordinary D nuclei and Pd induces the transformation $Z \rightarrow Z + 1$ inducing an alchemic phase transition $Pd \rightarrow Ag$. The most abundant Pd isotopes with $A = 105$ and 106 would transform to a state of same mass but chemically equivalent with the two lightest long-lived Ag isotopes. ^{106}Ag is unstable against β^+ decay

to Pd and ^{105}Ag transforms to Pd via electron capture. For ^{106}Ag (^{105}Ag) the rest energy is 4 MeV (2.2 MeV) higher than for ^{106}Pd (^{105}Pd), which suggests that the resulting silver cannot be genuine.

This phase transition need not be favored energetically since the energy loaded into electrolyte could induce it. The energies should (and could in the recent scenario) correspond to energies typical for condensed matter physics. The densities of Ag and Pd are 10.49 gcm^{-3} and 12.023 gcm^{-3} so that the phase transition would expand the volume by a factor 1.0465. The porous character of Pd would allow this. The needed critical packing fraction for Pd would guarantee one D nucleus per one Pd nucleus with a sufficient accuracy.

Exotic weak bosons seem to be necessary

The proposed phase transition cannot proceed via the exchange of the ordinary W bosons. Rather, W bosons having Compton length of order atomic size are needed. These W bosons could correspond to a scaled up variant of ordinary W bosons having smaller mass, perhaps even of the order of electron mass. They could be also dark in the sense that Planck constant for them would have the value $\hbar = n\hbar_0$ implying scaling up of their Compton size by n. For $n \sim 2^{48}$ the Compton length of ordinary W boson would be of the order of atomic size so that for interactions below this length scale weak bosons would be effectively massless. p-Adically scaled up copy of weak physics with a large value of Planck constant could be in question. For instance, W bosons could correspond to the nuclear p-adic length scale $L_e(k = 113)$ and $n = 2^{11}$.

Few weeks after having written this chapter I learned that cold fusion is in news again: both Nature and New Scientists commented the latest results [C1]. It seems that the emission of highly energetic charged particles which cannot be due to chemical reactions and could emerge from cold fusion has been demonstrated beyond doubt by Frank Cordon's team [C3] using detectors known as CR-39 plastics of size scale of coin used already earlier in hot fusion research. The method is both cheap and simple. The idea is that travelling charged particles shatter the bonds of the plastic's polymers leaving pits or tracks in the plastic. Under the conditions claimed to make cold fusion possible (1 deuterium per 1 Pd nucleus making in TGD based model possible the phase transition of D to its neutral variant by the emission of exotic dark W boson with interaction range of order atomic radius) tracks and pits appear during short period of time to the detector.

4.5.6 Strong Force As A Scaled And Dark Electro-Weak Force?

The fiddling with the nuclear string model has led to following conclusions.

1. Strong isospin dependent nuclear force, which does not reduce to color force, is necessary in order to eliminate polyneutron and polyproton states. This force contributes practically nothing to the energies of bound states. This can be understood as being due to the cancelation of isospin scalar and vector parts of this force for them. Only strong isospin singlets and their composites with isospin doublet (n, p) are allowed for $A \leq 4$ nuclei serving as building bricks of the nuclear strings. Only *effective* polyneutron states are allowed and they are strong isospin singlets or doublets containing charged color bonds.

2. The force could act in the length scalar of nuclear space-time sheets: $k = 113$ nuclear p-adic length scale is a good candidate for this length scale. One must be however cautious: the contribution to the energy of nuclei is so small that length scale could be much longer and perhaps same as in case of exotic color bonds. Color bonds connecting nuclei correspond to much longer p-adic length scale and appear in three p-adically scaled up variants corresponding to $A < 4$ nuclei, $A = 4$ nuclei and $A > 4$ nuclei.

3. The prediction of exotic deuterons with vanishing nuclear em charge leads to a simplification of the earlier model of cold fusion explaining its basic selection rules elegantly but requires a scaled variant of electro-weak force in the length scale of atom.

What is then this mysterious strong force? And how abundant these copies of color and electro-weak force actually are? Is there some unifying principle telling which of them are realized?

From foregoing plus TGD inspired model for quantum biology involving also dark and scaled variants of electro-weak and color forces it is becoming more and more obvious that the scaled up variants of both QCD and electro-weak physics appear in various space-time sheets of TGD Universe. This raises the following questions.

1. Could the isospin dependent strong force between nucleons be nothing but a p-adically scaled up (with respect to length scale) version of the electro-weak interactions in the p-adic length scale defined by Mersenne prime M_{89} with new length scale assigned with gluons and characterized by Mersenne prime M_{107}? Strong force would be electro-weak force but in the length scale of hadron! Or possibly in length scale of nucleus ($k_{eff} = 107+6 = 113$) if a dark variant of strong force with $h = nh_0 = 2^3 h_0$ is in question.
2. Why shouldn't there be a scaled up variant of electro-weak force also in the p-adic length scale of the nuclear color flux tubes?
3. Could it be that all Mersenne primes and also other preferred p-adic primes correspond to entire standard model physics including also gravitation? Could be kind of natural selection which selects the p-adic survivors as proposed long time ago?

Positive answers to the last questions would clean the air and have quite a strong unifying power in the rather speculative and very-many-sheeted TGD Universe.

1. The prediction for new QCD type physics at M_{89} would get additional support. Perhaps also LHC provides it within the next half decade.
2. Electro-weak physics for Mersenne prime M_{127} assigned to electron and exotic quarks and color excited leptons would be predicted. This would predict the exotic quarks appearing in nuclear string model and conform with the 15 year old lepto-hadron hypothesis [K115]. M_{127} dark weak physics would also make possible the phase transition transforming ordinary deuterium in Pd target to exotic deuterium with vanishing nuclear charge.

The most obvious objection against this unifying vision is that hadrons decay only according to the electro-weak physics corresponding to M_{89}. If they would decay according to M_{107} weak physics, the decay rates would be much much faster since the mass scale of electro-weak bosons would be reduced by a factor 2^{-9} (this would give increase of decay rates by a factor 2^{36} from the propagator of weak boson). This is however not a problem if strong force is a dark with say $n = 8$ giving corresponding to nuclear length scale. This crazy conjecture might work if one accepts the dark Bohr rules!

4.6 Giant Dipole Resonance As A Dynamical Signature For the xistence Of Bose-Einstein Condensates?

The basic characteristic of the Bose-Einstein condensate model is the non-linearity of the color contribution to the binding energy. The implication is that the de-coherence of the Bose-Einstein condensate of the nuclear string consisting of ^4He nuclei costs energy. This de-coherence need not involve a splitting of nuclear strings although also this is possible. Similar de-coherence can occur for ^4He $A < 4$ nuclei. It turns out that these three de-coherence mechanisms explain quite nicely the basic aspects of giant dipole resonance (GDR) and its variants both qualitatively and quantitatively and that precise predictions for the fine structure of GDR emerge.

4.6.1 De-Coherence At The Level Of ^4He Nuclear String

The de-coherence of a nucleus having n ^4He nuclei to a nucleus containing two Bose-Einstein condensates having $n-k$ and $k > 2$ ^4He nuclei requires energy given by

$$\begin{aligned}
\Delta E &= (n^2-(n-k)^2-k^2)E_s = 2k(n-k)E_s \ , \quad k>2 \ , \\
\Delta E &= (n^2-(n-2)^2-1)E_s = (4n-5)E_s \ , \quad k=2 \ , \\
E_s &\simeq .1955 \ MeV \ .
\end{aligned} \tag{4.6.1}$$

Bose-Einstein condensate could also split into several pieces with some of them consisting of single ^4He nucleus in which case there is no contribution to the color binding energy. A more general formula for the resonance energy reads as

final state	3+1	2+2	2+1+1	1+1+1+1
$\Delta E/MeV$	1.3685	2.7370	2.9325	3.1280

Table 4.8: The resonance energies for four ways of ^{16}O nucleus ($n = 4$) to lose its coherence.

final state	3+1	2+2	2+1+1	1+1+1+1
$\Delta E/MeV$	12.74	25.48	27.30	29.12

Table 4.9: Resonance energies for the four options $n \rightarrow \sum_i n_i$ for the loss of coherence.

$$\begin{aligned} \Delta E &= (n^2 - \sum_i k^2(n_i))E_s \ , \ \sum_i n_i = n \ , \\ k(n_i) &= \begin{cases} n_i \ \text{for} \ n_i > 2 \ , \\ 1 \ \text{for} \ n_i = 2 \ , \\ 0 \ \text{for} \ n_i = 1 \ . \end{cases} \end{aligned} \tag{4.6.2}$$

Table 4.8 lists the resonance energies for four ways of ^{16}O nucleus ($n = 4$) to lose its coherence. Rather small energies are involved. More generally, the minimum and maximum resonance energy would vary as $\Delta E_{min} = (2n-1)E_s$ and $\Delta E_{max} = n^2 E_s$ (total de-coherence). For $n = n_{max} = 13$ one would have $\Delta E_{min} = 2.3640$ MeV and $\Delta E_{max} = 33.099$ MeV.

Clearly, the loss of coherence at this level is a low energy collective phenomenon but certainly testable. For nuclei with $A > 60$ one can imagine also double resonance when both coherent Bose-Einstein condensates possibly present split into pieces. For $A \geq 120$ also triple resonance is possible.

4.6.2 De-Coherence Inside ^4He Nuclei

One can consider also the loss of coherence occurring at the level ^4He nuclei. Predictions for resonances energies and for the dependence of GR cross sections on mass number follow.

Resonance energies

For ^4He nuclei one has $E_s = 1.820$ MeV. In this case de-coherence would mean the decomposition of Bose-Einstein condensate to $n = 4 \rightarrow \sum n_i = n$ with $\Delta E = n^2 - \sum_{n_i} k^1(n_i) = 16 - \sum_{n_i} k^2(n_i)$. **Table 4.9** gives the resonance energies for the four options $n \rightarrow \sum_i n_i$ for the loss of coherence.

These energies span the range at which the cross section for $^{16}O(\gamma, xn)$ reaction has giant dipole resonances [C4]. Quite generally, GDR is a broad bump with substructure beginning around 10 MeV and ranging to 30 MeV. The average position of the bump as a function of atomic number can be parameterized by the following formula

$$E(A)/MeV = 31.2A^{-1/3} + 20.6A^{-1/6} \tag{4.6.3}$$

given in [C56]. The energy varies from 36.6 MeV for $A = 4$ (the fit is probably not good for very low values of A) to 13.75 MeV for $A = 206$. The width of GDR ranges from 4-5 MeV for closed shell nuclei up to 8 MeV for nuclei between closed shells.

The observation raises the question whether the de-coherence of Bose-Einstein condensates associated with ^4He and nuclear string could relate to GDR and its variants. If so, GR proper would be a collective phenomenon both at the level of single ^4He nucleus (main contribution to the resonance energy) and entire nucleus (width of the resonance). The killer prediction is that even ^4He should exhibit giant dipole resonance and its variants: GDR in ^4He has been reported [C97].

Some tests

This hypothesis seems to survive the basic qualitative and quantitative tests.

1. The basic prediction of the model peak at 12.74 MeV and at triplet of closely located peaks at $(25.48, 27.30, 29.12)$ MeV spanning a range of about 4 MeV, which is slightly smaller than the width of GDR. According to [C93] there are two peaks identified as iso-scalar GMR at $13.7 \pm .3$ MeV and iso-vector GMR at 26 ± 3 MeV. The 6 MeV uncertainty related to the position of iso-vector peak suggests that it corresponds to the triplet $(25.48, 27.30, 29.12)$ MeV whereas singlet would correspond to the iso-scalar peak. According to the interpretation represented in [C93] iso-scalar *resp.* iso-vector peak would correspond to oscillations of proton and neutron densities in same *resp.* opposite phase. This interpretation can make sense in TGD framework only inside single ^4He nucleus and would apply to the transverse oscillations of ^4He string rather than radial oscillations of entire nucleus.
2. The presence of triplet structure seems to explain most of the width of iso-vector GR. The combination of GDR internal to ^4He with GDR for the entire nucleus (for which resonance energies vary from $\Delta E_{min} = (2n-1)E_s$ to $\Delta E_{max} = n^2 E_s$ $(n = A/4)$) predicts that also latter contributes to the width of GDR and give it additional fine structure. The order of magnitude for ΔE_{min} is in the range [1.3685, 2.3640] MeV which is consistent with the with of GDR and predicts a band of width 1 MeV located 1.4 MeV above the basic peak.
3. The de-coherence of $A < 4$ nuclei could increase the width of the peaks for nuclei with partially filled shells: maximum and minimum values of resonance energy are $9E_s(^4He)/2 = 8.19$ MeV and $4E_s(^4He) = 7.28$ MeV for ^3He and ^3H which conforms with the upper bound 8 MeV for the width.
4. It is also possible that n ^4He nuclei simultaneously lose their coherence. If multiplet de-coherence occurs coherently it gives rise to harmonics of GDR. For de-coherent de-coherence so that the emitted photons should correspond to those associated with single ^4He GDR combined with nuclear GDR. If absorption occurs for $n \leq 13$ nuclei simultaneously, one obtains a convoluted spectrum for resonant absorption energy

$$\Delta E = [16n - \sum_{j=1}^{n} \sum_{i_j} k^2(n_{i_j})]E_s \ . \tag{4.6.4}$$

   The maximum value of ΔE given by $\Delta E_{max} = n \times 29.12$ MeV. For $n = 13$ this would give $\Delta E_{max} = 378.56$ MeV for the upper bound for the range of excitation energies for GDR. For heavy nuclei [C56] GDR occurs in the range 30-130 MeV of excitation energies so that the order of magnitude is correct. Lower bound in turn corresponds to a total loss of coherence for single ^4He nucleus.
5. That the width of GDR increases with the excitation energy [C56] is consistent with the excitation of higher GDR resonances associated with the entire nuclear string. $n \leq n_{max}$ for GDR at the level of the entire nucleus means saturation of the GDR peak with excitation energy which has been indeed observed [C4] (see **Fig. 4.1**).

One can look whether the model might work even at the level of details. Figure 3 of [C4] compares total photoneutron reaction cross sections for $^{16}O(\gamma, xn)$ in the range 16-26 MeV from some experiments so that the possible structure at 12.74 MeV is not visible in it. It is obvious that the resonance structure is more complex than predicted by the simplest model. It seems however possible to explain this.

1. The main part of the resonance is a high bump above 22 MeV spanning an interval of about 4 MeV just as the triplet at (25.48, 27.30, 29.12) MeV does. This suggest a shift of the predicted 3-peak structure in the range 25-30 MeV range downwards by about 3 MeV. This happens if the photo excitation inducing the de-coherence involves a dropping from a state with excitation energy of 3 MeV to the ground state. The peak structure has peaks roughly at the shifted energies but there is also an additional structure which might be understood in terms of the bands of width 1 MeV located 1.4 MeV above the basic line.

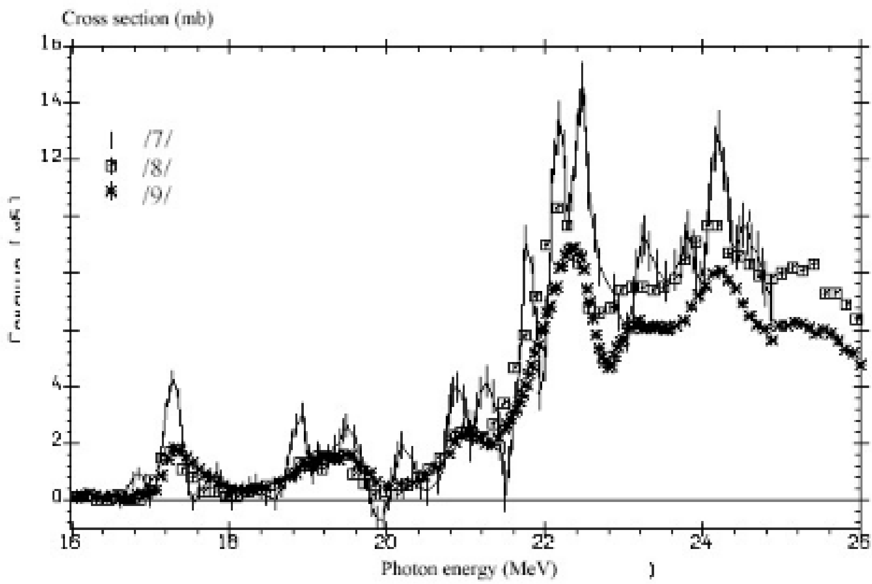

Figure 4.1: The comparison of photoneutron cross sections $^{16}O(\gamma, xn)$ obtained in one BR-experiment (Moscow State University) and two QMA experiments carried out at Saclay (France) Livermoore (USA). Figure is taken from [C4] where also references to experiments can be found.

2. There are three smaller bumps below the main bump which also span a range of 4 MeV which suggests that also they correspond to a shifted variant of the basic three-peak structure. This can be understood if the photo excitation inducing de-coherence leads from an excited state with excitation energy 8.3 MeV to ground state shifting the resonance triplet (25.48, 27.30, 29.12) MeV to resonance triplet at (17.2, 19.00, 20.82) MeV.

On basis of these arguments it seems that the proposed mechanism might explain GR and its variants. The basic prediction would be the presence of singlet and triplet resonance peaks corresponding to the four ways to lose the coherence. Second signature is the precise prediction for the fine structure of resonance peaks.

Predictions for cross sections

The estimation of collision cross sections in nuclear string model would require detailed numerical models. One approach to modelling would be to treat the colliding nuclear strings as random coils with finite thickness defined by the size of $A \leq 4$ strings. The intersections of colliding strings would induce fusion reactions and self intersections fissions. Simple statistical models for the intersections based on geometric probability are possible and allow to estimate branching ratios to various channels.

In the case of GR the reduction to ^4He level means strong testable predictions for the dependence of GR cross sections on the mass number. GR involves formation of eye-glass type configuration at level of single ^4He and in the collision of nuclei with mass numbers A_1 and A_2 GR means formation of these configurations for some $A = 4$ unit associated with either nucleus. Hence the GR cross section should be in a reasonable approximation proportional to $n_1 + n_2$ where n_i are the numbers of $A = 4$ sub-units, which can be either ^4He, tetra-neutron, or possible other variants of ^4He having charged color bonds. For $Z_i = 2m_i$, $N = 2n_i$, $A_i = 4(m_i + n_i)$ nuclei one has $n_1 + n_2 = (A_1 + A_2)/4$. Also a characteristic oscillatory behavior as a function of A is expected if the number of $A = 4$ units is maximal. If GR reactions are induced by the touching of ^4He units of nuclear string implying transfer of kinetic energy between units then the GR cross sections should depend only on the energy per ^4He nucleus in cm system, which is also a strong prediction.

4.6.3 De-Coherence Inside $A = 3$ Nuclei And Pygmy Resonances

For neutron rich nuclei the loss of coherence is expected to occur inside ^4He, tetra-neutron, ^3He and possibly also ^3n which might be stable in the nuclear environment. The de-coherence of tetra-neutron gives in the first approximation the same resonance energy spectrum as that for ^4He since $E_B(^4n) \sim E_B(^4He)$ roughly consistent with the previous estimates for $E_B(^4n)$ implies $E_s(^4n) \sim E_s(^4He)$.

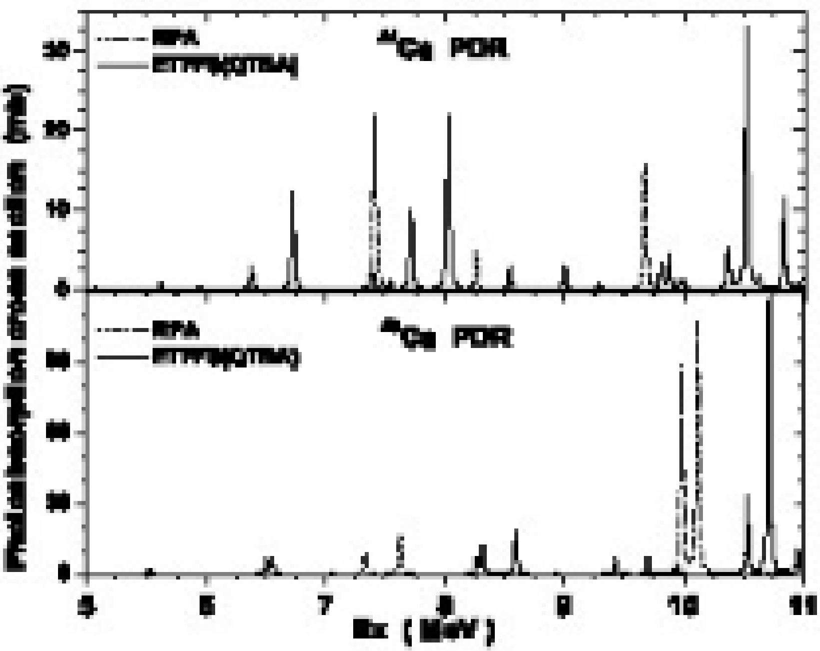

Figure 4.2: Pygmy resonances in ^{44}Ca and ^{48}Ca up to 11 MeV. Figure is taken from [C91].

The de-coherence inside $A = 3$ nuclei might explain the so called pygmy resonance appearing in neutron rich nuclei, which according to [C123] is wide bump around $E \sim 8$ MeV. For $A = 3$ nuclei only two de-coherence transitions are possible: $3 \rightarrow 2{+}1$ and $3 \rightarrow 1{+}1{+}1$ and $E_s = E_B(^3H) = .940$ MeV the corresponding energies are $8E_s = 7.520$ MeV and $9 * Es = 8.4600$ MeV. Mean energy is indeed ~ 8 MeV and the separation of peaks about 1 MeV. The de-coherence at level of ^4He string might add to this 1 MeV wide bands about 1.4 MeV above the basic lines.

The figure of [C91] (see **Fig. ??**) illustrating photo-absorption cross section in ^{44}Ca and ^{48}Ca shows three peaks at 6.8, 7.3, 7.8 and 8 MeV in ^{44}Ca. The additional two peaks might be assigned with the excitation of initial or final states. This suggests also the presence of also $A = 3$ nuclear strings in ^{44}Ca besides $^H4$ and ^4n strings. Perhaps neutron halo wave function contains $^3n + n$ component besides ^4n. For ^{48}Ca these peaks are much weaker suggesting the dominance of $2{\times}^4n$ component.

4.6.4 De-Coherence And The Differential Topology Of Nuclear Reactions

Nuclear string model allows a topological description of nuclear decays in terms of closed string diagrams and it is interesting to look what characteristic predictions follow without going to detailed quantitative modelling of stringy collisions possibly using some variant of string models.

In the de-coherence eye-glass type singularities of the closed nuclear string appear and make possible nuclear decays.

1. At the level of ^4He sub-strings the simplest singularities correspond to $4 \rightarrow 3+1$ and $4 \rightarrow 2+2$ eye-glass singularities. The first one corresponds to low energy GR and second to one of higher energy GRs. They can naturally lead to decays in which nucleon or deuteron is emitted in decay process. The singularities $4 \rightarrow 2+1+1$ *resp.* $4 \rightarrow 1+1+1+1$ correspond to eye-glasses with 3 *resp.* four lenses and mean the decay of ^4He to deuteron and two nucleons *resp.* 4 nucleons. The prediction is that the emission of deuteron requires a considerably larger excitation energy than the emission of single nucleon. For GR at level of $A = 3$ nuclei analogous considerations apply. Taking into account the possible tunnelling of the nuclear strings from the nuclear space-time sheet modifies this simple picture.
2. For GR in the scale of entire nuclei the corresponding singular configurations typically make possible the emission of alpha particle. Considerably smaller collision energies should be able to induce the emission of alpha particles than the emission of nucleons if only stringy excitations matter. The excitation energy needed for the emission of α particle is predicted to increase with A since the number n of ^4He nuclei increases with A. For instance, for $Z = N = 2n$ nuclei $n \rightarrow n-1+1$ would require the excitation energy $(2n-1)E_c = (A/2-1)E_c$, $E_c \simeq .2$ MeV. The tunnelling of the alpha particle from the nuclear space-time sheet can modify the situation.

The decay process allows a differential topological description. Quite generally, in the decoherence process $n \rightarrow (n-k)+k$ the color magnetic flux through the closed string must be reduced from n to $n-k$ units through the first closed string and to k units through the second one. The reduction of the color color magnetic fluxes means the reduction of the total color binding energy from n^2E_c $((n-k)^2+k^2)E_c$ and the kinetic energy of the colliding nucleons should provide this energy.

Faraday's law, which is essentially a differential topological statement, requires the presence of a time dependent color electric field making possible the reduction of the color magnetic fluxes. The holonomy group of the classical color gauge field $G^A_{\alpha\beta}$ is always Abelian in TGD framework being proportional to $H^AJ_{\alpha\beta}$, where H^A are color Hamiltonians and $J_{\alpha\beta}$ is the induced Kähler form. Hence it should be possible to treat the situation in terms of the induced Kähler field alone. Obviously, the change of the Kähler (color) electric flux in the reaction corresponds to the change of (color) Kähler (color) magnetic flux. The change of color electric flux occurs naturally in a collision situation involving changing induced gauge fields.

4.7 Nuclear anomalies

4.7.1 Individual Nucleons Inside Nuclei Do Not Behave According To Predictions

Accordingto popular article individual nucleons do not behave in nuclei as the existing theory predicts (see `http://tinyurl.com/yclmkzyp`). This is a conclusion reached by an international team of scientists which has published their findings as article article (see `http://tinyurl.com/ycryxjza`) in Phys. Rev. Letters).

I am not a nuclear physicists but have proposed what I call nuclear string model [L4]. Therefore I have good motivations for trying to understand what has been found and what nuclear string model can say about the findings.

Background And Results

There are many models of atomic nuclei and each of them explains some aspects of nucleus. Nucleus can be modelled rigid body or as a kind of quantum liquid. In the prevailing average field approach the presence of other nucleons is described in terms of a potential function and calculates the states of individual nucleons in this potential using Schrödinger equation. It is essential that nucleons are assumed to be independent.

The model taking potential function to be that of harmonic oscillator is surprisingly successful but one must introduce corrections such as spin-orbit coupling in order to understand the energy spectrum. In this approach the notion of nuclear shell emerges. In atomic physics and chemistry the closed shells do not participate to the interaction and the outermost shell characterized by valence dictates to a higher degree the chemical properties of atom. Valence is positive if outer shell contains particles. Valence if negative if some of them are lacking. Something similar is to be expected also now. In this case full shells correspond to magic numbers for protons and neutrons separately (note that protons and neutrons seem to behave rather independently, something highly non-trivial!). The nuclei with valence +1 or -1 would correspond to almost magic nuclei.

One generally accepted correction to the harmonic oscillator model is inspired by the assumption that heavier nuclei can be described as a kind of blob of condensed matter obeying equation of state allowing to introduce notions like acoustic waves and surface waves. The nucleon at the unfilled shell would reside at the surface of this blob. The blob has vibrational excitations characterized by multipolarity (spherical harmonic characterized by angular momentum quantum numbers and the radial part of the oscillation amplitude. These excitations give rise to analogs of surface waves in water. Valence nucleons interact with the oscillations and affect the energy levels of the valence nucleons. The predictions of this model are calculable.

The team has studied almost doubly magic nuclei with valence equal to plus or -1 and calculated the effects on the energy levels of the nucleon and found that the observed effects are significantly smaller than the predicted ones. This finding challenges both the mean field approach or the idea that nucleus can be idealized as a condensed matter like system or both.

Nuclear String Model

In TGD framework ordinary model of nucleus is replaced with what I call nuclear string model [L4].

1.Core ideas of nuclear string model

The core idea of nuclear string model is that the nucleons are ordered to a string like structure.

1. Nuclei consist of string like objects: protons and neutrons connected by color magnetic flux tubes form string like objects, perhaps separately. The color magnetic flux tubes would would be meson-like objects and could even carry net color. They are either neutral (quark and antiquark at the ends of flux tube have opposite charges) or carry em charge. What "meson-like" does mean is not completely trivial. Quark anti-quark pair connected by a flux tube is what comes in mind.

   Quarks correspond in TGD to closed flux tubes with length of order Compton length of quark traversing through two wormhole contacts and connecting them by monopole flux tubes at parallel space-time sheets. The first wormhole contact has quark quantum numbers and the second one those of a neutrino pair compensating for weak axial isospin of the quark. The compensating weak axial isospin for quark and antiquark would have opposite sign so that they are not necessary in the meson-like state. Does flux tube connect these flux tube structures or is there only single closed flux tube so that quarks would lose half of their identity.

   This predicts a large number of exotic states. The exotic states cannot be distinguished chemically from the isotopes of the nucleus. The hypothesis is that the energy scale of the excitations is in keV range and their existence explains the annual variation of nuclear decay rates which seems to be caused by X rays from Sun [C74].

   This would be new nuclear physics and perhaps relevant also to the cold fusion. The energy scale would derive from the string tension of the color magnetic flux tube. The lengths of the color magnetic flux tubes corresponding to keV scale would be rather long and correspond color magnetic bodies of the nucleons. If this is the case then the color magnetic energy of the system would depend only weakly on the positions of the nucleons of string inside nuclear volume. This assumption might allow to understand the anomalous finding that the charge radius of proton is smaller than predicted [K67].

   The presence of long flux tubes might allow to understand the anomalous finding that the charge radius of proton is smaller than predicted. u and d quarks are known to be light and have masses in the range 5-20 MeV. The TGD based model for elementary particles [K67] suggests that quarks correspond to closed flux tubes consisting of two portions at parallel space-time sheets with ends connected by wormhole contacts and with monopole magnetic flux rotating in the tube. Uncertainty principle suggests that the length of the flux tube structure is of the order of Compton length of the quark. The constituents of proton would be larger than proton itself! The paradox disappears if the Compton length is assigned with the magnetic flux tube connecting the two wormhole contacts associated with quark and rather near to each other and much shorter than the flux tube.

Flux tubes with Compton lengths corresponding to 10 keV photon energy would be however 3 orders of magnitude longer (10 nm). This could be due to the scaling by $h_{eff}/h \sim 10^3$. These flux tubes could also correspond to the flux tubes connecting neighboring nucleons of nuclear strings. The dark magnetic flux tubes of this length associated with neighboring nuclei could reconnect and bind nuclei to form lattice like structures. This process and thus dark nuclear physics could play a key role in in the formation of condensed matter phases as it is proposed to play also in living matter.

2. These strings of nucleons could topologically condense at larger magnetic flux tubes but could still touch also the nuclear spacetime sheet as suggested by the success of harmonic oscillator model. In biological length scales the assumption that effective Planck constant characterizing dark matter phase equals $h_{eff} = n \times h$ equals to gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where v_0 is a parameter with dimensions of velocity, implies that cyclotron frequencies are universal (no dependence on particle mass m) but also implies that particles with different masses correspond to different value of effective Planck constant so that living system would perform spectroscopy putting particles (elementary particles, atoms, ions, molecules, ..) neatly at different dark space-time sheets! If the nucleons inside nuclei are dark in this sense protons and neutrons would be at different flux tubes since their masses are slightly different.

3. Nucleus could consist of several - possibly knotted - closed flux tubes containing some number of nucleons each. An attractive hypothesis is that these flux tubes correspond to nuclear shells so that full flux tubes would correspond to full shells and define separate units. In semiclassical approximation this would mean that nuclear string is localized at the surface of sphere.

2. Could one regard nuclear string at sphere as Hamiltonian cycle?

Nuclear string means the introduction of additional structure to the many-nucleon state. One can consider the addition of even further additional structure, which is purely topological. This addition has not been considered in the earlier variant of the model and might well be unnecessary.

1. If the vertices of nuclear string at sphere define in a natural manner polyhedron, then nuclear string defines a closed non-intersecting curve going through the with n vertices of this polyhedron known as Hamilton cycle (see `http://tinyurl.com/2e5gz45`). If color magnetic flux tubes are long, it is convenient to consider a curve defined by line segments connecting the neighboring nucleons of the nuclear string.

   The notion of Hamilton cycle is well-defined for any graph so that it makes sense for any polyhedron. It is enough that the cycle is consistent with the underlying graph structure allowing to say which vertices are nearest neighbours (they need not be neighbours in the metric sense but only in the sense of homology that is ends of the same edge).

2. Graph structure however requires that one assumes graph structure involving not only vertices and edges connecting them but also faces which in homology theory are most naturally triangles (2-simplices). Faces are clearly an additional structure as also nuclear string in the framework of standard nuclear physics. If the state of nucleus is analogous to that of molecule with nucleons having almost fixed positions homology emerges in natural manner but for independent particle model situation is far from clear. Could one identify the 2-simplexes of the homology associated with a non-intersecting curve consisting of segments uniquely from the condition that the additional edges do not intersect at sphere? Already the example of square in plane shows that the additional edge can be either diagonal.

3. In the case of Platonic solids the rotational symmetries preserving Platonic solid generate finite number of Hamilton cycles of same shape from a given one and it is natural to define Hamilton cycles as equivalence classes of cycles with same shape. For instance, for icosahedron one has 17 Hamilton cycles and for 11 cycles one has symmetry group Z_n, $n \in 6, 4, 2$ and the cycles obtained from them by rotations. In this case one can however say that independent

particle approximation is given up and one considers equilibrium configurations analogous to those of molecules. Nuclear string however orders the nucleons and brings in additional information. Hamilton cycles make sense also for the deformations of icosahedron since it is only the homological nearness that matters. Note however that the allowed deformations of metric Hamilton cycle must be such that the edges do not intersect: in other words the deformation of nuclear string is not self intersecting.

4. If the nucleons can perform only small oscillations around the vertices of a polyhedron, independent particle assumption fails badly. One would however have collective wave function for orientations of the polyhedron. In this case Platonic solids or their homological generalization define good candidates for full shells.

How Does Nuclear String Model Relate To The Shell Model?

In the mean field approximation particles move independently in a potential describing the effects of the other nucleons. The basis for N-nucleon wave functions can be constructed as products of those associated with individual nucleons. The natural question is under what conditions nuclear string model is consistent with independent particle model.

3. What does the consistency of nuclear string model with independent particle model imply?

Quite generally, the consistency with independent particle approach requires that the nuclear string property does not contribute much to the energy of the states.

1. At classical level the independent motion of nucleons (along elliptic orbits in harmonic oscillator approximation) of the nuclear string would give rise to a rather complex motion of nuclear string leading to self intersections unless the flux tubes have much longer length scale than the nucleus. In this case nucleus would be like seed from which flux tubes would emerge like a plant and self intersections could be avoided but the motion of nucleons could induce local braiding of the strands emanating from nucleons. This is indeed what has been assumed. Note that the U shaped flux tubes connecting neighboring nucleons could reconnect with the similar tubes associated with other nuclei so that the motions of nucleons would give rise to genuine global braiding.

2. Harmonic oscillator states would induce wave function in the space of string configurations having interpretation as Hamilton cycles associated with polyhedron with N vertices whose positions can vary, also in the radial direction although semiclassical shell model would force particles at the same radius. TGD allows to consider a collective localization at spherical shells: this would be rather long range correlation but consistent with the spirit of shell model. A more general approximation would be the localization to a union of spherical shells associated with the maxima of modulus of the radial wave function.

3. In independent particle model basis wave functions are products. This is not consistent with the assumption that nucleons arrange to form a string unless the nearest neighbour nucleons at string can have arbitrary angular distance along the sphere: this would hold true exactly at the limit of vanishing string tension.

   The longer the angular distance, the higher the color magnetic energy of the string. This energy would give rise to correlations inducing the mixing of harmonic oscillator wave functions. This would be the minimal breaking of independent particle approximation and would describe possibly new kind of nuclear forces between neighboring nucleons of the nuclear string as color magnetic forces.

   If the color magnetic interaction corresponds to MeV scale, the length scale of the flux tubes is electron's Compton length and even in this case considerably longer than nuclear radius and independent particle approximation would not be badly broken. In this case the interpretation in terms of strong force might make sense. Even for the flux tubes which length of order Compton length for u and d quarks the flux tubes are much longer than the distance between nucleons.

   If the energy scale of exotic nuclei is 1-10 keV as the variation of the nuclear decay rates seemingly induced by the variations of X ray flux from Sun suggests, the color magnetic energy would be rather small and independent particle approximation would even better than in previous case. This is expected to be the case if the color magnetic flux tubes correspond to the length scale assignable to 1-10 keV scale and thus long so that the positions of nucleons inside nucleus do not matter. 10 keV scale would in fact correspond to photon wavelength about 1 Angstrom - size of atom - so that a new interaction between nuclear and atomic physics is predicted. Note that classical and quantal pictures are consistent with each other.

4. Independent particle model allows the nucleons with same quantum numbers to be in same position. This means self-intersection for nuclear string. Two-nucleon configuration space is $S^2 \times S^2$ and self-intersections occur in diagonal S^2 so that they are very rare and one could perhaps allow them when quantum numbers are different. Fermi statistics takes care that self-intersections do not take for nucleons with identical quantum numbers and also that the probability density for almost self-intersections is small. What is nice that Fermi statistics have geometric correlate int hat it would guarantee the absence of self-intersections in this strong sense if nucleons of given kind with given spin arrange on nuclear string so that one would have the analog of spontaneous magnetization. One would have four-kinds of strings corresponding to different directions of spin and strong isospin.

4. Semiclassical considerations

One can consider the situation also semi-classically.

1. Nuclear shells correspond in the Bohr model based on harmonic oscillator potential to spheres with radii fixed by Bohr's quantization rules. Wave functions are indeed concentrated also around the classical radius but for principal quantum number n one obtains $n+1$ local maxima (see `http://tinyurl.com/y7lasev8`). The wave function at given shell would be localized at $n+1$ surfaces rather than single surface, which is definitely a non-classical aspect. The probability density however concentrates mostly to the shell with the largest radius so that for large values of n the semiclassical approximation becomes better.

   One can of course ask, whether this picture contains deeper seed of truth expressible in terms of space-time topology. This would conform with the TGD based idea that matter resides on geometric shells: this idea is suggested already by the model for a final state of star [K14] predicting that mass is concentrated on shell. In many-sheeted space-time one expects an onion-like structure made of these shells.

   The TGD based proposal is that in solar system planets would be accompanied by this kind of dark matter shells with radii predicted approximately by Bohr rules. TGD based explanation for Pioneer and Flyby anomalies [K96] predicts the same surface density of dark matter at these shells as deduced for the effective surface density of dark matter in the case of galactic nucleus. Of course, nucleons inside nuclei cannot correspond to dark matter unless the value of $h_{eff}/n = n$ is small. Otherwise the size of nucleus would be too large.

2. In the semiclassical approximation the radii of the sphere at which the vertices of polyhedron are located would correspond to the radii of nuclear shells. An approximation in which one treats the angular degrees of freedom quantally using independent particle model and radial degree of freedom collectively looks reasonable and would allow to keep the rotational symmetries but would mean giving up the additional symmetries making if possible to solve harmonic oscillator model exactly. With this assumption nuclear strings would reside at spheres.

5. Could magic numbers be understood in terms of Platonic solids?

Harmonic oscillator model predicts the numbers of nucleons for magic nuclei (see `http://tinyurl.com/yd9t7pkg`) as sums of numbers of nucleons for the full shells involved but the predictions are not quite correct. One can however modify the model to get the observed magic numbers. This explanation is based on dynamics and slightly broken symmetries and arguably more convincing than explanations relying on elementary geometry.

Still one can ask whether these numbers could be consistent with the idea that a full shell corresponds to a Platonic solid such that closed nuclear string, which can connect only neighboring vertices goes through its vertices without intersecting itself?

1. Icosahedral and tetrahedral Platonic cycles are in a key role in TGD inspired vision about bio-harmony predicting that DNA sequences have interpretation as sequences of 3-chords of what I call bio-harmony realizing genetic code [K87].

   One can also consider replacing metric Platonic solid with combinatorial objects in which neighboring vertices are defined to be ends of the same edge which can be rather long. This option is consistent with independent particle model in angular degrees of freedom. In this case however the addition of 2-simplexes (triangles) is not unique so that it seems that the Platonic cycles are expected to be natural only for molecule like states.

2. If the polyhedron defined by the positions of nucleons can be interpreted as Platonic solid (cube, octahedron, tetrahedron, icosahedron, dodecahedron) the number of nucleons at given shell would be equal the number of vertices of the Platonic solid. One can of course consider more complex scenarios. One could consider adding nucleons also to the centers of edges and faces and even superpose different Platonic solids associated with the same sphere. Same Platonic solid could also appear as scaled variants.

3. One could consider building the nuclei by adding new spherical layers gradually and assuming that the nucleons are at the vertices (one could consider also putting them in the centers of the faces). The lowest magic numbers are 2, 8, 20, 28, 50, 82, 126, 184 and are reproduced if shells have $n = 2, 6, 12, 8, 22, 32, 44, 58$. In the standard approach one can say that each oscillator wave function corresponds to two spin directions so that the proper number to consider would be $m = n/2$. The values of m would be be $m = 1, 3, 6, 4, 11, 16, 22, 29$.

   If nuclear string contains only nucleons with given spin direction, the integers m are the numbers that one should explain: this option is strictly speaking the more convincing one. If nuclear string contains nucleons with both spin directions, one must explain the integers $n = 2 \times m$.

   Note that protons and neutrons can be assumed to belong to different nuclear strings.

Could one understand the integers m or n in terms of Platonic solids?

1. $m = 1$ would correspond to the nucleon at origin, where modulus of wave function has maximum. $m = 3$ would correspond to triangle. $m = 6$ could be interpreted in terms of octahedron, and $m = 4$ in terms of tetrahedron. The larger values of m would require constructions which look artificial.

2. $n = 2$ would correspond to line segment with 2-vertices. n=6 would correspond to octahedron. n=12 would correspond to icosahedron. $n = 8$ would correspond to cube. Note that tetrahedron, the only self-dual Platonic solid, predicting $n = 4$ is missing fron the list. Also dodecahedron with $n = 20$ is missing. $n = 22$ would require articial looking constructions.

These findings would suggest that the independent particle model is not a good approximation for light nuclei for which a model as a molecule like entity with rather rigid position of nucleons might be considered if Platonic solids are taken as metric objects. If one is not willing to give up so easily, one could argue that the exotic states in which some color bonds between nucleons are charged change the apparent numbers of neutrons and protons: one would have only apparently $n = 22$ rather than $n = 20$. For double magic nuclei the sum of the anomalous looking magic numbers would be however 20+20: say 22 protons and 18 neutrons.

The Experimental Findings From TGD Point Of View?

On basis of the experimental findings it is far from clear whether one can model nuclei as objects characterized by continuous nucleon densities and obeying some thermodynamical equation of state from which the dynamics describing the oscillations of nucleon densities can be deduced.

1. Suppose that nuclear shells make in TGD framework sense also as geometric objects, that is as (say) spherical space-time sheets containing the nuclear string for which the nucleons at vertices behave independently in angular degrees of freedom. In this kind of model the approximation as condensed matter blob is not the thing that comes first into mind. It would be like modelling of solar system by replacing planets by introducing planet density and oscillations of this density.

2. If the shell contains only single particle, the collective wave function for the radius of the sphere associated with shell co-incides with single particle wave function. In this case one cannot say that the particle is at the surface of nucleus.

3. There is no direct interaction with the oscillations of the full shell in the lowest order since the shells correspond to different space-time sheets. The interaction is only in terms of potential functions assignable to the large space-time sheet.

4.7.2 GSI Anomaly

"Jester" wrote a nice blog posting titled *Hitchhikers-guide-to-ghosts-and-spooks in particle physics* summarizing quite a bundle of anomalies of particle physics and also one of nuclear physics-known as GSI anomaly. The abstract of the article *Observation of Non-Exponential Orbital Electron Capture Decays of Hydrogen-Like* ^{140}*Pr and* ^{142}*Pm Ions* [C39] describing the anomaly is here.

We report on time-modulated two-body weak decays observed in the orbital electron capture of hydrogen-like ^{140}*Pr¡sup¿59+¡/sup¿ and* ^{142}*Pm¡sup¿60+¡/sup¿ ions coasting in an ion storage ring. Using non-destructive single ion, time-resolved Schottky mass spectrometry we found that the expected exponential decay is modulated in time with a modulation period of about 7 seconds for both systems. Tentatively this observation is attributed to the coherent superposition of finite mass eigenstates of the electron neutrinos from the weak decay into a two-body final state.*

This brings in mind the nuclear decay rate anomalies which I discussed earlier in the blog posting *Tritium beta decay anomaly and variations in the rates of radioactive processes* and in [K103]. These variations in decay rates are in the scale of year and decay rate variation correlates with the distance from Sun. Also solar flares seem to induce decay rate variations.

The TGD based explanation [K103] relies on nuclear string model in which nuclei are connected by color flux tubes having exotic variant quark and antiquark at their ends (TGD predicts fractal hierarchy of QCD like physics). These flux tubes can be also charged: the possible charges $\pm 1, 0$. This means a rich spectrum of exotic states and a lot of new low energy nuclear physics. The energy scale corresponds to Coulomb interaction energy $\alpha_{em}m$, where m is mass scale of the exotic quark. This means energy scale of 10 keV for MeV mass scale. The well-known poorly understood X-ray bursts from Sun during solar flares in the wavelength range 1-8 A correspond to energies in the range 1.6-12.4 keV -3 octaves in good approximation- might relate to this new nuclear physics and in turn might excite nuclei from the ground state to these excited states and the small mixture of exotic nuclei with slightly different nuclear decay rates could cause the effective variation of the decay rate. The mass scale $m \sim 1$ MeV for exotic quarks would predict Coulomb energy of order $\alpha_{em}m$ which is of order 10 keV.

The question is whether there could be a flux of X rays in time scale of 7 seconds causing the rate fluctuation by the same mechanism also in GSI experiment. For instance, could this flux relate to synchrotron radiation. I could no identify any candidate for this periodicity from the article. In any case, the prediction is what might be called X ray nuclear physics and artificial X ray irradiation of nuclei would be an easy manner to kill or prove the general hypothesis.

One can imagine also another possibility.

1. The first guess is that the transitions between ordinary and exotic states of the ion are induced by the emission of exotic W boson between nucleon and exotic quark so that the charge of the color bond is changed. In standard model the objection would be that classical W fields do not make sense in the length scale in question. The basic prediction deriving from induced field concept (classical ew gauge fields correspond to the projection of CP_2 spinor curvature to the space-time surface) is however the existence of classical long range gauge fields- both ew and color. Classical W field can induce charge entanglement in all length scales and one of the control mechanisms of TGD inspired quantum biology relies on remote control of charge densities in this manner. Also the model of cold fusion could involve similar oscillating time like entanglement allowing the bombarding nucleus to penetrate to the nucleus when proton has transformed to neuron in good approximation and charge is de-localized to the color bond having much larger size.

2. In the approximation that one has two-state system, this interaction can be modelled by using as interaction Hamiltonian hermitian non-diagonal matrix V, which can be written as $V\sigma_x$, where σ_x is Pauli sigma matrix. If this process occurs coherently in time scales longer than

$\hbar/V$, an oscillation with frequency $\omega = V/\hbar$ results. Since weak interactions are in question 7 second modulation period might make sense.

The hypothesis can be tested quantitatively.

1. The weak interaction Coulomb potential energy is of form

$$\frac{V(r)}{\hbar} = \alpha_W \frac{exp(-m_W r)}{r} \ , \tag{4.7.1}$$

where r is the distance between nucleon center of mass and the end of color flux tube and therefore of order proton Compton length r_p so that one can write

$$r = x \times r_p \ .$$

where x should be of order unity but below it.

2. The frequency $\omega = 2\pi/\tau = V/\hbar$ must correspond to 14 seconds, twice the oscillation period of the varying reaction rate. By taking W boson Compton time t_W as time unit this condition can be written as

$$\begin{array}{l} \frac{\alpha_W exp(-y)}{y} = \frac{t_W}{\tau} \ , \\ y = x\frac{r_p}{r_W} = x\frac{m_W}{m_p} \simeq 80 \times x \ , \\ \alpha_W = \alpha_{em}/sin^2\theta_W \ . \end{array}$$

3. This gives the condition

$$\frac{exp(-y)}{y} = \frac{t_p}{\tau} \times \frac{sin^2\theta_W}{80 \times \alpha_{em}} \ . \tag{4.7.2}$$

This allows to solve y since the left hand side is known. Feeding in proton Compton length $r_p = 1.321 \times 10^{-15}$ m and $sin^2\theta_W = .23$ one obtains that the distance between flux tube end and proton cm is $x = .6446$ times proton Compton length, which compares favorably with the guess $x \simeq 1$ but smaller than 1. One must however notice that the oscillation period is exponentially sensitive to the value of x. For instance, if the charge entanglement were between nucleons, $x > 1$ would hold true and the time scale would be enormous. Hence the simple model requires new physics and predicts correctly the period of the oscillation under very reasonable assumptions.

4. One could criticize this by saying that the masses of two states differ by amount which is of order 10 keV or so. This does not however affect the argument since the mass corresponds to the diagonal non-interaction part of the Hamiltonian contributing only rapidly oscillating phases whereas interaction potential induces oscillating mixing as is easy to see in interaction picture.

5. If one believes in the hierarchy of Planck constants and p-adically scaled variants of weak interaction physics, charge entanglement would be possible in much longer length scales and the time scale of it raises the question whether qubits could be realized using proton and neutron in quantum computation purposes. I have also proposed that charge entanglement could serve as a mechanism of bio-control allowing to induce charge density gradients from distance in turn acting as switches inducing biological functions.

So: it happened again! Again I have given a good reason for my learned critics to argue that TGD explains everything so that I am a crackpot and so on and so on. Well... after a first feeling of deep shame I dare to defend myself. In the case of standard model explanatory power has not been regarded as an argument against the theory but my case is of course different since I do not have any academic position since my fate is to live in the arctic scientific environment of Finland. And if my name were Feynman, this little argument would be an instant classic. But most theoreticians are just little opportunists building their career and this does not leave much room for intellectual honesty.

4.7.3 New Evidence For Anomalies Of Radio-Active Decay Rates

Lubos Motl (see `http://tinyurl.com/y7tgqzsr`) told about new evidence for periodic variations of nuclear decay rates reported by Sturrock *et al* in their article *Analysis of Gamma Radiation from a Radon Source: Indications of a Solar Influence* (see `http://tinyurl.com/d9ymwm3`) [C89]. The abstract of the article summarizes the results.

This article presents an analysis of about 29, 000 measurements of gamma radiation associated with the decay of radon in a sealed container at the Geological Survey of Israel (GSI) Laboratory in Jerusalem between 28 January 2007 and 10 May 2010. These measurements exhibit strong variations in time of year and time of day, which may be due in part to environmental influences. However, time-series analysis reveals a number of periodicities, including two at approximately 11.2 year^{-1} and 12.5 year^{-1}. We have previously found these oscillations in nuclear-decay data acquired at the Brookhaven National Laboratory (BNL) and at the Physikalisch-Technische Bundesanstalt (PTB), and we have suggested that these oscillations are attributable to some form of solar radiation that has its origin in the deep solar interior. A curious property of the GSI data is that the annual oscillation is much stronger in daytime data than in nighttime data, but the opposite is true for all other oscillations. This may be a systematic effect but, if it is not, this property should help narrow the theoretical options for the mechanism responsible for decay-rate variability.

Quantitative summary of findings

The following gives a brief quantitative summary of the findings. Radioactive decays of nuclei have been analyzed in three earlier studies and also in the recent study.

1. BNL data are about ^{36}Cl and ^{32}Si nuclei. Strong day-time variation in month time scale was observed. Two frequency bands ranging from 11.0 to 11.2 year^{-1} and from 12.6 to 12.9 year^{-1} were observed.
2. PTB data are about ^{226}Ra nuclei. Also now strong day-time variation was observed with frequency bands ranging from 11.0 to 11.3 year^{-1} and from 12.3 to 12.5 year^{-1}.
3. GIS data are about ^{222}Ra nuclei. Instead of strong day-time variation a strong night-time variation was observed. Annual oscillation was centered on mid-day. 2 year^{-1} is the next strongest feature. Also a night time feature with a peak at 17 hours was observed. There are also features at 12.5 year^{-1} and 11.2 year^{-1} and 11.9 year^{-1}. All these three data sets lead to oscillations in frequency bands ranging from 11.0 to 11.4 year^{-1} and from 12.1 to 12.9 year^{-1}.
4. Bellotti *et al* studied ^{137}Cl nuclei deep underground in Gran Sasso. No variations were detected.

Could exotic nuclear states explain the findings?

The TGD based new physics involved with the effect could relate to the excitations of exotic nuclear states induced by em radiation arriving from Sun. This would change the portions of various excited nuclei with nearly the same ground state energy and affect the average radio-active decay rates.

1. The exotic nuclei emerge in the model of nucleus as a nuclear string with nucleons connected by color flux tubes having quark and antiquark at ends [L4]. The excitations could be also involved with cold fusion. For the normal nuclei color flux tubes would be neutral but one can consider also excitations for which quark pair carries a net change $\pm e$. This would give rise to a large number of nuclei with same em charge and mass number but having actually abnormal proton and neutron numbers. If the energy differences for these excitations are in keV range they might represent a fine structure of nuclear levels not detected earlier.

   Could these exchanges take place also between different nuclei? For instance, could it be that in the collision of deuterium nuclei the second nucleus can be neutralized by the exchange of scaled down W boson leading to neutralization of second deuterium nucleus so that Coulomb wall could disappear and make possible cold nuclear reaction. It seems that the range of this scaled variant of weak interaction is quite too short. M_{127} variant of weak interactions with W boson mass very near to electron mass could make possible this mechanism.

2. The exchange of weak bosons could be responsible for generating these excitations: in this case two neutral color bonds would become charged with opposite charges. If one takes seriously the indications for 38 MeV new particle [C51], one can even consider a scaled variant of weak interaction physics with weak interaction length scale given by a length scale near hadronic length scale [K50]. Another explanation is as scaled down version on pion: the p-adic scaling factor would correspond to $k \rightarrow k - 4$ giving downwards scaling by factor 1/4 to pion mass.

Em radiation from Sun inducing transitions of ordinary nuclei to their exotic counterparts could be responsible for the variation of the radio-active decay rates. If course, exotic nuclei in the above sense are only one option and the following argument below applies quite generally.

Kinetic model for the evolution for the number of excited nuclei

A simple model for the evolution of the number of excited nuclei is as follows:

$$\begin{aligned} \frac{dN}{dt} &= kJ - k_1 N \quad \text{for} \quad t \in [t_0, t_1] \quad , \\ \frac{dN}{dt} &= -k_1 N \quad \text{for} \quad t \in [t_1, t_0 + T] \quad . \end{aligned} \tag{4.7.3}$$

J denotes the flux of incoming radiation and N the number of excited nuclei. t_0 corresponds to the time of sunrise and t_1 to the time of sunset and T is 24 hours in the approximation that sun rises at the same time every morning. The time evolution of $N(t)$ is given by

$$\begin{aligned} N(t) &= \frac{k}{k_1} J + (N(t_0) - \frac{k}{k_1} J) exp\left[-k_1(t - t_0)\right] \quad \text{for} \quad t \in [t_0, t_1] \quad , \\ N(t) &= N(t_1) exp\left[-k_1(t - t_1)\right] \quad \text{for} \quad t \in [t_1, t_0 + T] \quad . \end{aligned} \tag{4.7.4}$$

Explanation for the basic features of the data

The model can explain the qualitative features of the data rather naturally.

1. The period of 1 year obviously correlates with the distance from Sun..5 year period correlates with the fact that the distance from Sun is minimal twice during a year. Day-time night-time difference can be explained with the fact that em radiation at night-time does not penetrate Earth. This explains also why Gran Sasso in deep underground observes nothing.
2. The large long time scale variation for the day-time data for BNL and PTB seems to be in apparent contrast with that for the night-dime data at GIS. It is however possible to understand the difference.
   (a) If the rate parameter k_1 is large, one can understand why variations are strong at day-time in BNL and BTB. For large value of k_1 $N(t)$ increases rapidly to its asymptotic value $N_{max} = kJ/k_1$ and stays in it during day so that day-time variations due to solar distance are large. At night-time $N(t)$ rapidly decreases to zero so that night-time variation due to the variation of the solar distance is small.
   (b) For GIS the strong variation is associated with the night-dime data. This can be understood in terms of small value of k_1 which can be indeed smaller for ^{226}Ra than for the nuclei used in the other studies. During daytime $N(t)$ slowly increases to its maximum at $N(t_1)$ and decreases slowly during night-time. Since $N(t_1)$ depends on the time of the year, the night-time variation is large.
   (c) The variations in time scales of roughly the time scale of month should be due to the variations in the intensity of the incoming radiation. The explanation (see `http://tinyurl.com/d9ymwm3`) suggested in [C89] is that the dynamics of solar core has these periodicities manifested also as the periodicities of the emission of radiation at the frequencies involved. These photons would naturally correspond to the photons emitted in

the transitions between excited states of nuclei in the solar core or possibly in solar corona having temperature of about 300 eV. One could in fact think that the mysterious heating of solar corona (see `http://tinyurl.com/y988fs8b`) [E1] to a temperature of 3 million K could be due to the exotic excitations of the nuclei by radiation coming from Sun. At this temperature the maximum of black body distribution with respect to frequency corresponds to energy of.85 keV consistent with the proposal that the energy scale for excitations is keV.

(d) The difference of frequencies 12.49 year^{-1} and 11.39 year^{-1} is in good approximation 1 year^{-1}, which suggests modulation of the average frequencies with a period of year being due to the rotation of Earth around Sun. The average frequency is 11.89 year^{-1} that is 1/month. The explanation proposed in the article is in terms of rotation velocity of the inner core which would be smaller but same order of magnitude as that of outer core (frequency range from 13.7 to 14.7 year^{-1}). It is however not plausible that the keV photons could propagate from the inner core of Sun unless they are dark in TGD sense. In TGD framework it would be natural to assign the frequency band to solar Corona.

Can one assign the observed frequency band to the rotation of solar corona?

The rotation frequency band assignable to photosphere is too high by about $\Delta f = 3$ year^{-1} as compared to that appearing in decay rate variation. Could one understand this discrepancy?

1. One must distinguish between the synodic rotation frequency f_S measured in the rest system of Sun and the rotation frequency observed in Earth rotating with frequency $f = 1$ year^{-1} around Sun: these frequencies relate by $f_E = f_S - f$ giving frequency range 12.7 to 13.7 year^{-1}. This is still too high by about $\Delta f = 2$ year^{-1}.

2. Could corona rotate slower than photosphere? The measurements by Mehta (see `http://tinyurl.com/ycqcn7ta`) [E34] give the value range 22 - 26.5 days meaning that the the coronal synodic frequency f_C would be in the range 14.0-16.6 year^{-1}. The range of frequencies observed at Earth would be 13-15.6 year^{-1} and too high by about $\Delta = 2$ year^{-1}.

   If I have understood correctly, the coronal rotational velocity is determined by using solar spots as markers and therefore refers to the magnetic field rather than the gas in the corona. Could the rotation frequency of the gas in corona be about $\Delta f = 2$ year^{-1} lower than that for the magnetic spots?

One can develop a theoretical argument in order to understand the rotational periods of photosphere and corona and why they could differ by about $\Delta f = 2$ year^{-1}.

1. Suppose that one can distinguish between the rotation frequencies of magnetic fields (magnetic body in many-sheeted space-time) and gas. Suppose that photosphere (briefly "P") and corona (briefly "C") can be treated in the first approximation as rigid spherical shells having thus moment of inertia $I = (2/3)mR^2$ around the rotational axis. The angular momentum per unit mass is $dL/dm = (2/3)R^2\omega$. Suppose that the value of dL/dm is same for the photosphere and Corona. If the rotation velocity magnetic fields determined from magnetic spots is same as the rotation velocity of gas in corona, this implies $f_C/f_P = (R_S/R_C)^2$, where R_S is solar radius identifiable as the radius of photosphere. The scaling of 13 year^{-1} down to 11 year^{-1} would require $R_C/R_S \simeq 1.09$. This radius should correspond to the hottest part of the corona at temperature about 1-2 million K.

   The inner solar corona (see `http://tinyurl.com/ya8vbdfv`) extends up to $(4/3)R_S$. This would give average radius of the inner coronal shell about $1.15R_S$. The constancy of $dL/dm(R)$ would give a differential rotation with frequency varying as $1/R^2$. If the frequency band reflects the presence of differential rotation, one has $R_{max}/R_{min} \simeq (f_{max}/f_{min})^{1/2} \simeq (15/13)^{1/2} \simeq$ 1.07.

2. One can understand why angular momentum density per mass is constant if one accepts a generalization of the Bohr quantization of planetary orbits (see `http://tinyurl.com/yawof8yt`) originally proposed by Nottale and based on the notion of gravitational Planck constant $\hbar_{gr}$ [K96, K78]. One has $\hbar_{gr} = GMm/v_0$ and is assigned with the flux sheets mediating gravitational interaction between Sun and the planet or some other astrophysical object near Sun. The dependence on solar mass and planetary mass is is fixed by Equivalence Principle. v_0 has

dimensions of velocity and therefore naturally satisfies $v_0 < c$. For the 4 inner planets one has $v_0/c \simeq 2^{-11}$. Angular momentum quantization gives $mR^2\omega = n\hbar_{gr}$ giving $R^2\omega = nGM/v_0$ so that the angular momentum per mass is integer valued. For the 4 inner planets n has values 3, 4, 5, 6.

3. One could argue that for the photosphere and corona regarded as rigid bodies a similar quantization holds true but with the same vale of n since the radii are so near to each other. Also v_0 should be larger. Consider first photosphere. One can apply the angular momentum quantization condition to photosphere approximate as a spherical shell and rigid body. $I\omega_P = nGmM/v_{0P}$ for $n = 1$ gives $(2/3)R^2\omega = GM/v_{0P}$. For $v_{0P} = c$ one would obtain $\omega_P/\omega_E = (3/2)(R_E/R)^2(v_0/v_{0P}$. For $R_P = .0046491R_E$ (solar radius) this gives $\omega_P/\omega_E \simeq 12.466$ for the $v_0/c = 4.6 \times 10^{-4}$ used by Nottale [K96]: I have often used the approximate nominal value $v_0/c = 2^{-11}$ but now it this approximation is too rough. Taking into account the frequency shift due to Earth's orbital motion one obtains $\omega_P/\omega_E \simeq 11.466$ which is consistent with the lower bound of the observed frequency band and would correspond to R_{max}. The value $v_{0P} = v_{0C} = c$ looks unrealistic if interpreted as a physical velocity of some kind the increase of R_C allows however to reduce the value of v_{0C} so that it seems possible to understand the situation quantitatively.

   If one wants to generalize this argument to differential rotation, one must decompose the system spherical shells or more general elements rotating at different velocities and having different value of $\hbar_{gr}$ assignable to the flux tubes connecting them to Sun and mediating gravitational interaction. This decomposition must be physical.

4.7.4 Reactor antineutrino anomaly as indication for new nuclear physics predicted by TGD

A highly interesting new neutrino anomaly has emerged recently. The anomaly appears in two experiments and is referred to as reactor antineutrino anomaly. There is a popular article Symmetry Magazine (see `http://tinyurl.com/jaqrmdx`) about the discovery of the anomaly in Daya Bay experiment [C100] (see `http://tinyurl.com/z7b63ua`). Bee mentioned in Backreaction blog (see `http://tinyurl.com/y86934yo`) Reno expriment [C59] exhibiting the same anomaly. What happens that more antineutrinos with energies around 5 MeV are produced as should: the anomaly seems to extened to antineutrino energy about 6.3 MeV.

What makes me happy is that this anomaly might provide a new evidence for TGD based model of atomic nuclei.

1. In nuclear string model [L4]) nucleons are assumed to be bonded to nuclear strings by color magnetic flux tubes with quarks at ends. These nuclear quarks are different from hadronic quarks and can have different p-adic mass scales. Nuclear d quark is expected to be heavier than nuclear d quark and can decay to nuclear u quark by emission of a virtual$W$ boson decaying to electron antineutrino pair. These decays are anomalous from the point of view of standard nuclear physics.
2. The virtual W boson decaying to electron antineutrino pair in the anomalous region around 5 MeV should have energy which is two times neutrino energy since electron is relativistic. Since the upper boundary of anomalous region corresponds to about 6.3 MeV antineutrino energy, W energy should be below d-u mass difference, which must be therefore around 12.6 MeV . This is a highly valuable bit of information.

To proceed one can use p-adic mass calculations.

1. The topological mixing of quark generations (characterized by handle number for partonic two surfaces) must make u and d quark masses almost but quite not identical in the lowest p-adic order. In the model for CKM mixing of hadronic quarks they would be identical in this order.
2. p-Adic mass squared can be expressed as $m^2(q)/m(e)^2 = 2^{(k-127)/2}(s(q)+X(q))/(s(e)+X(e))$, where s is positive integer and and $X < 1$ is a parameter characterizing the poorly known second order contribution in p-adic mass calculations. For topologically unmixed u and d quarks one has $s(d) = 8$ and $s(u) = 5 = s(e)$. $p =\simeq 2^k$ characterizes the p-adic scale of quark (for p-adic mass calculations see [K61]).

Assume first that there is no breaking of isospin symmetry so that the p-adic mass scales of u and d type nuclear quarks are same.

1. By using the information about the mass difference $m(d) - m(u) \leq 12.3$ MeV and the above p-adic mass squared formula one can estimate the common p-adic mass scale of the nuclear quarks to be k=113. This is nothing but the p-adic mass scale assigned with nuclei and corresponds to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$. Looks very natural!
2. The maximal value 6.3 MeV for mass difference would be obtained for $s(d) = 8$ and $s(u) = 7$ and $X(e) = X(u) = X(d) = 0$ one obtains mass $m(d) - m(u) = 5.49$ MeV. Interestingly, figure 2 of the Reno article(see `http://tinyurl.com/y86934yo`) shows a sharp downwards shoulder at 5.5 MeV.

   $m(d) - m(u) = 6.3$ MeV can be reproduced accurately for $X(d)/8^{1/2} - X(u)/7^{1/2} \simeq .01$. There are several ways to reproduce the estimate for d-u mass difference by varying second order contributions. Mixing with higher quark generations would occur for both u quark. The mass of nuclear u (d) quark would be $(s(q)/5)^{1/2} \times 64$ MeV, $s(u) = 7$ ($s(d) = 8$) for $m(d) - m(u) = 5.5$ MeV. This mass is assumed to include the color magnetic energy of the color magnetic body of quark and would correspond to constituent quark mass rather than current quark mass, which is rather small.

   What is interesting that the sum of the u and d quark masses $m(d) + m(u) = 144.95$ MeV in absence of topological mixing is about 4 per cent larger than the charged pion mass $m(\pi^+) = 139.57$ MeV. In any case, it is difficult to see how this large additional mass could be compensated.

In an alternative scenario, which is in accordance with the original picture, the isospin symmetry would be broken in the sense that p-adic mass scales of u and d would be different so that the mass difference would corresponds to the mass scale of (say) d quark and could be much smaller.

1. For $k(d) = 119$, $s(d) = 10$ (small topological mixing) and $s(u) = 5$, $k(u) = 127$ (say) one would have $m(d) - m(u) = 10.8$ MeV so that neutrino energy would be below 5.4 MeV, which is near to the steep shoulder. One would have $m(d) = 11.3$ MeV and $m(u) = .5$ MeV (electron mass) in absence of topological mixing. Now $k(d) = 119$ is however not prime as the strongest form of p-adic length scale hypothesis would demands. $k(u) = 127$ is only the first guess. Also $k(u) = 137$ corresponding to atomic length scale can be considered.
2. The accepted values for hadronic current quark masses deduced from lattice calculations are about m(u)=2 MeV for m(d)=5 MeV and smaller than the values deduced above suggesting the interpretation of the masses estimate above as nuclear constituent quark masses.
3. Beta stable configurations would correspond to $u\overline{u}$ bonds with total energy about $2m(e) = 1$ MeV, which is consistent with the general view about nuclear binding energy scale. Also exotic nuclear excitations containing charged color bonds with quark or antiquark or both transformed to d type state are predicted. The first guess for the excitation energy of charged color bond is $m(d) - m(u) \simeq 10.8$ MeV. Each charged color bond increases the nuclear charge by one unit but proton and neutron numbers remain the same as for the original nucleus: I have called these states exotic nuclei [L4].
4. The so called leptohadron hypothesis [K115] postulates color excitations of leptons having as bound states leptopions with mass equal to $2m(e)$ in good approximation. An alternative option would replace colored leptons with quarks and assumes that unmixed u quark has electron mass and their production in heavy ion collisions would be natural if they appear as color bonds between nucleons. This would fix $s(u)$ to $s(u) = 5$ (no topological mixing).
5. X rays from Sun have anomalous effects on the observed nuclear decay rate with a periodicity of year and with magnitude varying like inverse of the distance from the Sun with which also solar X ray intensity varies [C39](see `http://tinyurl.com/y8ponx6`): this is known as GSI anomaly. I have proposed earlier that the energy scale of the excitations of nuclear color bonds is 1-10 keV on basis of these findings [L4]. Nuclei could be in exited states with excitation energies in 1-10 keV range and the X ray radiation would affect the fraction of excited states thus changing also the average decay rates.

One can try to understand the keV energy scale to the 1 MeV energy scale of beta stable color bonds in terms of fractal scaling. Above it was found that for $k = 113$ charged color bond would have energy $m(d) + m(u) = 144.95$ MeV if quarks are free. Since the actual charged pion mass is $m(\pi^+) = 139.57$ MeV, the pionic binding energy would be 5.38 MeV which makes about 3.7 per cent of the total mass. If one applies same fractal logic to the $k = 127$ color bond with $2m(u) = 1$ MeV, one obtains 37 keV, which has somewhat too high value. The Coulombic interaction is attractive between u and $\overline{u}$ in $k = 127$ pion with broken isospin symmetry. The naïve perturbative estimate is as $\alpha/m_e \simeq 3.6$ keV reducing the estimate to 34.4 keV. The fact that π^+ has positive Coulombic interaction energy reduces the estimate further but this need not be enough.

For $k(u) = 137$ (atomic length scale) one would obtain binding energy scale which is by factor 1/32 lower and about 1.2 keV. The simplest model for color bond would be as harmonic oscillator predicting multiples of 1.2 keV as excitation energies. This would conform with the earlier suggestion that color magnetic flux tubes are loops with size of even atom. This cold also explain the finding that the charge radius of proton is not quite what it is expected to be.

4.7.5 Pear-shaped Barium nucleus as evidence for large parity breaking effects in nuclear scales?

Nuclear physics anomalies continue to accumulate. Now there was a popular article (see http://tinyurl.com/z8ocjfj) telling about the discovery of large parity breaking in nuclear physics scale. What have been observed is pear-shaped ^{144}Ba nucleus not invariant under spatial reflection. The arXiv article [C86] (see http://tinyurl.com/yd8yvk4a) speaks only about octupole moment of ^{144}Ba nucleus difficult to explain using the existing models. Therefore one must take the popular article managing to associate the impossibility of time travel to the unexpectedly large octupole moment with some caution. As a matter fact, pear-shapedness has been reported earlier for Radon-220 and Radium-224 nuclei by ISOLDE collaboration working at CERN [C70] (see http://tinyurl.com/zmau4zd an¿ and http://tinyurl.com/jn6k2pk).

The popular article could have been formulated without any reference to time travel: the finding could be spectacular even without mentioning the time travel. There are three basic discrete symmetries: C,P, T and their combinations. CPT is belived to be unbroken but C,P, CP and T are known to be broken in particle physics. In hadron and nuclear physics scales the breaking of parity symmetry P should be very small since weak bosons break it and define so short scaled interaction: this breaking has been observed.

The possible big news is following: pear-shaped state of heavy nucleus suggests that the breaking of P in nuclear physics is (much?) stronger than expected. With parity breaking one would expect ellipsoid with vanishing octupole moment but with non-vanishing quadrupole moment. This suggests parity breaking in unexpectedly long length scale. This is not possible in standard model, where parity breaking is larger only in weak scale which is roughly 1/1000 of nuclear scale and fourth power of this factor reduces the weak parity breaking effects in nuclear scale.

Does this finding force to forget the plans for the next summer's time travel? If parity breaking is large, one expect s from the conservation of CPT also large compensating breaking of CT breaking. This might relate to the matter-antimatter asymmetry of the observed Universe but I cannot relate it to time travel since the very idea of time travel in its standard form does not make much much sense to me.

In TGD framework one can imagine two explanations involving large parity breaking in unexpectedly long scales. In fact, in living matter chiral selection represents mysteriously large parity breaking effect and the proposed mechanisms could be behind it.

1. In terms of p-adically scaled down variants of weak bosons having much smaller masses and thus longer Compton length - of the order of nuclear size scale - than the ordinary weak bosons have. After this phase transition weak interaction in nuclear scale would not be weak anymore.

2. In terms of dark state of nucleus involving magnetic flux tubes with large hbar carrying ordinary weak bosons but with scaled up Compton length (proportional to $h_{eff}/h = n$) of

order nuclear size. Also this phase transition would make weak interactions in nuclear scale much stronger.

There is a connection with X boson anomaly [L50] (see `http://tinyurl.com/ya3yuzeb`). The model for the recently reported X boson involves both options but 1) is perhaps more elegant and suggests that weak bosons have scaled down variants even in hadronic scales: the prediction is unexpectedly large parity breaking. This is amusing: large parity breaking in nuclear scales for three decades ago one of the big problems of TGD and now it might have been verified!

Unexpected support for the nuclear string model

Nuclear string model [L4] (see `http://tinyurl.com/zofj62f`) replaces in TGD framework the shell model. Completely unexpected support for nuclear string model emerged from a research published by CLAS Collaboration in Nature [C40] (see `http://tinyurl.com/yacfdebw`). The popular article "Protons May Have Outsize Influence on Properties of Neutron Stars" refers to possible implications for the understanding of neutron stars but my view is that the implications might dramatically modify the prevailing view about nuclei themselves. The abstract of popular article reads as (see `http://tinyurl.com/ybgjtckw`).

> A study conducted by an international consortium called the CLAS Collaboration, made up of 182 members from 42 institutions in 9 countries, has confirmed that increasing the number of neutrons as compared to protons in the atom's nucleus also increases the average momentum of its protons. The result, reported in the journal Nature, has implications for the dynamics of neutron stars.

The finding is that protons tend to pair with neutrons. If the number of neutrons increases, the probability for the pairing increases too. The binding energy of the pair is liberated as kinetic energy of the pair - rather than becoming kinetic energy of proton as the popular text inaccurately states.

Pairing does not fit with shell model in which proton and neutron shells correlate very weakly. The weakness of proton-neutron correlations in nuclear shell model looks somewhat paradoxical in this sense since - as text books tell to us - it is just the attractive strong interaction between neutron and proton, which gives rise to the nuclear binding.

In TGD based view about nucleus protons and neutrons are connected to nuclear strings with short color flux tubes connecting nucleons so that one obtains what I call nuclear string (see `http://tinyurl.com/zofj62f`). These color flux tubes would bind nucleons rather than nuclear force in the conventional sense.

What can one say about correlations between nucleons in nuclear string model? If the nuclear string has low string tension, one expects that nucleons far away from each other are weakly correlated but neighboring nuclei correlate strongly by the presence of the color flux tube connecting them.

Minimization of repulsive Coulomb energy would favor protons with neutrons as nearest neighbors so that pairing would be favored. For instance, one could have n-n-n... near the ends of the nuclear string and -p-n-p-n-... in the middle region and strong correlations and higher kinetic energy. Even more neutrons could be between protons if the nucleus is neutron rich. This could also relate to neutron halo and the fact that the number of neutrons tends to be larger than that of protons. Optimistic could see the experimental finding as a support for nuclear string model.

Color flux tubes can certainly have charge 0 but also charges 1 and -1 are possible since the string has quark and antiquark at its ends giving $u\overline{u}$, $d\overline{d}$, $u\overline{d}$, $d\overline{u}$ with charges 0,0,-1,+1. Proton plus color flux tube with charge -1 would effectively behave as neuron. Could this kind of pseudo neutrons exist in nucleus? Or even more radically: could all neurons in the nucleus be this kind of pseudo neutrons?

The radical view conforms with the model of dark nuclei as dark proton sequences - formed for instance in Pollack effect [L24] [L24] (see `http://tinyurl.com/gwasd8o`) - in which some color bonds can become also negatively charged to reduce Coulomb repulsion [L54]. Dark nuclei have scaled down binding energy and scaled up size. They can decay to ordinary nuclei liberating almost all ordinary nuclear binding energy: this could explaining "cold fusion" [L27, L54] (see `http://tinyurl.com/y7u5v7j4`).

4.8 EMC effect in nuclear string model

I received from Wes Johnson a a link (http://tinyurl.com/s939nrb) to a popular article about the recent work by CLAS collaboration related to EMC effect. See also Wikipedia article (http://tinyurl.com/rg5wwux) and second popular article (http://tinyurl.com/y44anveb). The popular articles refer to the publication of CLAS Collaboration relating to EMC effect [C41] (http://tinyurl.com/thspz2n). The conclusion of the research group is that the formation of correlated nucleon pairs leads to the observed surprisigly strong modification of quark structure functions insided nucleon.

Since deep inelastic scattering (DIS) occurs for large momentum exchanges (few GeV) and nuclear physics energy scale (few MeV) is much lower, one would expect that the nucleus behaves as a collection of free nucleons in DIS. Therefore EMC effect was a surprise. The distribution for longitudinal momenta of quarks inside nucleons inside nuclei deduced from the experiments seemed to differ dramatically from that for free nucleons. Nuclear binding would have large effect on quark behavior.

Very roughly, the ratio for the probabilities $f_{Fe}(x)$ and $f_D(x)$ of quark to have momentum fraction x in Fe and D is not constant equal to 1 as expected (and thus independent on the size of nucleus) but decreases almost linearly for x in range .3-.7. In heavier nuclei large longitudinal momentum fractions seem to be less probable. Somehow the quarks would be slowed down and small values of x would become more favored. The effect becomes stronger in heavier nuclei as the figure 1 of the Wikipedia article (http://tinyurl.com/rg5wwux) comparing the effect for D and Fe demonstrates.

The model of CLAS group assumes that there are strong short range correlations between nucleons in nuclei. About 20 per cent of nucleons would have these correlations at given moment of time. One might say that they are stuck together. The TGD based proposal based on nuclear string model is somewhat different. Formation of di-nucleons would occur as the nuclear flux tube touches itself. This implies a de-localization of quark color to the volume of di-nucleon formed by color confinement. Di-nucleons would consist of 3 di-quarks forming anti-color triplets and also meson-like quark pair is needed. The longitudinal momenta of quarks inside di-quark would be same and this constraint would reduces degrees of freedom. The distribution functions for the longitudinal momentum fraction of di-quark could be same as that for quarks.

The description of nuclei as nuclear strings is rather old part of TGD and EMC effect give hopes of testing this model.

4.8.1 Nuclear string model

In TGD nuclei are assumed to be nuclear strings [L4] (http://tinyurl.com/rc4umgv).

1. The 10 year old nuclear physics anomaly [E7, E43] meaning that the abundances in solar core seems to be higher than those at the surface of Sun and outside it in meteors led to a more detailed view about nuclear string model. TGD based model for "cold fusion" assumes nuclear strings consisting of nucleons at magnetic flux tubes can be dark in the sense that nucleons have effective Planck constant $h_{eff} = nh_0 > h$. The Compton length of nucleon would be essentially electron Compton length. Pollack effect would lead to formation of dark nuclei which then decay to ordinary ones liberating essentially all nuclear binding energy. Hot fusion would involve transformation of ordinary nuclei to dark nuclei as counterpart of tunneling and the resulting dark reaction products would decay to ordinary nuclei [L103] (http://tinyurl.com/yyjy5e2r).

2. This picture in turn led to a view about stellar interiors as dark nuclear flux tube tangles. Blackhole would correspond to a volume filling flux tube spaghetti for which the flux tube corresponds to $h_{eff} = h$ and has radius given by nucleon Compton length. One can consider the possibility that other asymptotic states of stars correspond to blackhole like spaghettis but having $h_{eff} > h$ and larger flux tube radius.

The idea that also ordinary nuclei are similar flux tube spaghetti is attractive. The flux tube need not be volume filling but it could touch itself and these touchings could correspond to the formation of nucleon pairs suggested by the experimental findings [C41]. Consider first nuclear string model.

1. Nucleons would be along magnetic flux tube like pearls in necklace.

2. The additional assumption is that two sub-sequent nucleons are connected by meson-like quark-antiquark pair having mass in MeV range - nuclear binding energy scale - rather than that of virtual pion about 140 MeV- p-adically scaled down pion. The motions of neighboring nucleons along the nuclear necklace would be strongly correlated: they would form correlated pairs but this need not affect the momentum distributions of quarks inside nucleons. These mesonlike flux tubes would be by Uncertainty Principle loops of order Compton length of light quark and would have no appreciable role in DIS since it would occur in the length scale of nucleon

3. One can consider two options for the meson like bonds between nucleons but neither is relevant for the model to be discused in the following.

   (a) The loop-like bonds are non-colored meson-like entities. The quark distributions inside nucleons would not be affected appreciably. DIS would take place from quarks of single nucleon. Bonds would have no appreciable effect on DIS so that this option fails.

   (b) The loop-like bonds between nucleons could be also colored. Also nucleons would be colored if di-nucleon would is color neutral. The point would be that color confinement would bind nucleons very strongly to single di-nucleons unlike in previous case and DIS would take place from quarks of di-nucleon rather than those of nucleon. The x-distributions of quarks inside colored nucleons *could but need not* differ from those for free nucleons. Only color confinement forming di-nucleon would matter.

4.8.2 Trying to understand EMC effect in TGD framework

What could happen in EMC effect.

1. The hypothesis is that the self-contacts of the flux tube in nuclear spaghetti would give rise to a formation of di-nucleons. Quark color is de-localized to the volume of di-nucleon formed by color confinement. There would be no EMC effect for D since it cannot have transversal self-contacts: this is observed. The probability of self-touchings increases with the atomic number A and increases with the local density of the nucleons: also this has been observed.

2. In self-contact di-nucleon {pp, pn, pn, np} is formed as color-confined 6-quark state. The observation that the tensor product $3\otimes 3$ of two color triplets contains color anti-triplet $\overline{3}$ and 6-plet suggests what could happen. Assume that the di-nucleon state is color singlet analogous to anti-nucleon in the sense that it is color singlet formed from 3 di-quarks (uu,ud,du,dd) in color anti-triplet state $\overline{3}$. Di-quarks are bosons and their wave functions be antisymmetric with respect to the exchange of quarks. Spatial wave function is symmetric so that also spin wave function must be symmetric. Spin 1 states would be in question. The magnetic moment of di-quark is proportional to $\overline{S}/2m_n$ and classically the same as that of quark so that the magnetic interaction of di-quark with the virtual photon in DIS should be nearly the same as that of quark.

3. The formation of di-quark state forces the values of longitudinal momentum fractions x_i of quarks to be same: $x_1 = x_2 = x$. Since the mass is doubled, the longitudinal momentum fraction of di-quark is same as that of quark: $x_D = x$. A stronger assumption is that di-quark distribution function $f_D(x)$ is same as quark distribution function: $f_D(x) = f(x)$.

The rate for DIS from nucleon is proportional to the sum $K = \sum_i Q_i^2$, where Q_i are quark charges. For proton one obtains $K(p) = 4/9 + 4/9 + 1/9 = 1$ and for neutron $K(n) = 4/9 + 1/9 + 1/9 = 2/3$. The behavior of the ratio of the form factor for heavier nuclei requires that the effective value of K for single nucleon deduced as the average of di-nucleon parameters $K(N_1N_2)$ for di-nucleons N_1N_2 is smaller than the average value for single nucleon states. Does this require conditions on allowed em charges of di-nucleons N_1N_2?

To proceed one must test various working hypothesis by comparing them with the qualitative behavior of the form factor F_2 displayed in the Wikipedia article.

Models without meson-like quark pairs

Assuming that the formation of contact does not involve creation of $q\overline{q}$ pair, one can consider two options :

Option 1: Allow all charge states for di-quarks.

Option 2: Allow only charge states for which K is minimum.

1. For di-nucleon pp$_1$ = (uud)(uud) = (uu)(ud)(ud) one obtains $K(pp_1) = 16/9 + 1/9 + 1/9 = 2 = 2K(p)$. For di-nucleon pp$_2$= (uu)(uu)(dd) one obtains $K(pp_2) = 36/9 > 3K(p)$. The average is $\langle K(pp)\rangle = (K(pp_1) + K(pp_2)/2 = (36 + 18)/18 = 3$.

   If one thinks di-nucleon effectively as two ordinary nucleons as done in experiment, one has $K(pp, eff) = 3/2 > 1 = K(p)$ for **Option 1**). Allowing only the state (uu)(ud)(ud) minimizing K (**Option 2**) one has $K_{eff}(pp) = 1 = K(p)$.

2. $nn_1 = (udd)(udd) = (ud)(ud)(dd)$ gives $K(nn_1) = 6/9$. $nn_2 = (uu)(dd)(dd) = (16+4+4)/9 = 24/9$. The average is $\langle K(nn)\rangle = 12/9$ giving $K_{eff}(nn) = 2/3 = K(n)$ for **Option 1**.

   Allowing only the state (ud)(ud)(dd) **Option 2** one has $K(nn, eff) = 1/3 < K(n)$.

3. For pn$_1$ = (uud) (udd)= (ud)(ud)(ud) one has $K(pn_1) = 1/3 < 2/3 = K(n)$. For pn$_2$= (uu)(ud)(dd) one has $K(pn_2) = 21/9 > K(p)$. The average is $\langle K(pn)\rangle = 8/3$ and $K(pn, eff) = 4/3 > K(p)$ **Option 1**.

   Allowing only state (ud)(ud)(ud) **Option 2** one has $K_{eff}(pn) = 1/3 < K(n)$.

The average of $K_{eff} = (K_{eff}(pp)+K_{eff}(nn)+2K_{eff}(pn)/4 = 11/8$ to be compared with the average $K_{st} = (K(p)+K(n))/2 = 5/6$. **Option 1** is therefore not consistent with the observations.

For **Option 2** the average over the $N_1N_2 \in \{pp, nn, pn, np\}$ is $K_{eff} = 7/12$ to be compared with $K_{st} = 5/6$. One has $K_{eff}/K_{st} = 42/60 = 7/10$. Assuming that fraction $p = 1/5$ of nucleons are paired by contacts one obtains for **Option 2** $K_1 = (1 - p) \times K_{st} + p \times K_{eff} = 47/60$ to be compared with $K_{st} = 50/60$. The ratio $K_{eff}/K_{st} = 47/50$ is 6 per cent smaller than unit whereas 10 per cent is suggested by Fig. 1 of Wikipedia article.

Model with di-quarks and quark pair

A more complex model assumes the presence of quark pair $q\overline{q}$ in the contact and minimization of K by a suitable choice of di-quarks q_iq_j and $q_1\overline{q}_2$ pairing.

1. $p(d\overline{d})p = (ud)(ud)(ud)(u\overline{d})$ gives $K_{eff} = 2/3$.
2. $n(u\overline{u})n = (ud)(ud)(ud)(d\overline{u})$ gives $K_{eff} = 2/3$.
3. $p(u\overline{u})n = (uud)(u\overline{u})(udd) = (ud)(ud)(ud)(u\overline{u})$ gives $K_{eff} = 1/3$.

The average value of K_{eff} over four pairs {uu,dd,ud,du} is $\langle K_{eff}\rangle = 1/2$. For $p = 1/5$ this gives $K_1 = (1 - p)K + pK_{eff} = 23/30$. K_1/K_{st} deviates by 8 per cent from unity. This is consistent with the result of the figure 1 of the Wikipedia article (`http://tinyurl.com/rg5wwux`).

This model resembles the earlier nuclear string model but could be criticized for being too complex. Second criticism concerns scales. Di-quarks and meson-like quark pair should behave like point-like particles in the GeV scale of DIS. Di-quarks should therefore have size scale not much larger than that of quark. Nucleons would reside along $k = 107$ flux tube with nucleon Compton radius as radius. The experimental data on EMC suggest that the nucleons are larger than normally by about 10-20 per cent. This could be average for the sizes of ordinary nucleon and 2 times larger di-nucleon: one would have $(1 - p) + 2p = 6/5$ and 20 per cent increase in effective nucleon size.

Could the notion of many-sheeted space-time allow to associate di-nucleons with space-time sheet with p-adic length scale $L_p \propto \sqrt{p} = L(k) = 2^{k/2}$ (by p-adic length scale physics one has $p \simeq 2^k$). One would have $k = 109$ (prime). I have proposed earlier that deuteron could correspond to $k = 109$ space-time sheet. Deuteron cannot be however regarded as $n(u\overline{u})n$ state since one would have $K_{eff} = 2/3$ instead of $K = 5/6$. Could one regard di-nucleons as states with $k = 107$ but $h_{eff} = 2h$ so that the radius would correspond to $k = 109$? Touching is indeed critical phenomenon and h_{eff} can increase at criticality.

4.9 X boson as evidence for nuclear string model

Anomalies seem to be popping up everywhere, also in nuclear physics and I have been busily explaining them in the framework provided by TGD. The latest nuclear physics anomaly that I have encountered (see `http://tinyurl.com/zlvngnv`) was discovered in Hungarian physics laboratory in the decays of the excited state ^{8}Be* of an unstable isotope of ^{8}Be (4 protons and 4 neutrons) to ground state ^{8}Be [L50, C68] (see `http://tinyurl.com/h9o5tb4`). For the theoretical interpretation of the finding in terms of fifth force see [C68] (see `http://tinyurl.com/h9o5tb4`) mediated by spin 1 X boson.

The anomaly manifests itself as a bump in the distribution of e^+e^- pairs in the transitions ^{8}Be*$\rightarrow$ ^{8}Be at certain angle (140 degrees) between electrons. The interpretation is in terms of a production of spin 1 boson - christened as X - identified as a carrier of fifth force with range about 12 fm, nuclear length scale. The attribute 6.8σ - if taken seriously - tells that the probably that the finding is statistical fluctuation is about 10^{-12}: already 5 sigma is regarded as a criterion for discovery.

The assumption about vector boson character looks at first well-motivated: the experimental constraints for the rate to gamma pairs are believed to eliminate the interpretation as pseudo-scalar boson whereas spin 1 bosons do not have these decays. In the standard reductionistic spirit it is assumed that X couples to p and n and the coupling is sum for direct couplings to u and d quarks making proton and neutron. The comparison with the experimental constraints forces the coupling to proton to be very small: this is called protophoby. Perhaps it signifies something that many of the exotic particles introduced to explain some bump during last years are assumed to suffer various kinds of phobies. The assumption that X couples directly to quarks and therefore to nucleons is of course well-motivated in standard nuclear physics framework relying on reductionism.

TGD inspired interpretation based on nuclear string model [L4] is different. The mass of the state is within .7 accuracy pion mass scaled down to nuclear p-adic scale characterized by p-adic prime $p \simeq 2^k$, $k = 113$. Scaled down pion in $l = 1$ state is possible and allows to p-adically scale the decay rates to gamma pair and e^+e^- pair from those of pion. The pleasant surprise was that the scaled $\Gamma(\pi, \gamma\gamma)$ turned out to be consistent with the experimental bounds reported in [C68].

There is however a problem: the estimate for $\Gamma(\pi, e^+e^-)$ obtained by p-adically scaling the model based on decay virtual gamma pair decaying to e^+e^- pair [C43] is by a factor 1/88 too low. One can consider the possibility that the dependence of f_π on p-adic length scale is not the naïvely expected one but this is not an attractive option. The increase of Planck constant seems to worsen the situation.

The dark variants of weak bosons appear in important role in both cold fusion and TGD inspired model for chiral selection. They are effectively massless below the scaled up Compton scale of weak bosons so that weak interactions become strong. Since pion couples to axial current, the decay to e^+e^- could proceed via annihilation to Z^0 boson decay to e^+e^- pair. The estimate for $\Gamma(\pi(113), e^+e^-)$ is in the middle of the allowed range. The same model explains also the decay width of the ordinary pion and a generalization of the model to all semileptonic decays of hadrons is highly suggestive and would explain the somewhat mysterious origin of CVC and PCAC [B23].

The model is also formulated in terms of nuclear string model. In particular, the mechanism for the decay as snipping of closed pionic flux loop from a colored flux tube connecting nucleus is discussed briefly. A possible manner to measure the value of h_{eff} emerges as a by-product. By measuring lifetime and decay width independently, one can deduce the value of h_{eff}/h predicted to be integer valued as $h_{eff}/h = \tau\Gamma/\hbar$. This essentially verifying of scaled up variant of Uncertainty Principle.

4.9.1 Two observations and a possible puzzle generated by them

What could TGD say about the situation? First two observations and the puzzle created by them.

1. The first observation is that 12 fm range corresponds rather precisely to p-adic length scale for prime $p \simeq 2^k$, $k = 113$ assigned to the space-time sheets of atomic nuclei in TGD framework. The estimate comes from $L(k) = 2^{(k-151)/2}L(151)$, $L(151) \simeq 10$ nm. To be precise, this scale is actually the p-adic Compton length of electron if it where characterized by k instead of $k_0 = 127$ labelling the largest not super-astrophysical Mersenne prime. $k = 113$ is very special: it labels Gaussian Mersenne prime $(1+i)^k - 1$ and also muonic space-time sheet.

2. A related observation made few days later is that the p-adic scaling of the ordinary neutral pion mass 135 MeV from $k = 107$ to $k = 113$ by $2^{-(113-107)/2} = 1/8$ gives 16.88 MeV! That p-adic length scale hypothesis would predict the mass of X with .7 per cent accuracy for nominal value $m(X) = 17$ MeV is hardly an accident. Note that the measured value is $16.7 \pm .35(stat) \pm .5(sys)$ MeV. This would strongly suggest that X boson is $k = 113$ pion.
3. There is however a potential problem. The decays to photon pairs producing pion in $l = 1$ partial wave have not been observed. Authors conclude that spin 1 particle is in question. If X is ρ meson like state with spin 1, why it should have same mass as pionic X? This is not plausible.

It turns out that I was too easily gullible! The decay width $\Gamma(\pi(113), \gamma\gamma)$ estimated by scaling from the decay width for ordinary pion is actually consistent with the experimental bound! The decay width $\Gamma(\pi(113), \gamma\gamma)$ is however problematic and suggests that non-standard value of h_{eff} is involved.

4.9.2 The estimate for $\Gamma(\pi(113), \gamma\gamma)$ is consistent with the limits on $\Gamma(X, \gamma\gamma)$

The estimate for the decay rate $\Gamma(\pi(113), \gamma\gamma)$ is easy to obtain by using effective action determined by PCAC hypothesis.

1. The effective action defined by the "instanton density" for Maxwell field is given by

$$g_{X\gamma\gamma} F^{\mu\nu} \tilde{F}_{\mu\nu} \ , \tag{4.9.1}$$

where $\tilde{F}$ is the dual of F. $g_{\pi\gamma\gamma}$ is given by

$$g_{\pi\gamma\gamma} = \frac{\alpha}{\pi f_\pi} \ . \tag{4.9.2}$$

$f_\pi = 93$ MeV characterizes the matrix elements of SU(2) axial currents between vacuum and 1 pion state and it scales like pion mass.

The direct dependence of $g_{\pi\gamma\gamma}$ and implicit dependence of f_π on α and α_s determines the value of $\Gamma(\pi, \gamma\gamma)$. All vertices of tree diagrams containing coupling constant give rise to a coefficient g^2/m having identification as charge radius not affected in the scaling $h \to h_{eff}$.

1. One motivation for the introduction of hierarchy of Planck constants is that the scaled up h_{eff} allows perturbative approach since one has $\alpha_k \to \alpha_k/n$. This argument makes sense in QFT context. If one can approximate the amplitude as box diagram with fermionic exchange with photons at the upper vertices and gluon exchange associated with the lower vertices, the dependence on $1/h_{eff}$ would come from α_s. α proportionality would boil down to the proportionality from the square of charge radius $r_s = e^2/4\pi m_\pi$ or of its analog $r_s = e^2/4\pi f_\pi$.
2. An objection emerges from the vision that all scattering diagrams in TGD framework for given p-adic length scale and given value of h_{eff} can be transformed to tree diagrams at topological level [K46]: scattering diagrams would be analogous to computations and could be always reduced to those involving no loops. Coupling constant evolution would reduce to p-adic coupling constant evolution. Also the functional integral using exponent of Kähler as weighting would reduce to tree diagrams. This picture is strongly favoured by number theoretical vision. If this is the case, there are no topological loops in the minimal representation for diagrams and the there is no dependence on coupling strengths $\alpha_k = g_k^2/4\pi h_{eff}$ but only on classical charge radii $r_s m$, $r_s = g_k^2/4\pi m$ of particles appearing in the vertices of tree diagrams.

   If loops are not present, the quark pair wave function of pion state should give rise to dependence on α_k and thus on h_{eff}. Radiative corrections would be localizable to the positive and negative energy parts of zero energy states at the boundaries of causal diamond (CD). Pion decay could be seen as $q\overline{q} \to \gamma\gamma$ scattering by quark exchange for quarks in bound state determined by color force. The dependence on $1/h_{eff}$ would come from the dependence of quark-antiquark wave function on α_s and would be analogous to $|\Psi(0)|^2$ proportionality in the case of positronium. In $\Gamma(\pi,\gamma\gamma)$ h_{eff} dependence could be localized to the dependence of $1/f_\pi^2$ on α_k and should increase/reduce the rate by reducing/increasing f_π^2. It must be emphasized that also the dependent on p-adic scale could be of from $f_\pi \propto 1/L(k)^n$, $n \neq 1$ as expected, and for $n > 1$ increase the scattering rate.

Consider now the detailed formula for the decay width $\Gamma(\pi,\gamma\gamma)$ [B23].

1. The formula for the gamma decay width of ordinary pion can be written as

$$\Gamma(\pi,\gamma\gamma) = \frac{1}{2^6\pi^3}\frac{m_\pi^2}{f_\pi^2}(r_\pi m_\pi)^2 m_\pi \ \ , \ \ r_\pi = \frac{e^2}{4\pi m_\pi} \ \ . \tag{4.9.3}$$

In this expression the only h_{eff}-dependence is contained by f_π. Using units $\hbar = 1, c = 1$ one would have apparent α^2 $(1/\hbar^2)$ dependence. One has $\Gamma(\pi) = 7.63$ eV whereas the experimental value is $\Gamma^{exp} = (7.37 \pm 1.5)$ eV. The radiative corrections are assumed to be possible only for the initial and final state wave functions in the case of bound states.

2. According to [C68] all values of $1/g_{\pi\gamma\gamma}$ outside the range [.1 GeV,10^{18} GeV] have been excluded. This translates to the allowed range [.2 MeV, 2.3×10^{15} GeV] implying $f_\pi \geq .2$ MeV. The p-adically scaled down value of $f_{\pi(113)} = f_\pi/8 = f_\pi/8 = 11$ MeV is inside the allowed range.

3. f_π depends on non-perturbative aspects of QCD and therefore on α_s and n in non-trivial manner. One might of course hope that the large value of h_{eff} makes the situation perturbative and that the dependence is simple. This could mean that f_π scales like m_π. In absence of h_{eff} dependence the scaling from the pion decay width would give $\Gamma(\pi(113)) = \Gamma(\pi)/8 = .95$ eV. Scaling down of f_π by a factor 55 is allowed by the experimental limits and there is no limit on scaling up. Contrary to the expectations inspired by [C68] $\Gamma(\pi,\gamma\gamma)$ does not exclude the identification of X as pion like state.

4.9.3 Model for $\Gamma(\pi(113), e^+e^-)$

The following considerations show that the generalization of the standard model for $\Gamma(\pi, e^+e^-)$ predicts too small production rate for $\Gamma(\pi(113), e^+e^-)$. The modification based on the assumption that either p-adically scaled down weak bosons or their dark variants are possible and color magnetic flux tubes allows to understand $\Gamma(\pi(113), e^+e^-)$ and leads to a radical proposal that dark or p-adically scaled up variants of weak physics are involved also with the semileptonic decays of hadrons so that the prevailing picture would be wrong.

The standard model prediction for $\Gamma(\pi(113), e^+e^-)$ is not consistent with the experimental limits

The estimate of [C68] for the decay width of $\Gamma(X, e^+e^-)$ (Eq. (6) of the article) of *spin* 1 X boson is of the form

$$\Gamma(X, e^+e^-) = \epsilon_e^2\frac{\alpha}{3}(1 + 2\frac{m_e^2}{m_X^2}) \times m_X \ \ . \tag{4.9.4}$$

The estimate of the authors for the range of allowed values of ϵ is $[2 \times 10^{-4}, 1.4 \times 10^{-3}]$. The rate would vary in the range $[2.3 \times 10^{-3}, 0.1]$ eV. A weaker lower bound for ϵ is 1.3×10^{-5} giving lower bound for decay width as 1.5×10^{-4} eV. The optimistic guess is that these bounds apply to pseudoscalar X.

The observed e^+e^- branching fraction for the ordinary pion is about $B(\pi, e^+e^-) = 7.5 \times 10^{-8}$ (see `http://tinyurl.com/ybl956pa`) giving the estimate $\Gamma(\pi, e^+e^-) \simeq 5.6 \times 10^{-7}$ eV. The challenge is to scale up this rate for $\pi(113)$. This requires a model for $\Gamma(\pi, e^+e^-)$.

In [C43] $\Gamma(\pi, e^+e^-)$ (see `http://tinyurl.com/ybl956pa`) is estimated as a loop correction by assuming that the decay proceeds via annihilation to virtual gamma pair decaying to electron pair by electron exchange. The reason is that there is no spinless current coupling to quarks and leptons directly (leptoquarks as carriers of this current have been considered). The estimate involves uncertainties since the form factor $F_{\pi\gamma*\gamma*}$ is not well-known off-mass-shell and must be modelled.

1. The general expression for the ratio of branching ratios to $B(\pi, e^+e^-)$ and $B(\pi,\gamma\gamma)$ reads as

$$\begin{aligned} R(\pi, e^+e^-) &\equiv \frac{B(\pi, e^+e^-)}{B(\pi,\gamma\gamma)} = 2(\frac{\alpha}{\pi}\frac{m_e}{m_\pi})^2 \beta_e(q^2)|A(m_\pi^2)|^2 \ , \\ \beta_e(q^2) &= \sqrt{1-\frac{4m_e^2}{q^2}} \ . \end{aligned} \tag{4.9.5}$$

   $\beta_e(m_\pi^2)$ is the relativistic velocity of electron. The strongest dependence of the branching ratio on pion mass is contained by the suppression factor $x = (\alpha/\pi)^2(m_e/m_\pi)^2$ coming from approximate helicity conservation (the helicities of electron and positron are parallel at massless limit where as the spin of pion vanishes). The dependence of A on mass ratios is logarithmic.

2. The general expression for A is as a loop integral with pion form factor defining the vertex.

$$\begin{aligned} A(q^2) &= \frac{2i}{q^2}\int \frac{d^4k}{\pi^2}\frac{q^2k^2-(q\cdot k)^2}{D(k^2)D((k-q)^2)D_e((k-p)^2)} F_{\pi\gamma*\gamma*}(-k^2-(k-q)^2) \ , \\ D(k^2) &= k^2+i\epsilon \ , D_e(k^2) = k^2-m_e^2+i\epsilon \ . \end{aligned} \tag{4.9.6}$$

   To calculate the integral one must continue $F_{\pi\gamma*\gamma*}$ for all values of its arguments and this requires modelling.

3. The approximate outcome of the calculations of [C43] is

$$\begin{aligned} Im(A(q^2)) &= \frac{\pi}{2\beta_e(q^2)} log(y_e(q^2)) \ , \ y_e = \frac{1-\beta_e}{1+\beta_e} \ , \\ Re(A(q^2)) &= A(q^2=0) + \frac{a^2}{\pi}\int_0^\infty ds \frac{Im(A)(s)}{s(s-q^2)} \ . \end{aligned} \tag{4.9.7}$$

   The real part of the loop integral diverges logarithmically and $A(m\pi^2)$ is obtained from a once subtracted dispersion relation. $A(q^2=0)$ contains the unkown dynamics and is outcome of the regularization procedure. One obtains approximate expression for $Re(A)$ as

$$Re(A(q^2)) = A(q^2=0) + \frac{1}{\beta(q^2)}\left[\frac{1}{4}\log^2(y_e(q^2)) + \frac{\pi^2}{2} + Li_2(-y_e(q^2))\right] \tag{4.9.8}$$

   Here $Li_2(z) = \int_0^z (dt/t) log(1-t)$ is dilogarith function. In good approximation one has

$$Re(A(m_{pi}^2)) = A(q^2=0) + log^2(\frac{m_e}{m_\pi}) + \frac{\pi^2}{2} \ . \tag{4.9.9}$$

4. For $A(q^2=0)$ containing the dynamics authors consider the parameterization

$$\begin{aligned} A(q^2=0) &= -\frac{3}{2}log(\frac{s^1}{m_e^2} = -23.2\pm 1 \ . \\ s^1 &= (776\pm 22 \ \ MeV)^2 \ . \end{aligned} \tag{4.9.10}$$

s^1 is essentially ρ meson mass squared. The value of the dispersion integral depends on the choice of cutoff fixing the value of the loop amplitude for zero momentum transer $q^2 = 0$ and ρ meson mass plays the role of the cutoff - this has also physical motivation coming from vector meson dominance.

5. The prediction is $B(\pi, e^+e^-) = (6.23\pm.09)\times 10^{-8}$ whereas the experimental value is $B(\pi, e^+e^-) = (7.49 \pm 0.29 \pm 0.25) \times 10^{-8}$. The result is rather satisfactory. Authors can reproduce the observed branching ratio by replacement $m(\rho), m(\rho/2$ but this leads to other problems.

What happens when ordinary pion is replaced with $\pi(113)$?

1. The suppression factor $x = (\alpha/\pi)^2(m_e/m_\pi)^2$ is scaled up by 64 if h_{eff} is not changed. A depends logarithmically on mass ratios and is not affected much as one finds by checking what happens to the terms contributing the expression of $|A|^2$: one obtains scaling down by a factor .35. If the pion decay rate scales as p-adic mass scale, one has in reasonable approximation $64 \times 7.5/8$-fold scaling giving $\Gamma(\pi(113), e^+e^-) \simeq 60 \times \times .35 \times \Gamma(\pi, e^+e^-) \simeq .17 \times 10^{-5}$ eV. The experimental lower bound is 1.5×10^{-4}, which is 88 times higher than the estimate.
2. This is a real problem and unless one is ready to consider exotic particles such as lepto-quark like states, the only solution seems to be that $F^2_{\pi\gamma*\gamma*}$ is scaled up by factor of order 30. This requires a reduction of f_π^2 by factor 1/88. As found, the limit on $\Gamma(X, \gamma\gamma)$ allows downwards scaling of f_π^2 by a factor about 1/55 so that it is marginally possible to satisfy the experimental bounds on both decay widths. Scaling by factor $n^2 = 64$ might save the situation.
3. What the increase of $F^2_{\pi\gamma*\gamma*}$ means is not quite clear. The analogy with positronium decay would suggest that the of $|\Psi(0)|^2$ at the origin of quark-antiquark relative coordinate is enhanced by a factor order 30. The scaling up of the size of the color flux tube does not support this view.

   The increase of $F^2_{\pi\gamma*\gamma*}$ could also come from the reduction of axial coupling strength f_π allowing interpretation in terms of the reduction of $|\Psi(0)|^2$ at the origin of the relative coordinate: quarks tend to be father away since p-adic length scale is longer. This might bring additional power of 8.
4. It would seem that the scaling of Planck constant does not work for the model based virtual gamma pair. The presence of α^2 in loop correction would in fact imply scaling down of $\Gamma(\pi, e^+e^-)$ by factor $1/n^2$ so that the scaling up of $1/f_\pi^2$ should compensate also this reduction: scaling by n^4 coming from α_s^4 proportionality of f_π^2 could do the job.

Could dark or p-adically scaled down weak bosons help?

In TGD framework one can criticize the model involving loop integral. If loops can be eliminated both topologically and at the level of Kähler action, they can be present only in QFT description, and one might argue that loopless description should be possible if the problem reduces to the level of single space-time sheet [K46]. If loops and radiative corrections appear at all, they do so only in the positive and negative parts of zero energy states but not in diagrams ad pion could contain also gamma pairs and electron pairs as contributions. This would end up with the virtual particle cloud picture. The most elegant description of course involves no loops at all and it seems that it is possible to achieve this by introducing dark or p-adically scaled down weak bosons.

If one does not accept loops then one must consider a loopless mechanism.

1. I have proposed dark weak bosons to be involved with both cold fusion and chiral selection in living matter [L31, L27, L39]. Since pion couples to axial current, it is natural ask whether dark weak boson Z^0 coupling to axial current could be involved.

   For ordinary weak boson the amplitude would be of course extremely small since it is proportional to $1/m_Z^2$. If weak bosons are dark at $k = 113$ color magnetic flux tubes, the range of weak interactions is scaled up and weak boson becomes effectively massless within dark Compton scale. This would make weak interaction long ranged and make possible the decay of pion via Z^0 annihilation of quark pair to dark Z^0 annihilating to electron pair. Z^0 propagator would be replaced with massless propagator at virtual mass squared given by the mass of dark pion and the rate would be scaled up by factor $m_Z^4/m^4_{\pi(113)} \simeq 0.7 \times 10^{15}$.

2. $\pi(113)-Z$ coupling $f_{\pi(113)Z}$ is analogous to vector-boson-photon coupling $f_{V\gamma}$ of vector boson dominance model. $f_{\pi(113)Z}$ can be identified as the the coupling $f_{\pi(113)Z} = f_\pi m_\pi$ of $\pi(113)$ to axial current [B23]. The order of magnitude for $\Gamma(\pi(113), e^+e^-)$ is given by the usual Feynman rules giving single particle decay rate, and one obtains (I hope that the numerical factors are correct!)

$$\Gamma(\pi, e^+e^-) = \frac{1}{8\pi}\frac{m_e^2}{m_\pi^2}\frac{f_\pi^2}{m_\pi^2}(1 - \frac{4m_e^2}{m_\pi^2} \times m_\pi) \ . \tag{4.9.11}$$

The estimate gives $\Gamma(\pi, e^+e^-) = .93$ eV, which is reasonably near to the experimental upper bound .1 eV.

One must of course be very cautious here. It could also be that p-adically scaled up variant of weak physics with standard value of Planck constant is involved and the weak bosons involved have p-adically scaled down mass scale. I have also proposed [K85] that in living matter a kind of resonant coupling between dark physics ($h_{eff} = n \times h$) and p-adically scaled up non-dark physics exists for $L(k, h_{eff}) = nL(k) = L(k_1)$ requiring $2^{(k-k_1)/2} = n$. Scaled dark particles would transform to ordinary p-adically scaled particles and vice versa.

Could dark electro-weak physics manifest itself in ordinary hadron physics?

Could also ordinary pion decay be understood in terms of the same mechanism? Now the p-adic length scale of pion would be $k = 107$. One would have $\Gamma(\pi(113), e^+e^-) = 2^9\Gamma(\pi(107), e^+e^-)$: the power of two comes from $m_{\pi(113)}^{-3}$ proportionallity of the rate. Using $\Gamma(\pi(107), e^+e^-) = .55 \times 10^{-6}$ eV one obtains the prediction $\Gamma(\pi(113), e^+e^-) = 2.8 \times 10^{-4}$ eV. This is an order of magnitude below the range $[2.3\times 10^{-3}, 0.1]$ eV of the allowed values deduced in [C68]. The estimate is however above the general experimental lower bound 1.5×10^{-4} eV.

Could the p-adic scaling down with ordinary value of Planck constant work better? The propagator factor would be $1/(m_Z^2(k) - m_{\pi(113)}^2)^2$ and if the two masses are near to each other, could increase the rate by resonance factor

$$r = \frac{m_{\pi(113)}^4}{\left[m_Z^2(k) - m_{\pi(113)}^2\right]^2} = \left[\frac{1}{(\frac{m_Z(k)}{m_{\pi(113)}})^2 - 1}\right]^2 \ . \tag{4.9.12}$$

From $m_Z/m_Z(k) = 2^{(k-89)/2} \sim (91/17) \times 10^3$ one obtains the estimate $k - 89 \in \{24, 25\}$ giving $k \in \{113, 114\}$.

1. For $k = 113$ - nuclear scale (!) - the value of the resonance factor would be $r = 1.6$ giving $\Gamma(\pi(113), e^+e^-) = 4.5 \times 10^{-4}$ eV still by factor .16 smaller than the lower bound of authors. The improvement would not be large.
2. For $k = 114$ the resonance factor would be 91.5 giving the estimate $\Gamma(\pi(113), e^+e^-) = .04$ eV belonging to the middle of the range of allowed values. Assuming that there are no numerical errors involved, the best option is $k = 114$ p-adically scaled up Z^0 boson.

This amazing finding forces to ask whether the prevailing picture about leptonic pion decays of hadrons is really correct.

1. The basic motivation for large $h_{eff} = n \times h$ hypothesis was that it makes perturbation theory possible. Strong interactions at low energies provide a key example of the situation in which this hypothesis could be useful.
2. The number theoretic vision that all scattering processes are describable using only tree diagrams in TGD framework [K46] suggests that the descriptions involving loops should have duals involving no loops and be based on couplings of mesons to dark weak bosons. A possible test is provided by the box diagrams associated with CP breaking for kaons and B mesons.

3. Could it be that dark weak interactions at length scale $k = 107$ are responsible for hadronic decays to leptons? Could also vector meson dominance be formulated in terms of dark weak currents? This would explain why the symmetries group $SU(2)_L \times SU(2)_R$ of low energy hadron physics is very much like weak gauge group and conserved vector current (CVC) hypothesis and partially conserved vector current (PCAC) hypothesis.
4. This picture would be also consistent with the M^8-H duality [K107] explaining why $SU(2)_L\times SU(2)_R$ for hadrons and SU(3) for partons provide dual descriptions. The identification of mesons as string like objects conforms with the description of hadronic reactions provided by hadronic string model and the couplings of various mesons to electroweak currents would allow to describe the hadronic weak decays. The scaled down variant of this description would apply to nuclear reactions. What is nice that this proposal is testable.

4.9.4 Model based on nuclear strings

One should construct a model for color bonds connecting nucleons to form nuclear strings.

1. In nuclear string model [L4] nuclei are identified as nuclear strings with nucleons connected by color flux tubes, which can be neutral or charged and can have net color so that color confinement would be in question in nuclear length scale. The possibility of charged color flux tubes predicts the existence of exotic nuclei with some neutrons replaced by proton plus negatively charged color flux tube looking like neuron from the point of view of chemistry or some protons replaced with neutron plus positively charged flux tube. Nuclear excitation with energy determined buy the difference of initial and final color bond energies is in question.
2. The color magnetic flux tubes are analogous to mesons of hadron physics except that they can be colored and are naturally pseudo-scalars in the ground state. These pion like colored flux tube can be excited to a colored state analogous to ρ meson with spin 1 and net color. Color bonds would be rather long flux loops with size scale determined by the mass scale of color bond: 17 MeV gives estimate which as electron Compton length divided by 34 and would correspond to p-adic length scale $k = 121 > 113$ so that length would be about $2^{(121-113)/2} = 16$ times longer than nuclear length scale.
3. If the color bonds (cb) are indeed colored, the mass ratio $m(\rho, cb)/m(\pi, cb)$ need not be equal to $m(\rho, 107)/m(\pi, 107) = 5.74$. If the ρ and π type closed string states are closed string like objects in the sense as elementary particles are so that there is a closed magnetic monopole flux tube along first sheet going through wormhole contact to another space-time sheet and returning back, the scaling $m(\rho/\pi, 107)/m(\rho/\pi, 113) = 8$ should hold true.

With these ingredients one can construct a model for the decay ^{8}Be* $\rightarrow$ ^{8}Be $+X$.

1. ^{8}Be* could correspond to a state for which pionic color(ed) bond is excited to ρ type color(ed) bond. The decay of ^{8}Be* $\rightarrow$ ^{8}Be $+X$ would mean a snipping of a color singlet π meson type *closed* flux tube from the color bond and leaving pion type color bond. The reaction would be analogous to an emission of closed string from open string. $m(X) = 17$ MeV would be the mass of the color-singled closed string emitted equal to $m(\pi, 113) = 17$ MeV. The emitted π would be in $l = 1$ partial wave so that resonant decay to gamma pair would not occur but decay to e^+e^- pairs is possible just like for the ordinary pion.
2. Energy conservation suggests the identification of the excitation energy of ^{8}Be* as the mass difference of ρ and π type colored bonds (cb): $E_{ex}(^8Be*) = m(\rho, cb) - m(\pi, cb) = m(\pi, 113) =$ 17 MeV in the approximation that X is created at rest. If one has $m(\rho, cb)/m(\pi, cb) = m(\rho)/m(\pi)$ - this is not necessary - this gives $m(\rho, cb) \simeq 20.6$ MeV and $m(\pi, cb) \simeq 3.5$ MeV.
3. This estimate is based on mass differences and says nothing about nuclear binding energy. If the color bonds carry positive energy, the binding energy should be localizable to the interaction of quarks at the ends of color bonds with nucleons. The model clearly assumes that the dynamics of color bonds separates from the dynamics of nuclei in the case of the anomaly.
4. The assumption about direct coupling of X to quarks and therefore to nucleons does not makes sense in this framework. Hence protophoby does not hold true in TGD and this is due to the presence of long color bonds in nuclear strings. Also the spin 1 assignment of [C68]

would be wrong. Also the vector boson character would be wrong assumption since pion property allows to obtain gamma decay rate consistent with the experimental limits.

4.9.5 Conclusion

To conclude, the proposed new nuclear physics is physics of the magnetic body of nucleus and involves hierarchy of Planck constants in an essential manner, and the proposed solution to the too low decay rate $\Gamma(\pi(113), e^+e^-)$ could turn out to provide a direct experimental proof for the hierarchy of Planck constants. It also suggests a new approach to the leptonic decays of hadrons based on dark or p-adically scaled down variants of weak interactions. The proposal for the explanation of the anomaly in charge radius of proton involves physics of the magnetic body of proton [K67]. TGD inspired quantum biology is to high degree quantum physics of magnetic body. Maybe the physics of magnetic body differentiates to its own branch of physics someday.

4.10 Cold Fusion, Plasma Electrolysis, Biological Transmutations,And Burning Salt Water

The article of Kanarev and Mizuno [D95] reports findings supporting the occurrence of cold fusion in NaOH and KOH hydrolysis. The situation is different from standard cold fusion where heavy water D_2O is used instead of H_2O.

One can understand the cold fusion reactions reported by Mizuno as nuclear reactions in which part of what I call dark proton string having negatively charged color bonds (essentially a zoomed up variant of ordinary nucleus with large Planck constant) suffers a phase transition to ordinary matter and experiences ordinary strong interactions with the nuclei at the catode. In the simplest model the final state would contain only ordinary nuclear matter. The generation of plasma in plasma electrolysis can be seen as a process analogous to the positive feedback loop in ordinary nuclear reactions.

Rather encouragingly, the model allows to understand also deuterium cold fusion and leads to a solution of several other anomalies.

1. The so called lithium problem of cosmology (the observed abundance of lithium is by a factor 2.5 lower than predicted by standard cosmology [E8]) can be resolved if lithium nuclei transform partially to dark lithium nuclei.
2. The so called $H_{1.5}O$ anomaly of water [D104, D93, D119, D60] can be understood if 1/4 of protons of water forms dark lithium nuclei or heavier dark nuclei formed as sequences of these just as ordinary nuclei are constructed as sequences of ^4He and lighter nuclei in nuclear string model. The results force to consider the possibility that nuclear isotopes unstable as ordinary matter can be stable dark matter.
3. The mysterious behavior burning salt water [D1] can be also understood in the same framework.
4. The model explains the nuclear transmutations observed in Kanarev's plasma electrolysis. Intriguingly, several biologically important ions belong to the reaction products in the case of NaOH electrolysis. This raises the question whether cold nuclear reactions occur in living matter and are responsible for generation of biologically most important ions.

4.10.1 The Data

Findings of Kanarev

Kanarev has found that the volume of produced H_2 and O_2 gases is much larger than the volume resulting in the electrolysis of the water used in the process. If one knows the values of p and T one can estimate the volumes of H_2 and O_2 using the equation of state $V = nT/p$ of ideal gas. This gives

$$V(H_2; p, T) = \frac{A(H_2)}{A(H_2O)} \times \frac{M(H_20)}{m_p} = \frac{1}{9}\frac{M(H_20)}{m_p} \times \frac{T}{p} \ .$$

	$M(H_2O)/kg$	$V(gas)/m^3$	$\frac{V(gas)}{V(H_2O)}$	$\frac{[V(gas)/V(H_2O)]}{r(gas)}$
KOH	.272	8.75	3.2×10^4	17.4
NaOH	.445	12.66	2.8×10^4	15.2

Table 4.10: The weight of water used in the electrolysis and the total volume of gas produced for KOH and NaOH electrolysis. $r(gas)$ denotes the naïve prediction for the total volume of gas per water volume appearing in previous table. For KOH *resp.* NaOH the volume ratio $[V(gas)/V(H_2O)]$ is by a factor $r = 17.4$ *resp.* $r = 15.2$ higher than the naïve estimate.

KOH				
Element(Z, N)	Al(13, 27)	Si(14, 28)	Cl(17, 18)	K(19, 20)
		0.94		4.50
Element(Z, N)	Ca(20, 20)	Cr(24, 28))	Fe(26, 29)	Cu(29, 34)
		1.90	93.0	0.45
NaOH				
Element(Z, N)	Al(13, 27)	Si(14, 28)	Cl(17, 18)	K(19, 20)
	1.10	0.55	0.20	0.60
Element(Z, N)	Ca(20, 20)	Cr(24, 28))	Fe(26, 29)	Cu(29, 34)
	0.40	1.60	94.0	0.65

Table 4.11: The per cent of various nuclei in catode for KOH and NaOH electrolysis.

Here $M(H_20)$ is the total mass of the water (.272 kg for KOH and.445 kg for NaOH).

In the situation considered one should be able to produce from one liter of water 1220 liters of hydrogen and 622 liters of oxygen giving

$$V(H_2)/V(H_2O) = 1.220 \times 10^3 \ , \qquad V(O_2)/V(H_2O) = .622 \times 10^3 \ ,$$

$$r(gas) = V(H_2 + O_2)/V(H_2O) = 1.844 \times 10^3 \ , \quad V(H_2)/V(O_2)) \simeq 1.96 \ .$$

$V(H_2)/V(O_2) \simeq 1.96$ is 4 per cent smaller than the prediction $V(H_2)/V(O_2) = 2$ of the ideal gas approximation.

The volumes of O_2 and H_2 are not reported separately. The table gives the total volumes of gas produced and ratios to the volume of water used.

Findings of Mizuno

Mizuno in turn found that the Fe catode contains Si, K, Cr, Fe, Cu for both KOH and NaOH electrolysis and in case of NaOH also Al, Sl, Ca. The fraction of these nuclei is of order one per cent. **Table 4.11** gives the fractions for both KOH and NaOH.

The results supports the view that nuclear reactions involving new nuclear physics are involved and that part of H_2 and O_2 could be produced by nuclear reactions at the catode.

1. For Si, K, Cr, Fe, and Cu the mechanism could be common for both $NaOH$ and KOH electrolysis and presumably involve fission of Fe nuclei. The percent of K in KOH is considerably larger than in $NaOH$ case and this is presumably due to the absorption of K^+ ions by the catode.
2. For Al, Si, and Ca the reaction occurring only for Na should involve Na ions absorbed by the catode and suffering cold fusion with some particles -call them just X - to be identified.
3. Cu is the only element heavier than Fe and is expected to be produced by fusion with X. Quite generally, the fractions are of order one per cent.

4. The authors suggests that the extra volume of H_2 and O_2 molecules is due to nuclear reactions in the catode. A test for this hypothesis would be the ratio of H_2 and O_2 volumes. Large deviation from value 2 would support the hypothesis. The value near 2 would in turn support the hypothesis that the water produced by electrolysis is considerably denser than ordinary water.

4.10.2 $H_{1.5}O$ Anomaly And Nuclear String Model

It would seem that some exotic nuclei, perhaps consisting of protons, should be involved with the cold fusion. Concerning the identification of these exotic particles there are several guidelines. $H_{1.5}O$ anomaly, anomalous production of e^+e^- pairs in heavy ion collisions, and nuclear string model.

$H_{1.5}O$ anomaly and anomalous production of electron-positron pairs in heavy ion collisions

There exists an anomaly which could be explained in terms of long open nuclear strings. The explanation of $H_{1,5}O$ anomaly [D104, D93, D119, D60] discussed in [K42] as a manifestation of dark protons was one of the first applications of TGD based ideas about dark matter. The proposed explanation is that the fraction of 1/4 of protons is in atto-second time scale dark and invisible in electron scattering and neutron diffraction. Note that atto-second time scale corresponds to the time during which light travels a length of order atomic size.

A natural identification of the dark protons would be in terms of protonic strings behaving like nuclei having anomalously large size, which would be due to the anomalously large value of Planck constant. A partial neutralization by negatively charge color bonds would make these states stable.

The TGD based explanation of anomalous production of electron-positron pairs in the collisions of heavy nuclei just above the Coulomb wall [K115] is in terms of lepto-pions consisting of pairs of color octet electron and positron allowed by TGD and having mass slightly below $2m_e \simeq 1$ MeV. The strong electromagnetic fields created in collision create coherent state of lepto-pions decaying into electron positron pairs.

Nuclear string model

The nuclear string model describes nuclei as string like structures with nucleons connected by color magnetic flux tubes whose length is of order electron Compton length about 10^{-12} meters and even longer and thus much longer than the size scale of nuclei themselves which is below 10^{-14} meters. Color magnetic flux tubes define the color magnetic body of nucleus and each flux tube has colored fermion and anti-fermion at its ends. The net color of pair is non-vanishing so that color confinement binds the nucleons to the nuclear string. Nuclei can be visualized as structures analogous to plants with nucleus taking the role of seed and color magnetic body of much larger size taking the role of plant with color flux tubes however returning back to another nucleon inside nucleus.

One can imagine two basic identifications of the fermions.

1. For the first option fermions are identified as quarks. The color flux tube can have three charge states $q = +1, 0, -1$ according to whether it corresponds to $u\overline{d}, u\overline{u} + d\overline{d}$, or $\overline{u}d$ type state for quarks. This predicts a rich spectrum of exotic nuclei in which neutrons consist actually of proton plus negatively charged flux tube. The small mass difference between neutron and proton and small mass of the quarks (of order MeV) could quite well mean that these exotic nuclei are identified as ordinary nuclei. The findings of [C30] [C30] support the identification as quarks.
2. Lepto-hadron hypothesis [K115] encourages to consider also the possibility that color bonds have color octet electrons at their ends. This would make it easier to understand why lepto-pions are produced in the collisions of heavy nuclei.
3. One can also consider the possibility that the color bonds are superpositions of quark-antiquark pairs and colored electron-positron pairs.

Two options

One can consider two options for protonic strings. Either their correspond to open strings connected by color magnetic flux tubes or protons are dark so that giant nuclei are in question.

1. Protonic strings as open strings?

Color flux tubes connecting nucleons are long and one can ask whether it might be possible also open nuclear strings with long color flux tubes connecting widely separate nucleons even at atomic distance. These kind of structures would be favored if the ends of nuclear string are charged.

Even without assumption of large values of Planck constant for the color magnetic body and quarks the net length of flux tubes could be of the order of atomic size. Large value $\hbar$ would imply an additional scaling.

The simplest giant nuclei constructible in this manner would consist of protons connected by color magnetic flux tubes to from an open string. Stability suggest that the charge per length is not too high so that some minimum fraction of the color bonds would be negatively charged. One could speak of exotic counterparts of ordinary nuclei differing from them only in the sense that size scale is much larger. A natural assumption is that the distance between charged protonic space-time sheets along string is constant.

In the sequel the notation $X(z,n)$ will be is used for the protonic string containing net charge z and n negatively charged bonds. $a = z + n$ will denote the number of protons. z, n and a are analogous to nuclear charge Z, neutron number N, and mass number A. For open strings the charge is $z \geq 1$ and for closed strings $z \geq 0$ holds true.

This option has however problem. It is difficult imagine how the nuclear reactions could take place. One can imagine ordinary stringy diagrams in which touching of strings means that proton of protonic string and ordinary nucleus interact strongly in ordinary sense of the word. It is however difficult to imagine how entire protonic string could be absorbed into the ordinary nucleus.

2. Are protons of the protonic string dark?

Second option is that protonic strings consist of dark protons so that nuclear space-time-sheet has scale up size, perhaps of order atomic size. This means that fermionic charge is distributed in much larger volume and possibly also the fermions associated with color magnetic flux tubes have scaled up sized. The value $\hbar = 2^{11}\hbar_0$ would predict Compton length of order 10^{-12} m for nucleon and upper size of order 10^{-11} for nuclei.

Cold nuclear reactions require a transformation of dark protons to ordinary ones and this requires leakage to the sector of the embedding space in which the ordinary nuclei reside (here the book metaphor for embedding space is very useful). This process can take place for a neutral part of protonic string and involves a reduction of proton and fermion sizes to normal ones. The phase transition could occur first only for a neutral piece of the protonic string having charges at its ends and initiate the nuclear reaction. Part of protonic string could remain dark and remaining part could be "eaten" by the ordinary nucleus or dark protonic string could "eat" part of the ordinary nuclear string. If the leakage occurs for the entire dark proton string, the nuclear reaction itself is just ordinary nuclear reaction and is expected to give out ordinary nuclei. What is important that apart from the crucial phase transition steps in the beginning and perhaps also in the end of the reaction, the model reduces to ordinary nuclear physics and is in principle testable.

The basic question is how plasma phase resulting in electrolysis leads to the formation of dark protons. The proposal [K43] that the transition takes place with perturbative description of the plasma phase fails, might be more or less correct. Later a more detailed nuclear physics picture about the situation emerges.

3. What happens to electrons in the formation of protonic strings?

One should answer two questions.

1. What happens to the electrons of hydrogen atoms in the formation of dark protonic strings?
2. In plasma electrolysis the increase of the input voltage implies a mysterious reduction of the electron current with the simultaneous increase of the size of the plasma region near the catode [C82]. This means reduction of conductance with voltage and thus non-linear behavior. Where does electronic charge go?

Obviously the negatively charged color bond created by adding one proton to a protonic string could take the charge of electron and transform electrons as charge carriers to color bonds of dark Li isotopes which charge $Z = 3$ by gluing to existing protons sequence proton and negatively charged color bond. If the proton comes from H_2O OH^- replaces electron as a charge carrier. This would reduced the conductivity since OH^- is much heavier than electron. This kind of process and its reversal would take place in the transformation of hydrogen atoms to dark proton strings and back in atto-second time scale.

The color bond could be either $\overline{u}d$ pair or $e_8\overline{\nu}_8$ pair or quantum superposition of these. The basic vertex would involve the exchange of color octet super-symplectic bosons and their neutrino counterparts. Lepton number conservation requires creation of color singlet states formed of color octet neutrinos which ar bosons and carrying lepton number -2. One color confined neutrino pair would be created for each electron pair consumed in the process and might escape the system: if this happens, the process is not reversible above the time scale defined by colored neutrino mass scale of order.1 eV which happens to be of order.1 atto-seconds for ordinary neutrinos. Also ordinary nuclei could consist of nucleons connected by identical neutral color bonds (mostly).

The exchange of light counterparts of charged ρ mesons having mass of order MeV could lead to the transformation of neutral color bonds to charged ones. In deuterium cold fusion the exchange of charged ρ mesons between D and Pd nuclei could transform D nuclei to states behaving like di-neutrons so that cold fusion for D could take place. In the earlier proposal exchange of W^+ boson of scaled variant of weak interactions was proposed as a mechanism.

The formation of charged color bonds binding new dark protons to existing protonic nuclear strings or giving rise to the formation of completely new protonic strings would also increase of the rates of cold nuclear reactions.

Note that this picture leaves open the question whether the fermions associated with color bonds are quarks or electrons.

Nuclei and their dark variants must have same binding energy scale at nuclear quantum criticality

The basic question is what happens to the scale of binding energy of nuclei in the zooming up of nuclear space-time sheet. Quantum criticality requires that the binding energies scales must be same.

1. Consider first the binding energy of the nuclear strings. The highly non-trivial prediction of the nuclear string model is that the contributions of strong contact interactions at nuclear space-time sheet (having size $L < 10^{-14}$ m) to the binding energy vanish in good approximation for ground states with vanishing strong isospin. This means that the binding energy comes from the binding energy assignable to color bonds connecting nucleons together.

2. Suppose that this holds true in a good approximation also for dark nuclei for which the distances of nucleons at zoomed up nuclear space-time sheet (having originally size below 10^{-14} meters) are scaled up. As a matter fact, since the scale of binding energy for contact interactions is expected to reduce, the situation is expected to improve. Suppose that color bonds with length of order 10^{-12} m preserve their lengths. Under these assumptions the nuclear binding energy scale is not affected appreciably and one can have nuclear quantum criticality. Note that the length for the color bonds poses upper limit of order 100 for the scaling of Planck constant.

It is essential that the length of color bonds is not changed and only the size of the nuclear space-time sheet changes. If also the length and thickness of color bonds is scaled up then a naïve scaling argument assuming that color binding energy related to the interaction of transforms as color Coulombic binding energy would predict that the energy scales like $1/\hbar$. The binding energies of dark nuclei would be much smaller and transformation of ordinary nuclei to dark nuclei would not take place spontaneously. Quantum criticality would not hold true and the argument explaining the transformation of ordinary Li to its dark counterpart and the model for the deuterium cold fusion would be lost.

4.10.3 A Model For The Observations Of Mizuno

The basic objection against cold nuclear reactions is that Coulomb wall makes it impossible for the incoming nuclei to reach the range of strong interactions. In order that the particle gets to the catode from electrolyte it should be positively charged. Positive charge however implies Coulomb wall which cannot be overcome with the low energies involved.

These two contradictory conditions can be satisfied if the electrolysis produces exotic phase of water satisfying the chemical formula $H_{1.5}O$ with 1/4 of protons in the form of almost neutral protonic strings can possess only few neutral color bonds. The neutral portions of the protonic string, which have suffered phase transition to a phase with ordinary Planck constant could get very near to the target nucleus since the charges of proton can be neutralized in the size scale of proton by the charges $\overline{u}$ and d quarks or e and $\overline{\nu}$ associated with the two bonds connecting proton to the two neighboring protons. This could make possible cold nuclear reactions.

It turns out that the model fixes protonic strings to isotopes of dark Lithium (with neutrons replaced with proton plus negatively charged color bond). What is intriguing is that the biologically most important ions (besides Na^+) Cl^-, K^+, and Ca^{++} appear at the catode in Kanarev's plasma electrolysis actually result as outcomes of cold nuclear reactions between dark Li and Na^+.

General assumptions of the model

The general assumptions of the model are following.

1. Ordinary nuclei are nuclear strings, which can contain besides neutrons also "pseudo-neutrons" consisting of pairs of protons and negatively charged color bonds. The model for D cold fusion requires that the Pd nuclei contain also "pseudo-neutrons".
2. Reaction products resulting in the fusion of exotic protonic string transforming partially to ordinary nuclear matter (if originally in dark phase) consist of the nuclei detected in the catode plus possibly also nuclei which form gases or noble gases and leak out from the catode.
3. Si, K, Cr, and Cu are produced by the same mechanism in both KOH and NaOH electrolysis.
4. Al, Cl, and Ca is produced by a mechanism which must involve cold nuclear reaction between protonic string and Na ions condensed on the catode.
5. $Cu(Z,N) = Cu(29,34)$ is the only product nucleus heavier than $Fe(26,29)$. If no other nuclei are involved and Cu is produced by cold fusion

   $$X(z,n) + Fe(26,29) \rightarrow Cu(29,34) \ ,$$

   the anatomy of protonic string must be

   $$X(z,n) = X(3,5)$$

   so that dark variant $Li(3,5)$ having charge 3 and mass number 8 would be in question. $X(3,5)$ would have 2 neutral color bonds and 5 negatively charged color bonds. To minimize Coulomb interaction the neutral color bonds must reside at the ends of the string. For quark option one would have charge $1+2/3$ at the first end and $1+1/3$ at the second end and charges of all protons between them would be neutralized. For color octet lepton color bond one would have charge 2 at the other end and zero at the other end.

   For quark option the net protonic charge at the ends of the string causing repulsive interaction between the ends could make protonic string unstable against transition to dark phase in which the distance between ends is much longer even if the ends are closed within scaled up variant of the nuclear volume.

Arbitrarily long strings $X(3,n)$ having neutral bonds only at their ends are possible and their fusions lead to neutron rich isotopes of Cu nucleus decaying to the stable isotope. Hence the prediction that only Cu is produced is very general.

The simplest dark protonic strings $X(3,n)$ have quantum numbers of $Li(3,n)$. One of the hard problems of Big Bang cosmology is that the measured abundance of lithium is by a factor of about 2.5 lower than the predicted abundance [E8]. The spontaneous transformation of $Li(3,n)$ isotopes to their dark variants could explain the discrepancy. Just by passign notice that Li has mood stabilizing effect [C6]: the spontaneous transformation of Li^+ to its dark variant might relate to this effect.

Production mechanisms for the light nuclei common to Na and K

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These nuclei must be produced by a fission of Fe nuclei.

1. For $Si(14,14)$ production the mechanism would be cold fission of Fe nucleus to two parts in the collision with the protonic string:

$$X(3,5) + Fe(26,29) \rightarrow Si(14,14) + Al(13,14) + X(2,6) \ .$$

   $X(2,6)$ represent dark or ordinary $He(2,6)$. As a noble gas He isotope would leave the catode. Note that arbitrarily long proton strings with two neutral bonds at their ends give neutron rich isotope of Si and exotic or ordinary isotope of He so that again the prediction is very general.

2. $K(19,20)$ is produced much more in KOH which most probably means that part of K^+ is absorbed from the electrolyte. In this case the reaction could proceed as follows:

$$X(3,5) + Fe(26,29) \rightarrow K(19,20) + Ne(7,7) + X(3,7) \ .$$

   Note that the neutron number could be distributed in many ways between final states. For arbitrarily long proton string with two neutral bonds at ends higher neutron rich isotopes of K and Ne are produced. As noble gas Ne would leak out from the catode.

   Ordinary $Li(3,7)$ would decay by neutron emission to stable isotopes of Li. The temperature of the system determines whether Li boils out (1615 K under normal pressure). Li is not reported to appear in the catode. In plasma electrolysis the temperature is in the interval $.5\times 10^4$- 10^4 C and around 10^3 C in the ordinary electrolysis so that the high temperature might explain the absence of Li. Also the in-stability of Li isotopes against transition to dark Li in electrolyte would imply the absence of Li.

3. For $Cr(24,28)$ production the simplest reaction would be

$$X(3,5) + Fe(26,29) \rightarrow Cr(24,28) + He(2,2) + X(3,4) \ .$$

   Helium would leak out as noble gas. Proton string would shorten by one unit and keep its charge. $X(3,4)$ would represent the stable isotope $Li(3,4)$ or its dark counterpart and what has been said in 2) applies also now.

How to understand the difference between KOH and NOH?

One should understand why Al, Cl, and Ca are not detected in the case of KOH electrolysis.

Al, Cl, and Ca would be created in the fusion of protonic strings with $Na(11,12)$ nuclei absorbed by the catode. With this assumption the rates are expected to be of same order of magnitude for all these processes as suggested by the one per cent order of magnitude for all fractions.

One can imagine two reaction mechanisms.

I: One could understand the production assuming only $X(3,5)$ protonic strings if the number of $X(3,5)$ strings absorbed by single Na nucleus can be $k=1,2,3$ and that nuclear fission can take place after each step with a rate which is slow as compared to the rate of absorptions involving also the phase transition to dark matter. This is however highly implausible since ordinary nuclear interactions are in question.

II: Second possibility is that the protonic strings appearing with the highest probability are obtained by fusing copies of the basic string $X(3,5)$ by using neutral color bond between the strings. The minimization of electrostatic energy requires that neutral color bonds are equally spaced so that there are three completely neutralized protons between non-neutralized protons.

One would have thus at least the strings $X(3,5)$, $X(6,10)$, and $X(9,15)$, which correspond to dark $Li(3,5)$ and dark variants of the unstable isotopes $C(6,10)$ and $F(9,15)$. In nuclear string model also ordinary nuclei are constructed from $He(2,2)$ strings and lighter strings in completely analogous manner, and one could perhaps see the dark nuclei constructed from $Li(3,5)$ as the next level of hierarchy realized only at the level of dark matter.

The charge per nucleon would be 3/8 and the length of the string would be a multiple of 8. Interestingly, the numbers 3, 5, and 8 are subsequent Fibonacci numbers appearing very frequently also in biology (micro-tubules, sunflower patterns). The model predicts also the occurrence of cold fusions $X(z=3k, n=5k) + Fe(26,29) \to (Z,N) = (26+3k, 29+5k)$. For $k=2$ this would give $Ge(32,39)$ which is stable isotope of Ge. For $k=3$ one would have $(Z,N) = (35,44)$ which is stable isotope of Br [C137, C12].

Consider now detailed description of the reactions explaining the nuclei detected in the catode.

1. $Al(13,14)$ would be produced in the reaction

$$X(3,5) + Na(11,12) \to Al(13,14) + X(1,3) \ .$$

   $H(1,3)$ or its dark variant could be in question. Also the reaction $X(3,5) + Na(11,12) \to Al(13,17) + p$, where $Al(12,17)$ is an unstable isotope of Al is possible.

   The full absorption of protonic string would yield $Si(14,17)$ beta-decaying to $P(15,16)$, which is stable. Either P leaks out from the catode or full absorption does not take place appreciably.

2. $Cl(17,18)$ would be produced by the sequence

$$\begin{array}{lrcl} \mathbf{I1}: & 2X(3,5) + Na(11,12) & \to & Cl(17,18) + X(0,4) \ , \\ \mathbf{I2}: & X(6,10) + Na(11,12) & \to & Cl(17,18) + X(0,4) \ . \end{array}$$

   $X(0,4)$ represents ordinary or dark tetra-neutron [C115, C81, C25]. The instability of the transformation of tetra-neutron to dark matter could explain why its existence has remained controversial.

   If the protonic string were absorbed completely, the resulting $Cl(17,22)$ - if equivalent to ordinary nucleus - would transform via beta-decays to $A(18,23)$ and then to $K(19,22)$, which is stable and detected in the target.

3. $Ca(20,20)$ would be produced in the reaction

$$\begin{array}{lrcl} \mathbf{I1}: & 3X(3,5) + Na(11,12) & \to & Ca(20,20) + X(0,7) \ , \\ \mathbf{I2}: & X(9,15) + Na(11,12) & \to & Ca(20,20) + X(0,7) \ . \end{array}$$

   $X(0,7)$ would be dark counterpart of "septa-neutron". The complete absorption of nuclear string would produce $Ca(20,27)$, which (if ordinary nucleus) transforms via beta decays to $Sc(21,26)$ and then to $Ti(22,25)$, which is stable.

4.10.4 Comparison With The Model Of Deuterium Cold Fusion

It is interesting to compare the model with the model for cold fusion [C112, C1] reported using deuterium target and D_2O instead of water.

Earlier model

1. The model is based on the assumption that D nuclei in the target suffer a phase transition to a state in which D nuclei become neutral so that the color bond between neutron and proton becomes negatively charged: one has effectively di-neutrons.

2. The mechanism of charging of color bond must either involve weak interactions or exchange of lepto-ρ mesons already discussed briefly. The proposal is that the exchange of W bosons of scaled up version of weak physics is involved with the range of interactions given by atomic length scale. The exchange of W^+ bosons was assumed to take place between Pd and D nuclei. This mechanism could lead to the formation of negatively charged color bonds in also ordinary nuclei.

3. The neutrality of exotic D nuclei allows to overcome Coulomb wall. One can understand the reported selection rules: in particular the absence of Helium isotopes (only isotopes of H are detected). The absence of gamma rays can be understood if the resulting gamma rays are dark and leak out before a transformation to ordinary gamma rays.

Are D nuclei in Pd target dark or not?

The question whether the exotic D nuclei are dark was left pending. The recent model suggests that the answer is affirmative.

1. The basic difference between the two experiments would be that in Kanarev's experiments incoming nuclei are dark whereas in D fusion catode contains the dark nuclei and cold nuclear reactions occur at the "dark side" and is preceded by ordinary-to-dark phase transition for incoming D.
2. D cold fusion occurs for a very restricted range of parameters characterizing target: the first parameter is doping ratio: essentially one D nucleus per one Pd nucleus is needed which would fit with the assumption that scaled up size is of the order of atom size. Temperature is second parameter. This and the fact that the situation is highly sensitive to perturbations conforms with the interpretation as a phase transition to dark matter occurring at quantum criticality.
3. The model for Kanarev's findings forces to consider the possibility that dark D nuclei combine to form longer strings and can also give rise to dark $Li(3,5)$ explaining the observed nuclear transmutations in the target.
4. In cold nuclear reactions incoming nuclei would transform to dark nuclei (the picture as a leakage between different pages of a book like structure defined by the generalized embedding space is helpful). The reaction would take place for dark nuclei in zoomed up nuclear physics and the reaction products would be unstable against phase transition to ordinary nuclei.
5. Is it then necessary to assume that target D nuclei are transformed to neutral ones (di-neutrons effectively) in order to have cold nuclear reactions? Nuclear space-time sheets are scaled up. If nucleon space-time sheets are not scaled up, p and n are connected by color magnetic flux tubes of same length as in the case of ordinary nuclei but located at much larger nuclear space-time sheet. The classical analog for the quantal distribution of nucleon charges is even charge distribution in a sphere or radius R defined by the charge of the scaled up nucleus. The height of the Coulomb wall is $E_c = e^2/R$. If $R = a$, a the atomic radius, one has $E_c \sim .1$ keV. The wall is by a factor 10^{-4} lower than in ordinary nuclear collision so that the incoming D nucleus might overcome the Coulomb wall.

   If Coulomb wall can be overcome, all dark variants of $D+D$ reaction are possible. Helium nuclei have not been however detected, which supports the view that D in target is transformed to its neutral variant. Gamma rays would be dark and could leak out without detection which would explain the absence of gamma rays.

Nuclear quantum criticality is essential

A note about the energetics of cold nuclear reactions is in order. The nuclear quantum criticality deriving from the cancelation of the contact interaction energies between nucleons for isospin singlets and scaling up of *only* nuclear space-time sheet is an absolutely essential assumption. Otherwise dark D would have much smaller binding energy scale than the visible one, and ordinary D in the Pd target could not transform to dark "di-neutron" state. Also the transformation of incoming D to its dark variant D at catode could not take place.

4.10.5 What Happens To Oh Bonds In Plasma Electrolysis?

For an innocent novice one strange aspect of hydrolysis is how the OH bonds having energies of order 8 eV can be split in temperatures corresponding to photon energies of order.5 eV. Kanarev has suggested his own theory for how this could happen [D117]. TGD suggests that OH bonds are transformed to their dark variants with scaled down bond energy and that there might be no essential difference between OH bond and hydrogen bond.

The reduction of energy of OH bonds in plasma electrolysis

Kanarev has found that in plasma electrolysis the energy of OH bonds is reduced from roughly 8 eV to about.5 eV, which corresponds to the fundamental metabolic energy quantum identifiable as the zero point kinetic energy liberate as proton drops from $k = 137$ space-time sheet to much larger space-time sheet. In pyrolysis [D14] similar reduction could occur since the pyrolysis occurs above temperature about 4000 C conforming with the energy scale of hydrogen bond.

The explanation discussed in [K113] is that there is some mechanism exciting the bonds to a state with much lower bond energy. Dark matter hierarchy [K43] suggests that the excitation corresponds to the transformation of OH bond to dark bond so that the energy scale of the state is reduced.

Also in the ordinary electrolysis of water [D4] the energy of OH bonds is reduced to about 3.3 eV meaning a reduction factor of order 2. The simplest interpretation would be as a transformation of OH bonds to dark OH bond with $\hbar \to 2\hbar$ (the scaling could be also by some other integer or even rational). The energy needed to transform the bond to dark bond could come from remote metabolism via the dropping of dark protons from a dark variant of some sub-atomic space-time sheet with size not smaller than the size of the atomic space-time sheet to a larger space-time sheet.

In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

$H_{1.5}O$ anomaly suggests that 1/4 of protons of water are dark in atto-second time scale [K42] and one can imagine that both protons of water molecule can become dark under conditions defined by plasma electrolysis. Also the atomic space-time sheets and electron associated with OH bonds could become dark.

Atomic binding energies transform as $1/\hbar^2$. If the energy of hydrogen bond transforms like Coulombic interaction energy as given by the perturbative calculation, it is scaled down as $1/\hbar$ since the length of the bond scales up like $\hbar$. Effectively $\alpha_{em} \propto 1/\hbar$ is replaced by its scaled down value. For $\hbar \to 2^4\hbar_0$ the energy would scale from 8 eV to.5 eV and the standard metabolic energy quantum could induce the splitting of the dark OH bond. If 2^4 is the scale factor of $\hbar$ for dark nuclear space-time sheets, their size would be of order 10^{-3} meters. The model for cold fusion is consistent with this since what matters is different value of Planck constant for the dark nuclear space-time sheets.

There is an objection against the reduction of OH bond energy. The bonds could be split by a process in which dark nuclear reactions kick protons to $k = 133$ dark space-time sheet. In this case the maximal zero point kinetic energy liberated in the dropping back would be 8 eV and could induce breaking of OH bond. For $\hbar/\hbar_0 \geq 4$ the size of $k = 133$ dark space-time sheet would be larger than the size of $k = 137$ atomic space-time sheet.

Are hydrogen bonds dark OH bonds?

The fact that the energy of hydrogen bonds [D9] is typically around.5 eV forces to ask what distinguishes hydrogen bond from dark OH bond. Could it be that the two bonds are one and the same thing so that dark OH bonds would form standard part of the standard chemistry and molecular biology? In hydrogen bond same hydrogen would be shared by the oxygen atoms of the neighboring atoms. For the first O the bond would be ordinary OH bond and for the second O its dark variant with scaled down Coulomb energy. Under conditions making possible pyrolysis and plasma electrolysis both bonds would become dark. The variation of the hydrogen bond energy could reflect the variation of the scaling factor of $\hbar$.

The concentration of the spectrum of bond energies on integer multiples of fundamental energy scale - or even better, on powers of 2 - would provide support for the identification. There is evidence for two kinds of hydrogen bonds with bond energies in ratio 1: 2 [D101] : the TGD based model is discussed in [K42].

Mechanism transforming OH bonds to their dark counterparts

The transformation of OH bonds to dark bonds would occur both in ordinary and plasma electrolysis and only the change of Planck constant would distinguish between the two situations.

1. Whatever the mechanism transforming OH bonds to their dark counterparts is, metabolic energy is needed to achieve this. Kanarev also claims over-unity energy production [D117]. Cold fusion researchers make the same claim about ordinary electrolysis. Cold nuclear reactions between Na^+ (K^+) and dark protons and dark Li could obviously serve as the primary energy source. This would provide the fundamental reason for why $NaOH$ or KOH must be present. Cold nuclear reactions would thus occur also in the ordinary electrolysis of water and provide the energy inducing the transition of OH bonds to dark ones by (say) $\hbar \rightarrow 2\hbar$ transition.
2. One can imagine several metabolic mechanisms for the visible-to-dark transformation of HO bonds. The energy spectrum of cold nuclear reactions forms a continuum whereas the energies needed to transform OH bonds to their dark variants presumably are in narrow bands. Therefore the energy liberated in cold nuclear reactions is not probably used as such. It is more plausible that standard metabolic energy quanta liberated in the dropping of protons (most naturally) to larger space-time sheets are utilized. The most important metabolic energy quanta for the dropping of proton come as $E_k = 2^{k-137}kE_0$: $E_0 = .5$ eV is liberated in the dropping of proton from atomic space-time sheet ($k = 137$) to much larger space-time sheet (the discrete spectrum of increments of the vacuum energy in the dropping approaches this energy [K78]). The energy liberated in the dark nuclear reactions would "load metabolic batteries" by kicking the dark protons to the dark variants of $k < 137$ space-time sheet (the size of dark atomic space-time sheet scales like $\hbar$). Their dropping to larger space-time sheets would liberate photons with energies near to those transforming OH bonds to hydrogen bonds.
3. A signature for the standard metabolic energy quanta would be visible light at $2eV$ and also discrete lines below it accumulating to $2eV$. Kanarev's indeed reports the presence of red light [D117] as a signature for the occurrence of process.

4.10.6 A Model For Plasma Electrolysis

Kanarev's experiments involve also other strange aspects which lead to the view that cold nuclear reactions and dark matter physics are essential aspects of not only plasma electrolysis of Kanarev but also of ordinary electrolysis and responsible for the claimed over unity energy production. Biologically important ions are produced in reactions of dark Li and Na^+ and there is very strong electric voltage over the cell membrane. This inspires the question whether cold nuclear reactions serve as a metabolic energy source in living cell and are also responsible for production of ions heavier than Na^+.

Brief description of plasma electrolysis

Electrolysis [D4], pyrolysis [D14] , and plasma electrolysis [C82], [D117] of water are methods of producing free hydrogen. In pyrolysis the temperature above 4000 C leads to hydrogen and oxygen production. Oxygen production occurs also at catode and hydrogen yield is higher than given by Faraday law for ordinary electrolysis [D4].

The article of Mizuno and collaborators [C82] about hydrogen production by plasma electrolysis contains a brief description of plasma electrolysis. A glow discharge occurs as the input voltage used in electrolysis is above a critical value and plasma is formed near catode. In the arrangement of [C82] plasma state is easily achieved above 140 V. If the values of temperature and current density are right, hydrogen generation in excess of Faraday's law as well as a production of oxygen at catode (not possible in ideal electrolysis) are observed. Above 350 V the control of the process becomes difficult.

What really happens in electrolysis and plasma electrolysis?

1. Ordinary electrolysis

To understand what might happen in the plasma electrolysis consider first the ordinary electrolysis of water.

1. The arrangement involves typically the electrolyte consisting of water plus $NaOH$ or KOH without which hydrolysis is impossible for thermodynamical reasons.
2. Electronic current flows from the anode to catode along a wire. In electrolyte there is a current of positively charged ions form anode to catode. At the catode the reaction $2H_2O + 2e^- \rightarrow 2H_2 + 2OH^-$ yields hydrogen molecules seen as bubbles in water. At the anode the reaction $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ is followed by the reaction $2H^+ + 2e^- \rightarrow H_2$ and the flow of $2e^-$ to the catode along wire. The net outcome is hydrolysis: $H_2O \rightarrow 2H_2 + 2O_2$. Note that O_2 is produced only at anode and H_2 at both anode and catode.

2. What happens in plasma electrolysis?

In plasma electrolysis something different might happen.

1. Cold nuclear reactions should take place at catode in presence of Na^+ ions plus dark Li and should be in equilibrium under ordinary conditions and contribute mainly to the formation of dark OH bonds. The rate of cold nuclear reactions increases with input voltage V since the currents of Na^+ and dark Li to the catode increase. Obviously the increased rate of energy yield from dark nuclear reactions could be the real reason for the formation of plasma phase above critical voltage.
2. By previous considerations the reduction of electron current above critical voltage has interpretation as a transition in which electronic charge is transferred to negative charge of color bonds of dark proton strings. Existing protonic strings could grow longer and also new strings could be created from the ionized hydrogen resulting in the electrolysis of water. The increase of the size of the dark nuclei would mean increase of the cross sections for cold nuclear reactions. The liberated energy would ionized hydrogen atoms and give rise to a positive feedback loop somewhat like in ordinary nuclear reactions.
3. The increased energy yield in cold nuclear reactions suggests that OH bonds are transformed very effectively to dark OH bonds in the plasma region. This means that the thermal radiation can split the hydrogen bonds and induce the splitting of two water molecules to $4H$ and $2O$ and therefore production of $2H_2 + O_2$ everywhere in this kind of region. The temperature used by Kanarev corresponds to energy between .5-1 eV [D117] which conforms with the fact that OH bond energy is reduced to about.5 eV. Note that the presence of anode and catode is not absolutely necessary if cold nuclear reactions can take place in the entire electrolyte volume and generate plasma phase by positive feedback loop.
4. The prediction is that Faraday's law for hydrogen production does not hold true. O/H ratio has the value $r = O/H = 0$ for the ordinary electrolysis at catode. $r = 1/2$ holds true if local dissociation of water molecules dominates. According to [C82] r increases from electrolysis value $r = .066$ above $V = 140$ V achieving the value $r = .45$ for $V = 350$ V where the system becomes unstable. Also cold nuclear reactions could contribute to hydrogen and oxygen production and affect the value of r as suggested by the large volume of gas produced in Kanarev's experiments [D95].

Over-unity energy production?

Over-unity energy production with output power 2- or even 3-fold as compared with input power has been reported from plasma electrolysis. The effectiveness is deduced from the heating of of the system. Note that Mizuno reports in [C82] that 10 per cent effectiveness but this is for the storage of energy to hydrogen and does not take into account the energy going to the heating of water.

The formation of higher isotopes of Li by fusing dark protons to existing dark proton strings is a good candidate for the dominant energy production mechanism. An estimate for the energy liberate in single process $Li(3,n) + m_p + e \rightarrow Li(3,n+1) + 2\nu_8$ is obtained by using energy conservation. Here $2\nu_8$ denotes color singlet bound state of two color octet excitations of neutrino.

Since e_8 and ν_8 are analogous to u and d quarks one expects that their masses are very nearly the same. This gives as the first guess $m_{\nu_8} = m_e$ and since lepto-pion (color bound state of color octet electrons, [K115]) has mass $m = 2m_e$ a good guess is $m(2\nu_8) = 2m_{\nu_8} = 2m_e$. The energy conservation would give

$$m(Li(3,n)) + m_p \quad = \quad m(Li(3,n+1)) + m_e + T(2\nu_8) + E(\gamma) \ . \tag{4.10.1}$$

Here $T(2\nu_8)$ is the kinetic energy of $2\nu_8$ state and E_γ is the energy of photon possibly also emitted in the process.

The process is kinematically possible if the condition

$$\Delta m \quad = \quad m(Li(3,n)) + m_p - m(Li(3,n+1) \geq m_e \ . \tag{4.10.2}$$

is satisfied. All incoming particles are approximated to be at rest, which is a good approximation taking into account that chemical energy scales are much lower than nuclear ones. For the left hand side one obtains from the mass difference of $Li(3,n=4)$ and $Li(3,5)$ isotopes the estimate $\Delta m = 1.2312$ MeV for the liberated binding energy which is considerably larger than $m_e = .51$ MeV. Hence the process is kinematically possible and $2\nu_8$ would move with a relativistic velocity $v = .81c$ and presumably leave the system without interacting with it.

The process can involve also the emission of photons and the maximal amount of energy that photon can carry out corresponds to $E = \Delta m = 1.2312$ MeV. Let us denote by $\langle E\rangle < \Delta m$ the average photonic energy emitted in the process and express it as

$$\langle E\rangle = z\Delta m \ , \ \ z < 1. \tag{4.10.3}$$

One obtains an estimate for the production rate of photon energy (only this heats the system) from the incoming electron current I. If a fraction $x(V)$ of the current is transformed to negatively charged color bonds the rate for energy production becomes by a little manipulation

$$\frac{P/kW}{I/A} \quad = \quad x(V)z \times 3.5945 \ . \tag{4.10.4}$$

This formula allows to estimate the value of the parameter $x(V)z$ from experimental data. Since simplest Feynman graph producing also photons is obtained by adding photon line to the basic graph, one expects that z is of order fine structure constant:

$$z \quad \sim \quad \alpha_{em} = 1/137 \ . \tag{4.10.5}$$

The ratios of the excess power for a pair of (V,I) values should satisfy the condition

$$\frac{P(V_1)I(V_2)}{P(V_2)I(V_1)} \quad = \quad \frac{x(V_1)}{x(V_2)} \ . \tag{4.10.6}$$

$x(V)$ should be deducible as a function of voltage using these formulas if the model is correct.

These formulae allow to compare the predictions of the model with the experimental results of Naudin for Mizuno-Omori Cold Fusion reactor [C14]. **Table 4.12** gives the values of $\epsilon = x(V)z$ and ratios $x(V(n))/x(V(n_1)$ deduced from the data tabulated by Naudin [C111] for the various series of experiments using the formulae above.

1. Most values of $x(V)z$ are in the range $.03 - .12$. $z = 1/137$ would give $x(V)z \leq 1/137$ so that order of magnitude is predicted correctly. One cannot over-emphasize this result.
2. Apart from some exceptions the values look rather reasonable and do not vary too much. If one neglects the exceptional values, ones has $x_{max}(V)/x_{min}(V) < 4$. $n = 1,5,8,9,29$ correspond to exceptionally small values of $x(V)$. Perhaps cold fusion is not present for some reason. The output power is smaller than input power for $n = 9$ and $n = 29$.

n	$Voltage/V$	$Current/A$	$x(V)z$	$x(V(n))/x(V(2))$
1	185	8.56	0.005	.145
2	147	2.45	0.036	1.00
3	215	2.10	0.046	1.30
4	220	9.32	0.044	1.22
5	145	1.06	0.001	.03
6	213	1.40	0.05	1.34
7	236	1.73	0.08	2.18
8	148	.83	0.01	.21
9	148	1.01	-0.00	-0.008
10	221	1.31	0.03	.87
11	279	3.03	0.05	1.46
12	200	8.58	0.03	0.89
13	199	7.03	0.07	1.91
14	215	9.78	0.04	1.07
15	207	8.34	0.03	0.74
16	247	2.19	0.06	1.69
17	260	2.20	0.02	0.55
18	257	2.08	0.03	0.71
19	195	2.95	0.06	1.59
20	198	2.62	0.07	1.98
21	182	2.40	0.05	1.26
22	212	2.27	0.06	1.74
23	259	2.13	0.12	3.22
24	260	4.83	0.04	1.05
25	209	3.53	0.04	1.16
26	230	4.99	0.10	2.79
27	231	5.46	0.09	2.53
28	233	5.16	0.10	2.85
29	155	4.60	-0.00	-0.04
30	220	4.44	0.11	2.95
31	256	5.25	0.05	1.36
32	211	3.68	0.03	.97
33	201	3.82	0.04	1.06

Table 4.12: The values of $x(V)z$ and $x(V(n))/x(V(1))$ deduced from the data of *Cold Fusion reaction-Experimental test results on June 25, 2003 by JL Naudin* at `http://tinyurl.com/y8llbyj6`.

Has living matter invented cold nuclear physics?

Intriguingly, the ions Na^+, Cl^-, K^+, Ca^{++} detected by Mizuno in the catode in Kanarev's experiments [D95] correspond to the most important biological ions. There is also a considerable evidence for the occurrence of nuclear transmutations in living matter [C33, C150]. For instance, Kervran claims that it is not possible to understand where the Ca needed to form the shells of eggs comes from. A possible explanation is that dark nuclear reactions between Na^+ and dark Litium produced the needed Ca.

There is extremely strong electric field through cell membrane (resting voltage is about.06 V). The acceleration of electrons in this field could generate plasma phase and creation of dark Li nuclei via a positive feedback loop. This could mean that cold nuclear reactions serve also in living cell as a basic metabolic energy source (possibly in the dark sector) and that also biologically important ions result as products of cold nuclear reactions.

4.10.7 Tests And Improvements

Test for the hypothesis about new physics of water

The model involves hypothesis about new physics and chemistry related to water.

1. The identification of hydrogen bond as dark OH bond could be tested. One could check whether the qualitative properties of bonds are consistent with each. One could try to find evidence for quantization of bond energies as integer multiples of same energy (possible power of two multiples).
2. $H_{1.5}O$ formula in atto-second scale should be tested further and one could look whether similar formula holds true for heavy water so that sequences of dark protons might be replaced with sequences of dark deuterons.
3. One could find whether plasma electrolysis takes place in heavy water.

Testing of the nuclear physics predictions

The model in its simplest form assumes that only dark Li, C, F, etc. are present in water. This predicts quite specific nuclear reactions in electrolyte and target and reaction product. For both target and electrolyte isotopes of nuclei with atomic number $Z + k3$ are predicted to result in cold fusion reactions if energetically possible. For a target heavier than Fe also fission reactions might take place.

The estimates for the liberated energies are obtained assuming that dark nuclei have same binding energies as ordinary ones. In some cases the liberated energy is estimated using the binding energy per nucleon for a lighter isotope. Ordinary nuclei with maximal binding energy correspond to nuclear strings having ^4He or its variants containing negatively charged color bonds as a basic structural unit. One could argue that gluing $nLi(3, 5)$ or its isotope does not give rise to a ground state so that the actual energy liberated in the process is reduced so that process might be even impossible energetically. This could explain the absence of Ge from Fe catode and the absence of Ti, Mn, and Ni in KOH plasma electrolysis [D95].

catode: For catode Fe and W have been used. For Fe the fusions $Fe + Li \rightarrow Cu + 28.84\ MeV$ and $Fe + C \rightarrow Ge + 21.64\ MeV$ are possible energetically. Mizuno does not report the presence of Ge in Fe target. The reduction of the binding energy of dark $C(6, 10)$ by 21.64 MeV (1.35 MeV per nucleon) would make second reaction impossible but would still allow $Li + C$ and $Na + C$ fusion. Second possibility is that Ge containing negatively charged color bonds has smaller binding energy per nucleon than ordinary Ge. $W + Li \rightarrow Ir$ would liberate 8.7 MeV if binding energy of dark Li is same as of ordinary Li.

Electrolyte: Consider electrolytes containing ions X^+ with atomic number Z. If X is lighter than Fe, the isotopes of nuclei with atomic number $Z + 3k$ might be produced in fusion reactions $nLi+X$. $X = Li, K, Na$ has one electron at s-shell whereas $B, Al, Cr, ...$ has one electron at p-shell.

Reaction	$\mathbf{Li} + Li \to C$	$\mathbf{C} + Li \to F$	$\mathbf{F} + Li \to Mg$
E/MeV	27.1	24.0	31.5
	$\mathbf{Li} + Na \to Si$	$\mathbf{C} + Na \to Cl$	$\mathbf{F} + Na \to Ca$
E/MeV	34.4	30.5	33.7
	$\mathbf{Li} + K \to Ti$	$\mathbf{C} + K \to Mn$	$\mathbf{F} + K \to Ni$
E/MeV	32.2	33.6	32.7

Table 4.13: The estimates for the energies liberated in fusions of dark nuclei of water and the ion of electrolyte. Boldface refers to dark nuclei $Li(3,5), C(6,10)$, and $F(9,15)$.

Relationship to the model of Widom and Larsen and further tests

W. Guglinski kindly informed me about the theory of cold fusion by Widom and Larsen [C154]. This theory relies on standard nuclear physics. The theory is reported to explain cold fusion reaction products nicely in terms of the transformation of electrons and protons to very low energy neutrons which can overcome the Coulomb barrier. The problem of the theory is that very high energy electrons are required since one has $Q = .78$ MeV for $e + p \to n$ and $Q = -3.0$ MeV for $e + D \to n + n$. It is difficult to understand how so energetic electrons could result in ordinary condensed matter.

Since proton plus color bond is from the point of view of nuclear physics neutron and the fusion reactions would obey ordinary nuclear physics rules, the predictions of TGD are not expected to deviate too much from those of the model of Widom and Larsen.

An important class of predictions relate to ordinary nuclear physics. Tetra-neutron could be alpha particle with two negatively charged color bonds and neutron halos could consist of protons connected to nucleus by negatively charged color bonds. This could reduce the binding energy considerably.

Cold nuclear fusion might also provide an in situ mechanism for the formation of ores. Nuclear ores in places where they should not exist but involving remnants of organic matter would be the prediction. Cold fusion has a potential for a technology allowing to generate some metals artificially.

How to optimize the energy production?

The proposed model for the plasma electrolysis suggests following improvements to the experimental arrangement.

The production of energy in process is due to three reactions: 1) $Li + p$ in plasma. 2) $Li + Fe/W...$ in target, and 3) $Li + Na/K...$ in plasma. The model suggests that 1) dominates so that basic process would occur in plasma rather than catode.

1. Since W does not evaporate so easily, it is better material for catode if the production of dark Li dominates energy production.

2. catode could be replaced with a planar electrode with fractal peaky structure generating the required strong electric fields. This could increase the effectiveness of the energy production by increasing the effective area used.

3. Since $H_2O \to OH^- + p$ is required by the generation of dark Li sequences. The energy feed must be able to follow the rapidly growing energy needs of this reaction which seems to occur as bursts.

4. The prediction is that the output power is proportional to electron current rather than input power. This suggests minimization of input power by minimizing voltage. This requires maximization of electron conductivity. Unfortunately, the transformation of electrons to OH^- ions as charge carriers reduces conductivity.

4.11 Anomalies Possible Related To Electrolysis Of Water And Cold Fusion

4.11.1 Comparison With The Reports About Biological Transmutations

Kervran's book "Biological Transmutations" [C33] contains a surprisingly detailed summary about his work with biological transmutations and it is interesting to find whether the proposed model could explain the findings of Kervran. TGD suggests two general mechanisms.

1. The nuclear reactions involving dark Li, C, and F predicted to be present in living matter.
2. Nuclear fusions made possible by a temporary transformation of ordinary nuclear space-time sheets to dark ones with much larger size so that Coulomb wall is reduced considerably. The nuclear reaction might proceed if it is energetically possible. Almost any reaction $A+B\rightarrow C$ is possible via this mechanism unless the nuclei are not too heavy.

Fortuitous observations

In his childhood Kervran started to wonder why hens living in a limestone poor region containing thus very little calcium in ground and receiving no calcium in their nutrition could develop the calcium required by eggs and by their own bones. He noticed that hens had the habit of eating mica, which contains silicon. Later this led to the idea that Si could somehow transmute to Ca in living matter. In the proposed model this could correspond to fusion of $Si(14,14)+\mathbf{C(6,6)}\rightarrow Ca(20,20)$ which occurs spontaneously.

Second fortuitous observation were the mysterious CO poisonings by welders working in factory. After careful studies Kervran concluded that CO must be produced endogenously and proposed that the inhaled air which had been in contact with incandescent iron induces the transformation $N_2\rightarrow CO$ conserving both neuron and neutron number. This transformation might be understood in TGD context if the nuclear space-time sheets are part of time in dark with much larger size so that a direct contact becomes possible for nuclear space-time sheets and Coulomb wall is reduced so that the reaction can proceed with some probability if energetically possible. The thermal energy received from hot iron might help to overcome the Coulomb barrier. The mass difference $m(2N)-m(O)-m(C)=10.45$ MeV allows this reaction to occur spontaneously.

Examples of various anomalies

Kervran discusses several plant anomalies. The ashes of plants growing in Si rich soil contain more Ca than they should: this transmutation has been already discussed. The ashes of a plant growing on Cu fibres contain no copper but 17 per cent of iron oxides in addition to other elements which could not have come from the rain water. The reaction $Cu(58)+\mathbf{Li(3,4)}\rightarrow Fe(26,32)+\mathbf{C(6,6)}$ would liberate energy of 11.5 MeV.

There are several mineral anomalies.

1. Dolomite rock is formed inside limestone rocks which would suggest the transmutation of $Ca(20,20)$ into $Mg(12,12)$. The nuclear reaction $Ca(20,20)+\mathbf{Li(3,4)}\rightarrow Mg(12,12)+Na(11,12)$ would liberate energy of 3.46 MeV. Ca emerges from Si in soil and in what Kervran refers to a "sickness of stone". The candidate reaction has been already discussed.
2. Graphite is found in siliceous rocks. Kervran proposes the reaction $Si\rightarrow C+O$. $m(Si)-m(C)-M(O)=-16.798$ MeV does not allow this reaction to proceed spontaneously but the reaction $Si+\mathbf{Li}\rightarrow C+Na$ liberates the energy 2.8880 MeV.
3. Kervran mentions the reaction $O+O\rightarrow S$ as a way to produce sulphur from oxygen. This reaction is obviously energetically favored.

Kervran discusses the transmutations $Na\rightarrow K$ and $Na\rightarrow Ca$ occurring also in plasma electrolysis and explained by TGD based model. Further transmutations are $Na\rightarrow Mg$ and $Mg\rightarrow Ca$. $Na\rightarrow Mg$ could correspond to the reaction $Na(11,12)+\mathbf{Li(3,2)}\rightarrow Mg(12,12)+He(2,2)$ favored by the high binding energy per nucleon for ^4He (7.072 MeV). $Mg\rightarrow Ca$ would correspond to the reaction $Mg+O\rightarrow Ca$, which obviously liberates energy.

4.11.2 Are The Abundances Of Heavier Elements Determined By Cold Fusion In Interstellar Medium?

According to the standard model, elements not heavier than Li were created in Big Bang. Heavier elements were produced in stars by nuclear fusion and ended up to the interstellar space in supernova explosions and were gradually enriched in this process. Lithium problem forces to take this theoretical framework with a grain of salt.

The work of Kervran [C33] suggests that cold nuclear reactions are occurring with considerable rates, not only in living matter but also in non-organic matter. Kervran indeed proposes that also the abundances of elements at Earth and planets are to high degree determined by nuclear transmutations and discusses some examples. For instance, new mechanisms for generation of O and Si would change dramatically the existing views about evolution of planets and prebiotic evolution of Earth.

Where did the Lithium go?

Ulla - one of the commentators in my blog - sent an interesting link concerning Lithium problem to an article by Elisabetta Caffau *et al* (see `http://tinyurl.com/oys6a5v`) titled "An extremely primitive halo star" [E16].

What has been found is a star which is extremely poor on metallic elements: ("metallic" refers to elements heavier than Li). The mystery is that not only elements heavier than Li but also Li itself, whose average abundance is believed to be determined by cosmological rather than stellar nucleosynthesis, is very scarcely present in these stars.

This finding can be coupled with too other observations about anomalies in Li abundance.

1. The average abundance of Li (see `http://tinyurl.com/m79tcg`) in Cosmos is lower than predicted by standard cosmology by a factor between 2 and 3 [E3].
2. Also Sun has too low Li abundance (see `http://tinyurl.com/ycuxntst`) [E2].

Authors think that some process could have created very high temperature destroying the Li in this kind of stars: maybe dark matter annihilation might have caused this. This looks rather artificial to me and would not explain too low Li abundance for other stars and for interstellar medium.

The transformation of Li to dark matter (ordinary Lithium in a phase with larger value of Planck constant) would mean its effective disappearance. This process would have occurred both in interstellar medium and in stars so that all three Li problems would be solved at once. Many question marks remain. What about the rate for the phase transition to dark matter? Also lighter elements should be able to transform to dark form. Why the cosmological abundances for them are however essentially those predicted by the standard model of primordial nucleosynthesis? Is the reason that Li their fusion to Li was much faster than transformation to dark matter during primordial nucleosynthesis whereas Li fused very slowly and had time to transform to dark Li?

Li problem would rather sharply distinguish between two very different views about dark matter: dark matter as some exotic elementary particles on one hand and dark matter as phases of ordinary matter implied by generalization of quantum theory on the other hand.

Are heavier nuclei produced in the interstellar space?

TGD based model is consistent with the findings of Kervran and encourages to a consider a simple model for the generation of heavier elements in interstellar medium. The assumptions are following.

1. Dark nuclei $X(3k,n)$, that is nuclear strings of form $Li(3,n)$, $C(6,n)$, $F(9,n)$, $Mg(12,n)$, $P(15,n)$, $A(18,n)$, etc..., form as a fusion of Li strings. $n=Z$ is the most plausible value of n. There is also ^4He present but as a noble gas it need not play an important role in condensed matter phase (say interstellar dust). The presence of water necessitates that of $Li(3,n)$ if one accepts the proposed model as such.
2. The resulting nuclei are in general stable against spontaneous fission by energy conservation. The binding energy of $He(2,2)$ is however exceptionally high so that alpha decay can occur in dark nuclear reactions between $X(3k,n)$ allowed by the considerable reduction of the Coulomb wall. The induced fissions $X(3k,n)\rightarrow X(3k-2,n-2)+He(2,2)$ produces nuclei with atomic

H(1, 0)							He(2, 2)
Li(3, 4)	Be(4, 5)	B(5, 6)	C(6, 6)	N(7, 7)	O(8, 8)	F(9, 10)	Ne(10, 10)
Na(11, 12)	Mg(12, 12)	Al(13, 14)	Si(14, 14)	P(15, 16)	S(16, 16)	Cl(17, 18)	A(18, 22)
K(19, 20)	Ca(20, 20)						

Table 4.14: Table gives the most abundant isotopes of stable nuclei.

number $Z\ mod\ 3 = 1$ such as $Be(4,5)$, $N(7,7)$, $Ne(10,10)$, $Al(13,14)$, $S(16,16)$, $K(19,20)$, ... Similar nuclear reactions make possible a further alpha decay of $Z\ mod\ 3 = 1$ nuclei to give nuclei with $Z\ mod\ 2$ such as $B(5,6)$, $O(8,8)$, $Na(11,12)$, $Si(14,14)$, $Cl(17,18)$, $Ca(20,20)$, ... so that most stable isotopes of light nuclei could result in these fissions.

3. The dark nuclear fusions of already existing nuclei can create also heavier Fe. Only the gradual decrease of the binding energy per nucleon for nuclei heavier than Fe poses restrictions on this process.

Table 4.14 allows the reader to build a more concrete view about how the heavier nuclei might be generated via the proposed mechanisms.

The abundances of nuclei in interstellar space should not depend on time

The basic prediction of TGD inspired model is that the abundances of the nuclei in the interstellar space should not depend on time if the rates are so high that equilibrium situation is reached rapidly. The $\hbar$ increasing phase transformation of the nuclear space-time sheet determines the time scale in which equilibrium sets on. Standard model makes different prediction: the abundances of the heavier nuclei should gradually increase as the nuclei are repeatedly re-processed in stars and blown out to the interstellar space in super-nova explosion.

Amazingly, there is empirical support for this highly non-trivial prediction [E39]. Quite surprisingly, the 25 measured elemental abundances (elements up to $Sn(50,70)$ (tin) and $Pb(82,124)$ (lead)) of a 12 billion years old galaxy turned out to be very nearly the same as those for Sun. For instance, oxygen abundance was 1/3 from that from that estimated for Sun. Standard model would predict that the abundances should be.01-.1 from that for Sun as measured for stars in our galaxy. The conjecture was that there must be some unknown law guaranteeing that the distribution of stars of various masses is time independent. The alternative conclusion would be that heavier elements are created mostly in interstellar gas and dust.

Could also "ordinary" nuclei consist of protons and negatively charged color bonds?

The model would strongly suggest that also ordinary stable nuclei consist of protons with proton and negatively charged color bond behaving effectively like neutron. Note however that I have also consider the possibility that neutron halo consists of protons connected by negatively charged color bonds to main nucleus. The smaller mass of proton would favor it as a fundamental building block of nucleus and negatively charged color bonds would be a natural manner to minimizes Coulomb energy. The fact that neutron does not suffer a beta decay to proton in nuclear environment provided by stable nuclei would also find an explanation.

1. Ordinary shell model of nucleus would make sense in length scales in which proton plus negatively charged color bond looks like neutron.
2. The strictly nucleonic strong nuclear isospin is not vanishing for the ground state nuclei if all nucleons are protons. This assumption of the nuclear string model is crucial for quantum criticality since it implies that binding energies are not changed in the scaling of $\hbar$ if the length of the color bonds is not changed. The quarks of charged color bond however give rise to a compensating strong isospin and color bond plus proton behaves in a good approximation like neutron.
3. beta decays might pose a problem for this model. The electrons resulting in beta decays of this kind nuclei consisting of protons should come from the beta decay of the d-quark neutralizing negatively charged color bond. The nuclei generated in high energy nuclear reactions would presumably contain genuine neutrons and suffer beta decay in which d quark is nucleonic

quark. The question is whether how much the rates for these two kinds of beta decays differ and whether existing facts about beta decays could kill the model.

4.11.3 Burning Salt Water By Radio-Waves And Cold Fusion By Plasma Electrolysis

John Kanzius has made a strange discovery [D1]: salt water in the test tube radiated by radio waves at harmonics of a frequency f=13.56 MHz burns. Temperatures about 1500 C, which correspond to.17 eV energy have been reported. One can radiate also hand but nothing happens. The original discovery of Kanzius was the finding that radio waves could be used to cure cancer by destroying the cancer cells. The proposal is that this effect might provide new energy source by liberating chemical energy in an exceptionally effective manner. The power is about 200 W so that the power used could explain the effect if it is absorbed in resonance like manner by salt water. In the following it is proposed that the cold nuclear reactions are the source of the energy.

Do radio waves of large Planck constant transform to microwave photons or visible photons in the process?

The energies of photons involved are very small, multiples of 5.6×10^{-8} eV and their effect should be very small since it is difficult to imagine what resonant molecular transition could cause the effect. This leads to the question whether the radio wave beam could contain a considerable fraction of dark photons for which Planck constant is larger so that the energy of photons is much larger. The underlying mechanism would be phase transition of dark photons with large Planck constant to ordinary photons with shorter wavelength coupling resonantly to some molecular degrees of freedom and inducing the heating. Microwave oven of course comes in mind immediately. The fact that photosynthesis means burning of water and the fact that visible light is emitted in turn suggests that the radio wave photons are transformed to visible or nearly visible photons corresponding to the energy scale of photons involved with photosynthesis.

The original argument inspired by the analogy with microwave oven is discussed below. The generalization to the case of visible photons is rather straightforward and is discussed in [K42].

1. The fact that the effects occur at harmonics of the fundamental frequency suggests that rotational states of molecules are in question as in microwave heating. The formula for the rotational energies [D15] is

$$E(l) = E_0 \times (l(l+1) \ , \ \ E_0 = \hbar_0^2/2\mu R^2 \ , \ \ \mu = m_1 m_2/(m_1+m_2) \ .$$

   Here R is molecular radius which by definition is deduced from the rotational energy spectrum. The energy inducing the transition $l \rightarrow l+1$ is $\Delta E(l) = 2E_0 \times (l+1)$.

2. $NaCl$ molecules crystallize to solid so that the rotational heating of $NaCl$ molecules cannot be in question.

3. The microwave frequency used in microwave ovens is 2.45 GHz giving for the Planck constant the estimate 180.67 equal to 180 with error of.4 per cent. The values of Planck constants for $(\hat{M}^4/G_a)\times\hat{CP}_2\hat{\times}G_b$ option (factor space of M^4 and covering space of CP_2 maximizing Planck constant for given G_a and G_b) are given by $\hbar/\hbar_0 = n_a n_b$. $n_a n_b = 4\times 9\times 5 = 180$ can result from the number theoretically simple values of quantum phases $exp(i2\pi/n_i)$ corresponding to polygons constructible using only ruler and compass. For instance, one could have $n_a = 2\times 3$ and $n_b = 2\times 3\times 5$.

Connection with plasma electrolysis?

The burning of salt water involves also the production of O_2 and H_2 gases. Usually this happens in the electrolysis of water [D4]. The arrangement involves typically electrolyte consisting of water plus $NaOH$ or KOH present also now but anode, catode and electronic current absent. The proposed mechanism of electrolysis involving cold nuclear reactions however allows the splitting of water molecules to H_2 and O_2 even without these prerequisites.

The thermal radiation from the plasma created in the process has temperature about 1500 C which correspond to energy about.17 eV: this is not enough for splitting of bonds with energy.5 eV. The temperature in salt water could be however considerably higher.

The presence of visible light suggests that plasma phase is created as in plasma electrolysis. Dark nuclear reactions would provide the energy leading to ionization of hydrogen atoms and subsequent transformation of the electronic charge to that of charged color bonds in protonic strings. This in turn would increase the rate of cold nuclear reactions and the liberated energy would ionize more hydrogen atoms so that a positive feedback loop would result.

Cold nuclear reactions should provide the energy transforming hydrogen bonds to dark bonds with energy scaled down by a factor of about 2^{-6} from say 8 eV to.125 eV if $T = 1500C$ is accepted as temperature of water. If Planck constant is scaled up by the factor $r = 180$ suggested by the interpretation in terms of microwave heating, the scaling of the Planck constant would reduce the energy of OH bonds to about.04 eV, which happens to be slightly below the energy assignable to the cell membrane resting potential. The scaling of the size of nuclear space-time sheets of D by factor $r = 180$ is consistent with the length of color bonds of order 10^{-12} m. The role of microwave heating would be to preserve this temperature so that the electrolysis of water can continue. Note that the energy from cold nuclear reactions could partially escape as dark photons.

There are some questions to be answered.

1. Are the radio wave photons dark or does water - which is a very special kind of liquid - induce the transformation of ordinary radio wave photons to dark photons by fusing 180 radio wave massless extremals (MEs) to single ME. Does this transformation occur for all frequencies? This kind of transformation might play a key role in transforming ordinary EEG photons to dark photons and partially explain the special role of water in living systems.

2. Why the radiation does not induce a spontaneous combustion of living matter which also contains Na^+ and other ions. A possible reason is that $\hbar$ corresponds to Planck constant of dark Li which is much higher in living water. Hence the energies of dark photons do not induce microwave heating.

3. The visible light generated in the process has yellow color. The mundane explanation is that the introduction Na or its compounds into flame yields bright yellow color due to so called sodium D-lines [D53] at 588.9950 and 589.5924 nm emitted in transition from 3p to 3s level. Visible light could result as dark photons from the dropping of dark protons from dark space-time sheets of size at least atomic size to larger dark space-time sheets or to ordinary space-time sheets of same size and de-cohere to ordinary light. In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system.

   Yellow light corresponds roughly to the rather narrow energy range.96-2.1 eV ($.59 - .63\ \mu m$). The metabolic quanta correspond to jumps to space-time sheets of increasing size give rise to the fractal series $E/eV = 2 \times (1 - 2^{-n})$ for transitions $k = 135 \rightarrow 135 + n$, $n = 1, 2, ...$ [K78]. For $n = 3, 4, 5$ the lines have energies $1.74, 1.87, 1.93$ eV and are in the visible red ($\lambda/\mu m = .71, .66, .64$). For $n > 5$ the color is yellow. In Kanarev's experiments the color is red which would mean the dominance of $n < 6$ lines: this color is regarded as a signature of the plasma electrolysis. In the burning of salt water the light is yellow [D1], which allows to consider the possibility that yellow light is partially due to $n > 5$ lines. Yellow color could also result from the dropping $k = 134 \rightarrow 135$ ($n = 1$).

4.12 About Physical Representations of Genetic Code in Terms of Dark Nuclear Strings

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas. One can argue that genetic code is realized in several ways just like bits can be represented in very many ways. Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony involving icosahedral and tetrahedral geometries. Second model has two variants based on dark nuclear strings: the original version maps codons do dark nucleons, the more recent version maps codons to dark 3-nucleon states. Both models predict correctly the numbers of DNA codons coding for a given amino-acid but the model based on dark 3-nucleon triplets is favoured by some recent findings suggesting a pairing between DNA nucleotides and dark nucleons. Also the counterparts of RNA,tRNA, and amino-acids are predicted. In the sequel the updated nuclear string variant is summarized and also its connection with the model of harmony is discussed.

4.12.1 Background

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas (see chapters of [K48] and [L4, K51]). One can argue that genetic code is realized in several ways just like bits can be represented in very many ways.

Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony [L22] involving icosahedral and tetrahedral geometries. Second one having two variants is based on dark nuclear strings. Both models predict correctly the numbers of DNA codons coding for a given amino-acid. In the sequel the nuclear string variant and also its connection with the model of harmony is discussed in detail.

It is good to start with an overall view about physical realization of genetic code that I have discussed during last twenty years.

Genetic code and Combinatorial Hierarchy

The first proposal [K49] was purely mathematics inspired and in terms of so called Combinatorial Hierarchy consisting of certain Mersenne primes $M_k = 2^k - 1$ via the formula $M(n+1) = M_{M(n)}$ having interpretation in terms of abstraction. The list beginning from $M(1) = 2$ is $2, M_2 = 3, M_3 = 7, M_7 = 127, M_{127} = 2^{127} - 1$: it is not known whether subsequent integers are Mersenne primes. The idea is that the $2^k - 1$ points define almost full Boolean algebra spanned by k bits- one visualization is as a polygon. The algebra defined $k-1$ bits is maximal full Boolean sub-algebra having interpretation as maximal number of mutually independent statements, which can hold true simultaneously. For M_7 ($k = 3$) one would have 2 bits and 4 codons. For M_7 one would have $k = 7$ and 6 bits and genetic code. For M_{127} one would have 126 bits and one would have "memetic" code realizable in terms of sequences of 21 DNA codons.

Geometric theory of harmony and genetic code

The idea that the 12-note scale could allow mapping to a closed path going through all vertices of icosahedron having 12 vertices and not intersecting itself is attractive. Also the idea that the triangles defining the faces of the icosahedron could have interpretation as 3-chords defining the notion of harmony for a given chord deserves study. The paths in question are known as Hamiltonian cycles and there are 1024 of them [A3]. There paths can be classified topologically by the numbers of triangles containing 0, 1, or 2 edges belonging to the cycle representing the scale. Each topology corresponds to particular notion of harmony and there are several topological equivalence classes.

In the article [L25] I introduced the notion of Hamiltonian cycle as a mathematical model for musical harmony and also proposed a connection with biology: motivations came from two observations. The number of icosahedral vertices is 12 and corresponds to the number of notes in 12-note system and the number of triangular faces of icosahedron is 20, the number of amino-acids. This led to a group theoretical model of genetic code and replacement of icosahedron with tetra-icosahedron to explain also the 21st and 22nd amino-acid and solve the problem of simplest model due to the fact that the required Hamilton's cycle does not exist. The outcome was the notion of bioharmony.

All icosahedral Hamilton cycles with symmetries(Z_6,Z_4, Z_2^{rot} and Z_2refl turned out to define harmonies consistent with the genetic code. In particular, it turned out that the symmetries of the Hamiltonian cycles allow to to predict the basic numbers of the genetic code and its extension to include also 21st and 22nd amino-acids Pyl and Sec: there are actually two alternative codes - maybe DNA and its conjugate are talking different dialects! One also ends up with a proposal for what harmony is leading to non-trivial predictions both at DNA and amino-acid level.

The conjecture is that DNA codons correspond to 3-chords perhaps realized in terms of dark photons or even ordinary sound. There are 256 different bio-harmonies and these harmonies would give additional degrees of freedom not reducing to biochemistry. Music expresses and creates emotions and a natural conjecture is that these bio-harmonies are correlates of emotions/moods at bio-molecular level serving as building bricks of more complex moods. Representations of codons as chords with frequencies realized as those of dark photons and also sound is what suggests itself naturally. This together with adelic physics involving hierarchy of algebraic extensions of rationals would explain the mysterious lookin connection between rational numbers defined by ratios of frequencies with emotions.

Letter-wise representations of genetic code in terms of single particle states

The model for DNA-cell membrane system as topological quantum computer with lipids and DNA nucleotide or codons connected by flux tubes led to a proposal for the correspondence of letters of genetic code with particle states.

1. The original proposal was that the 4 letters A,T,C,G correspond to dark u and d quark and their antiparticles $\overline{u}$ and $\overline{d}$. Quarks and their antiparticles would reside at the ends of the flux tube. Spin would not matter in this model. The obvious criticism is that introducing dark antiquarks is too far fetched.
2. One can also consider a variant for which one has u and d quarks and spin matters.
3. TGD based model of bio-superconductivity assumes that flux tubes appear as pairs with members of Cooper pair at parallell flux tubes [K85, K86]. This suggests that electron pairs at in spin 1 and spin 0 states could realize the code. The spin of the electrons would matter and one would obtain 4 states - two qubits in correspondence with A,T,C,G.

Also the model of dark nuclear strings allows to imagine letter-wise representations of the genetic code. The model for cold fusion based on the findings of Prof. Holmlid and his group [C23, L48] leads to the idea that Pollack's EZs [L24] are accompanied by dark nuclear strings consisting of dark protons connected by color flux tubes analogous to mesons [L27, L48]. Color bonds would have quark and antiquark at their ends [L4]. This leads to non-trivial predictions and nuclear anomalies giving support for the notion of nuclear string have emerged, the latest anomaly is so called X boson with mass of 17 MeV [L50, C68] having identification as p-adically scaled analog of pion.

Dark protons could also decay to neutrons by dark weak decays rapidly since dark weak bosons are effectively massless below dark Compton length. Furthermore, proton plus negatively charged color bond could behave like neutron as far as chemistry is considered. The X boson anomaly of nuclear physics [L50] suggests that the flux tubes in the ground state correspond to pion-like states which can be colored: this could bind the nucleons to form a nucleus. The evidence for the occurence of cold fusion in living matter gives support for the role of dark nuclear strings [L31] [L48].nOne can consider several representations of the genetic code in this framework.

Consider first models for which letters are represented separately.

1. Dark protons and neutrons have 4 spin states and could correspond to letter A,T,C,G. In this case dark color bonds would not matter. A rather convincing proposal for a pathway leading to a selection purines as DNA nucleotides has been proposed [I9]. TGD based model [L45] suggests that acidic solutions contain dark protons and purine results when the precursor amine combines with dark proton such that the proton remains dark. Could DNA nucleotide pair with dark protons and neutrons (resulting in dark beta decay from dark proton strings yielded by Pollack's mechanism)?
2. Also the 4 states of dark color bonds between dark nucleons (3 pion-like states and one eta meson like state: spin 1 bonds would be analogous to ρ and ω mesons and have higher mass)

correspond to letters A,T,C,G. Now the dark protons and neutrons would not matter. This option would require that the character of the nucleotide correlates with the color flux tube attached to the dark proton. They would have at their ends charge conjugate color bonds. The states would be of form $u\overline{u}, d\overline{d}, u\overline{d}, d\overline{u}$ with the ordering of q and $\overline{q}$ correlating with the direction in which transcription and replication take place being thus same or opposite). For conjugate strand the direction of strand would be opposite in the sense that one would have $\overline{u}u, \overline{d}u, \overline{du}, \overline{u}u$.

For this option one could consider the strands of dark DNA double strand being connected by flux tube pairs resulting when U-shaped color flux tube have reconnected. If color flux tubes are colored, color confinement could bind the dark protons to dark nucleus. Similar mechanism could be at work for the ordinary nuclei.

The basic problem of all the proposals based on letter-wise correspondence is that they do not even try to explain the numbers of DNA codons coding for a given amino-acid and are also silent about tRNA.

Codon-wise representations of genetic code realized in terms of dark strings

For this option entire codons rather than letters would be represented. The difference between two representations is analogous to that between spoken and written languages. In spoken languages words are not analyzed further to letters. These models are able to predict also the numbers of codons coding for a given amino-acid successfully.

1. The geometric theory of harmony represents codons as 3-chords without assigning fixed notes to A,T,C,G and explains also DNA-amino-acid correspondence.
2. The map of codons to the dark nucleon states of dark nucleon consisting of dark u and d type quarks does the same and also predicts the degeneracies successfully.
3. This model can be modified by replacing u and d by dark nucleon states p and n without any change in predictions related to genetic code. The evidence that DNA codons indeed couple to dark nucleon states [L45] supports this option.

In the sequel I consider the models mapping DNA codons to dark nucleons and then generalize the model so that it applies to triplets of dark nucleons.

4.12.2 Codons as dark quark-triplet strings

Water memory is one of the ugly words in the vocabulary of the main stream scientist. The work of pioneers is however now carrying fruit. The group led by Jean-Luc Montagnier, who received Nobel prize for discovering HIV virus, has found strong evidence for water memory and detailed information about the mechanism involved [K51, K114], [I15]. The work leading to the discovery was motivated by the following mysterious finding. When the water solution containing human cells infected by bacteria was filtered in purpose of sterilizing it, it indeed satisfied the criteria for the absence of infected cells immediately after the procedure. When one however adds human cells to the filtrate, infected cells appear within few weeks. If this is really the case and if the filter does what it is believed to do, this raises the question whether there might be a representation of genetic code based on nano-structures able to leak through the filter with pores size below 200 nm.

The question is whether dark nuclear strings might provide a representation of the genetic code. In fact, I posed this question year before the results of the experiment came with motivation coming from the attempts to understand water memory. The outcome was a totally unexpected finding: the states of dark nucleons formed from three quarks can be grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

Could DNA and amino-acids correspond to dark quark triplet strings

The dark model emerged from the attempts to understand water memory [K51]. The outcome was a totally unexpected finding [L4, K51]: the states of dark nucleons formed from three quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, 20 amino-acids, and tRNA and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks - just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η.

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino-acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would be not be anymore separable to letters but entangled states of 3 quarks.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics and maybe even in ordinary nuclear physics if the nucleons of ordinary nuclear physics are linear nucleons. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

The ability of the model to explain genetic code in terms of spin pairing is an impressive achievement, which I still find difficult to take seriously.

1. The original model identifying codons to dark nucleon states assumed the overall charge neutrality of the dark proton strings: the idea was that the charges of color bonds cancel the total charge of dark nucleon so that all states uuu, uud, udd, ddd can be considered. The charge itself would not affect the representation of codons. Neutrality assumption is however not necessary. The interpretation as dark nucleus resulting from dark proton string could quite well lead to the formation the analog of ordinary nucleus via dark beta decays [L48] so that the dark nucleus could have charge. Isospin symmetry breaking is assumed so that neither quarks nor flux tubes are assigned to representations of strong $SU(2)$.

   There is a possible objection. For ordinary baryon the mass of Δ is much larger than that of proton. The mass splitting could be however much smaller for linear baryons if the mass scale of excitations scales as $1/h_{eff}$ as indeed assumed in the model of dark nuclear strings [L27, L48].

2. The model assumes that the states of DNA can be described as tensor products of the four 3-quark states with spin content $2 \otimes 2 \otimes 2 = 4 \oplus 2_1 \oplus 2_2$ with the states formed with the 3 spin triplet states $3 \otimes 3 = 5 \oplus 3 \oplus 1$ with *singlet state dropped*. The means that flux tubes are spin 1 objects and only spin 2 and spin 1 objects are accepted in the tensor product. One could consider interpretation in terms of ρ meson type bonding or gluon type bonding. With these assumptions the tensor product $(2 \otimes 2 \otimes 2) \otimes (5 \oplus 3)$ contains $8 \times 8 = 64$ states identified as analogs of DNA codons.

   The rejection of spin 0 pionic bonds looks strange. These could however occur as bonds connecting dark codons and could correspond to different p-adic length scale as suggested by the successful model of X boson [L50].

   One can also ask why not identify dark nucleon as as closed triangle so that there would be 3 color bonds. In this case $3 \otimes 3 \otimes 3$ would give 27 states instead of 8 ($\oplus 1$). This option does not look promising.

3. The model assumes that amino-acids correspond to the states 4×5 with $4 \in \{4 \oplus 2 \oplus 2\}$ and $5 \in \{5 \oplus 3\}$. One could tensor product of spin 3/2 quark states and spin 2 flux tube states giving 20 states, the number of amino-acids.

4. Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino-acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allow immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ to the states of 4×5 with same or opposite spin projection. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1,2,3,2\}$ and $D_b \in \{1,2,2,2,1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1,2,3,4,6$ are predicted. The numbers $N(k)$ of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2,7,2,6,3] \ .$$

The correct numbers for vertebrate nuclear code are $(N(1), N(2), N(3), N(4), N(6)) = (2,9,1,5,3)$. Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2,9,1,5,3)$!

This simple observation would suggest that genetic code could be realized already at the level of dark or even ordinary nuclear physics and bio-chemistry is only a kind of shadow of dark matter physics.

Objections against the identification of codons as dark quark triplets

Consider next some particle physicist's objections against the option mapping codons to dark nucleon states.

1. The realization of the model of codon as dark quark triplet requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one would have a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states could be scaled up.

2. Both the absolute and relative mass differences between Δ and N *resp.* ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller - say of the same order of magnitude as fine structure constant 1/137 - so that the mass splittings could be so small as to make decays impossible.

   The color magnetic spin interaction energy give rise to hyperfine splitting of quark in perturbative QCD is of form $E_c \propto \hbar g B/m$, where m is mass parameter which is of the order of baryon mass. Magnetic flux scales as $\hbar$ by flux quantization and if flux tube thickness scales as $\hbar^2$, one has $B \propto 1/\hbar$. Mass splittings would not depend on $\hbar$, which does not make sense. Mass splitting becomes small for large $\hbar$ if the area of flux quantum scales as $\hbar^{2+n}$, $n > 0$ so that color magnetic hyper-fine splitting scales as $1/\hbar^n$ from flux conservation. The magnetic energy for a flux tube of length L scaling as $\hbar$ and thickness $S \propto \hbar^{2+n}$ has order of magnitude $g^2 B^2 LS$ and does not depend on $\hbar$ for $n = 1$. Maybe this could provide first principle explanation for the desired scaling.

   The size scale of DNA would suggest that single DNA triplet corresponds to 3 Angstrom length scale. Suppose this corresponds to the size of dark nucleon. If this size scales as $\sqrt{\hbar}$ as p-adic mass calculations suggest, one obtains a rough estimate $\hbar/\hbar_0 = 2^{38}$. The proton-Δ mass difference due to hyper-fine splitting would be scaled down to about $2^{-38} \times 300$ MeV $\sim 10^{-9}$ eV, which is completely negligible in the metabolic energy scale .5 eV. If the size of dark nucleon scales as $\hbar$ the mass difference is about 12 eV which corresponds to the energy scale for the ionization energy of hydrogen. Even this might be acceptable.

For these reasons the option mapping codons to dark nucleon triplets is clearly favored and will be discussed in the following.

4.12.3 Codons as dark nucleon-triplet strings?

The assumption that entire codon rather than letter corresponds to a state of dark proton does not conform with the model for the origin of purines as DNA nucleotides [L45] assuming that purines, and in fact all nucleotides, are combined with dark proton unless one assumes that 3 nucleotides combine with the same dark proton. This looks somewhat artificial but cannot be excluded.

The arguments of the model involve only the representations of rotation group and since p and n have same spin as u and d, the arguments generalize to 3- nucleon states (ppp, ppn, pnn, nnn) connected by two color bounds and organized to linear structures. Concerning genetic code, exactly the same predictions follow in the recent formulation of the model. In this case quark color is not present. One could however use the 1-dimensionality and the ordering of dark nucleons as already described.

The model with linear quark triplets generalizes by replacing dark u and d quarks with dark nucleons p and n. The analogs of ρ mesons would correspond to 2 bonds also now. Irrespective of changes of nucleons, all states would have decomposition $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ corresponding to the degrees of freedom associated with 3 nucleon spins and 2 neutral ρ meson spins.

ppp could correspond to DNA and RNA and proton charges would neutralize the negative charges of ordinary DNA codons. The singlet formed by bonds would be neglected. nnn triplets could correspond to amino-acids and trNA. Amino-acids could correspond to $4 \times 5 = 20$ and the remaining states $4 \otimes 3 \oplus (2 \oplus 2) \otimes 5 \oplus\ 3$. could correspond to 44 tRNAs. Also other options are possible and have net charges 2 and 1.

This variant has several nice features. The model is consistent with the model for dark nucleon strings consisting of nucleons and color bonds between them. There is no need to introduce Δ type nucleon states and colored states are not needed in fermionic sector. Color bonds must be colored if one wants ordinary bosonic statistics for flux tubes but here braid statistics might help. Colored bonds could of course have some important function.

Could dark DNA, RNA, tRNA and amino-acids correspond to different charge states of codons?

If dark codons correspond to dark nucleon triplets as assumed in the following considerations there are 4 basic types of dark nucleon triplets: ppp, ppn, pnn, nnn. Also dark nucleons could represent codons as uuu, uud, udd, ddd: the following discussion generalizes as such also to this case. If strong isospin/em charge decouples from spin the spin content is same independently of the nucleon content. One can consider the possibility of charge neuralization by the charges assignable to color flux tubes but this is not necessarily. In any case, one would have 4 types of nucleon triplets depending on the values of total charges.

Could different dark nucleon total charges correspond to DNA,RNA, tRNA and amino-acids? Already the group representation content - perhaps correlating with quark charges - could allow to distinguish between DNA, RNA, tRNA, and amino-acids. For amino-acids one would have only 4×5 and ordinary statistics and color singlets. For DNA and RNA one would have full multiplet also color non-singlets and for tRNA one could consider $(4 \oplus 2_1 \oplus 2_2) \times 5$ containing 40 states. 31 is the minimum number of tRNAs for the realization of the genetic code. The number of tRNA molecules is known to be between 30-40 in bacterial cells. The number is larger in animal cells but this could be due to different chemical representations of dark tRNA codons.

If the net charge of dark codon distinguishes between DNA,RNA, tRNA, and amino-acid sequences, the natural hypothesis to be tested is that dark ppp, ppn, pnn, and nnn sequences are accompanied by DNA,RNA, tRNA, and amino-acid sequences. The dark beta decays of dark protons proposed to play essential role in the model of cold fusion [**?**]ould transform dark protons to dark neurons. Peptide backbones are neutral so that dark nnn sequence could be also absent but the dark nnn option is more natural if the general vision is accepted. There is also the chemically equivalent possibility that only dark protons are involved: dark proton + neutral color bond would represent proton and dark proton + negatively charged color bond would represent neutron. At this moment it is not possible to distinguish between these two options.

Is this picture consistent with what is known about charges of amino-acids DNA,RNA, tRNA, and amino-acids? Consider first the charges of these molecules.

1. DNA strand has one negative charge per nucleotide. Also RNA molecule has high negative

charge. This conforms with the idea that dark nucleons accompany both DNA and RNA. DNA codons could be accompanied by dark ppp implying charge neutralization in some scale and RNA codons by dark ppn. The density of negative charge for RNA would be 2/3 for that for DNA.

2. Arg, His, and Lys have positively charged side chains and Asp,Glu negative side chains (see `http://tinyurl.com/jsphvgt`). The charge state of amino-acid is sensitive to the pH value of solution and its conformation is sensitive to the counter ions present. Total charge for amino-acid in peptide however vanishes unless it is associated with the side chain: as in the case of DNA and RNA it is the backbone whose charge is expected to matter.

3. Amino-acid has central C atom to which side chain, NH_2, H and COOH are attached. For free amino-acids in solution water solution $NH_2 \rightarrow NH_3^+$ tends to occur pH=2.2 by receiving possibly dark proton whereas COOH tends to become negatively charged above pH= 9.4 by donating proton, which could become dark. In peptide OH attach to C and one H attached to N are replaced with peptide bond. In the pH range 2.2-9.4 amino-acid is zwitterion for which both COOH is negatively charged and NH_2 is replaced with NH_3^+ so that the net charge vanishes. The simplest interpretation is that the ordinary proton from negatively ionized COOH attaches to NH_2 - maybe via intermediate dark proton state.

4. The backbones of peptide chains are neutral. This conforms with the idea that dark amino-acid sequence consists of dark neutron triplets. Also free amino-acids would be accompanied by dark neutron triplets. If the statistics is ordinary only 4 dark nnn states are possible as also 5 dark color flux tube states.

5. tRNA could involve dark pnn triplet associated with the codon. An attractive idea is secondary genetic code assigning RNA codons to tRNA-amino-acid complex and projecting $8 \otimes (5 \oplus 3)$ containing 64 dark RNA spin states to $8 \otimes 5$ containing 40 dark tRNA spin states with same total nucleon and flux tube spins. Dark tRNA codons would in turn be attached to dark amino-acids by a tertiary genetic code projecting spin states $8 \otimes 5$ to $4 \otimes 5$ by spin projection. In the transcription dark tRNA would attach to dark mRNA inducing attachment of dark amino-acid to the growing amino-acid sequence and tRNA having only dark tRNA codon would be left. The free amino-acids in the water solution would be mostly charged zwitterions in the pH range 2.2-9.4 and the negative charge of COO^- would be help in the attachement of the free amino-acid to the dark proton of tRNA codon. Therefore also the chemistry of free amino-acids would be important.

   An interesting question is why pnn triplets for tRNA would only 5 in flux tube degrees of freedom entire 8 in nucleon degrees of freedom. For RNA consisting of ppn triplets also 3 would be possible. What distinguishes between ppn and pnn?

The model should explain the widely different properties of DNA, RNA, tRNA, and amino-acids. There are two options.

1. DNA/RNA/amino-acid codons could correspond to ppp/ppn/nnn and tRNA would correspond to pnn (order is not necessarily this). Different charge or dark codons explain why DNA (RNA) has H (OH) in $2'$ position. The repulsive Coulomb energy between dark codons would be stronger for DNA and the compensation of this forces by the magnetic tension associated with the flux tube pair connecting codon and anticodon this might have something to do with the stability of DNA double strand.

   (a) The instability of RNA as compared to DNA would result from the instability of the ribose in RNA (deoxiribose in DNA) as indeed believed. The absence of RNA double strands could be due to the instability of the flux tube pair assignable to n-n. This trivially implies absence of replication and transcription if it is based on same mechanism as in the case of DNA.

   (b) pnn structure could explain why tRNA does not form sequences and allow to understand wobble pairing, which states that the third mRNA codon does not correspond to unique tRNA anticodon but one has C,A,U $\rightarrow$ I and U$\rightarrow$ I. Due to the symmetries of the third letter of the codon, this is consistent with the genetic code. The physical explanation for wobble base pairing could relate to pnn structure of tRNA. If the charge ordering is random one would have nnp,npn,pnn and C,A,U $\rightarrow$ I could correspond to these 3 situations whereas for U→ I the correspondence would not depend on the ordering. Also for RNA one would have ppn,pnp, npp degeneracy but in this case one would have charge independence.

A possible charge pairing between RNA and tRNA would be p↔n. The charge pairing between DNA and RNA could be p → n for the third least significant letter of DNA. This would minimize the coding errors possibly induced this pairing.

(c) One can criticize the charge assignment ppn (possibly allowing permutations) for RNA codons. Could dark weak beta decays give rise to 1-D lattice like structure? Could the repetitive structure be due to energy minimization.

2. Could the correspondence be letterwise? For DNA A,T,C,G would correspond to p, and for RNA A,C,G to p and U to n. Codons not containing U wold be ppp type codons and one can wonder why the oxiribose for them is not replaced with de-oxiribose. The possible presence of n in dark codons could explain why RNA sequences are highly unstable and why they do not replicate and transcribe.

Objections based on group theory and statistics

The quark-triplet model and its generalization replacing u, d with nucleon states p, n works nicely but is better to try to invent objections against the proposal and try to find inconsistencies. Fermi and Bose statistics are the most obvious providers of killer arguments.

1. The basic objection is that if the quarks are organized in linear structures, one cannot talk about representation of 3-D rotation group since symmetry breaking to SO(2) acting along common axis which could be either the local axis along dark DNA helix of the axis of the entire helix. The linear ordering of the quarks is not consistent with the full harmonics. Rather, harmonics restricted to half space $0 \leq \theta \leq \pi/2$ ($\pi \geq \theta \geq \pi/2$) should characterize the "upper" ("lower") flux tube direction at the position of quark in the middle.

   If reflection along quantization axis and SO(2) generate the symmetries one still has labelling of the states by angular momentum projection and states form doublets $(m, -m)$. The representations of SO(3) split into these representation and the numbers of states with given spin projection remain the same. Therefore the predictions for the numbers of DNA codons coding given aminoacid are not changed. It is quite possible that braid statistics made possible by 1-dimensionality is needed to realize the idea about ordering and this would allow to have full DNA multiplets.

2. In quark model one forms tensor product of tensor products of 3 quark spin states and 3 quark isospin states and by color singletness requires that the state is completely antisymmetric in quark degrees of freedom. The state is completely symmetric in the non-colored degrees of freedom. One obtains only two representations $\Delta \leftrightarrow (3/2, 3/2)$ and $N = (1/2, 1/2)$ with positive parity. In quark model context the presence of other tensor products in $(4 \oplus 2_1 \oplus 2_2)_S \otimes (4 \oplus 2_1 \oplus 2_2)_I$ is forbidden. One reason is that spatial wave function is assumed to be symmetric in ground state. This forbids 2_2 in spin degrees of freedom. Symmetrization leaves only the Δ and N (Note that the total number of these state is 20!). Now strong isospin is broken and it is natural to not include it to the tensor product.

3. The presence of 2_2 would be forbidden in quark model since it would require antisymmetric spatial wave function to compensate for the antisymmetry of 2_2. In the recent case the situation is 1-dimensional and the ordering along nuclear string forces localization of quarks and one cannot have identical wave functions for quarks.

   1-D situation also suggests strongly braid statistics. Perhaps the situation could be understood in terms of fermionic oscillator operators along nuclear string having anti-commutation relations corresponding to non-trivial braid statistics - maybe making the statistics commutative. This could naturally allow anti-symmetrization along nuclear string for 2_2 states.

4. If one assumes ordinary statistics, one could one take care of the statistics of the 16 states in $2_2 \otimes (5 \oplus 3)$ by assuming that for 2_2 the color state is symmetric and thus 10-D representation of $SU(3)$. The state associated with color flux tubes cannot compensate this color (triality is 1) since it must correspond to triality zero representation. If the colors of DNA strand and

conjugate correspond to 10 and $\overline{10}$ and color entanglement could guarantee color singletness for the codon pairs. This would however require anti-quarks for the conjugate strand.

3 10:s associated with 3 codons contains in their tensor product a singlet (see `http://tinyurl.com/zjxxqhj`). Minimal color singlet dark DNA sequence would requite 3 color codons. One can of course wonder whether the presence of 3 decouplet codons - 2 at the beginning and 2 at end and one in the middle could define genes as basic units.

5. The statistics problem is encountered also for the flux tubes. 5 (and 1) as symmetric representation is allowed by statistics but triplet is antisymmetric and thus not allowed. Again braid statistics might help. If one assumes that the flux tubes are colored - say color octets - and color wave function for flux tube pairs is antisymmetric, one can achieve Bose statistics for 3. Flux tube pair would correspond to $8 \in \{8 \times 8\}$ and minimum of two flux codons would be needed for color singletness in flux tube degrees of freedom.

6. For the counterparts of amino-acids one has only $4 \otimes 5$ allowed also by statistics considerations assuming color singlets. Could distinction between DNA/RNA and amino-acids related to statistics, perhaps braid statistics. The suggested role of braid strands possibly connecting DNA double strands and DNA double strands and lipid layers of cell membrane encourages the question whether the DNA strand and its conjugate entangle via via the reconnection of the color flux tubes defining U-shaped "tentacles" to a flux tube pair connecting the strands. For amino-acids they would not be needed. Same could happen in the transcription process of DNA to mRNA and in the translation process for mRNA tentacles and those associated with tRNA.

Ordinary or braid statistics?

There are four options to consider: ordinary/braid statistics (1/2) and dark nucleon as dark quark/nucleon triplet as representation of DNA codon (a/b). One has options 1a,1b,2a,2b. Options 1b and 2b are at this moment the only options, which can be taken seriously: the reason is that dark protons would neutralize the negative charges of ordinary DNA nucleotides.

1. Option 1a: codons as quark-triplets with ordinary statistics. For the ordinary statistics amino-acid like dark nucleons are color singlets. Part of DNA codons are represented as dark nucleons and would be colored and 10-D representation of SU(3). Dark amino-acids need not have color bonds with dark parts of other colored biomolecules like DNA,RNA, with exception possible formed by dark tRNA. DNA double strand could realize color confinement via the reconnection of color flux tubes.

2. Option 1b: codons as nucleon-triplets with ordinary statistics. Option 1b requires in ordinary statistics for antisymmetric doublet and antisymmetric wave function for the 3 nucleons not allowing constant valued wave function also disfavored by the linear ordering. This condition might have the same implications as braid statistics.

3. Options 1a and 1b. DNA is the only molecule that appears as double strands. A possible explanation is that codons and anticodons are paired by U-shaped flux tubes associated with the color bonds of dark DNA to form color singlets. Nucleonic colors would sum up to zero along the strand.

4. Option 2a. For braid statistics it could be possible to avoid colored states of nucleon and flux tubes.

5. Option 2b. The 3-nucleon codons would have no color and amino-acids could obey braid statistics reducing to ordinary statistics. This would not be the case for DNA/RNA.

It must be admitted that the situation is unsatisfactory as far as statistics is considered. For the option 1b) with codons identified as dark proton triplets one can however consider the following variant to satisfy statistics requirement.

1. Years after writing the above comments it has become clear that adelic physics [L64] brings in additional discrete degrees of freedom assignable to the group algebra of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele.

2. Galois group acts on the space of space-time surfaces, and one can say that one has wave function at the orbit of the Galois group consisting of space-time sheets. At quantum level quantum states correspond to wave functions in the group algebra of Galois group of extension.
3. The role of color in helping to achieve correct statistics could be taken by Galois degrees of freedom. One can even consider the notion of Galois confinement as a generalization of color confinement [L125] binding codons as dark proton triplets to dynamical units. Even genes as sequences of codons could be bound to dynamical units as Galois singlets.

4.12.4 Further considerations

Replication, transcription, translation

The formation of flux tube pairs between molecules would be central in replication and transcription and in all bio-catalysis. Dark DNA would replicate first to dark DNA or mRNA. This requires that the building bricks of dark DNA and mRNA emerge from environment perhaps by mechanism involving reconnection for the magnetic tentacles and reduction of h_{eff} bringing the molecules near each other. Flux tube pairs between dark DNA codonsandtheir conjugates (individual dark RNA codons) would be formed during replication (transcription). The formation of flux tube pair between mRNA and dark tRNA part of tRNA would bring tRNA to mRNA, where amino-acid would associate with the growing amino-acid sequence.

For options 1a and 1b based on ordinary statistics color singletness condition could play an important role in the replication and transcription.

1. If the value of h_{eff} before reconnection and contraction of flux tube dictating the scale of color confinement is large enough, colored dark nucleons could float as free - possibly colored states - in the environment for option 1a). For option 1b dark nucleons could be present in environment - this could relate directly to the ionization in electrolyte. For options 1a and 1b dark codons representing dark tRNA molecules would accompany them.
2. For options 1a) and 1b) color confinement in flux tube degrees of freedom by forming dark color flux tube pairs between dark DNA and its conjugate in codon-wise manner could give rise to DNA double strands as chemical shadows of dark double strands. The coupling between codon and anticodon would be defined by the condition that the total color bond spins of paired codons are opposite. Quark color could be compensated for option 1a along DNA strand: 3 10:s give singlet. One can of course ask whether dark DNA RNA sequences exist rather than being built during replication and transcription.

Are sound-like bubbles whizzing around in DNA essential to life?

I got a link to a very interesting article [I14] about sound waves in DNA (see `http://tinyurl.com/z7hod9b`). The article tells about THz de-localized modes claimed to propagate forth and back along DNA double strand somewhat like bullets. These modes involve collective motion of many atoms. These modes are interpreted as a change in the stiffness of the DNA double strand leading to the splitting of hydrogen bonds in turn leading to a splitting into single strands. The resulting gap is known as transcriptional bubble propagating along double strand is the outcome. I do not how sound the interpretation as sound wave is.

It has been proposed that sound waves along DNA give rise to the bubble. The local physical properties of DNA double strand such as helical structure and elasticity affect the propagation of the waves. Specific local sequences are proposed to favor a resonance with low frequency vibrational modes, promoting the temperary splitting of the DNA double strand. Inside the bubble the bases are exposed to the surrounding solvent, which has two effects.

Bubbles expose the nucleic acid to reactions of the bases with mutagens in the environment whereas so called molecular intercalators may insert themselves between the strands of DNA. On the other hand, bubbles allow proteins known as helicases to attach to DNA to stabilize the bubble, followed by the splitting the strands to start the transcription and replication process. The splitting would occur at certain portions of DNA double strand. For this reason, it is believed that DNA directs its own transcription.

The problem is that the strong interactions with the surrounding water are expected to damp the sound wave very rapidly. Authors study experimentally the situation and report that propagating bubbles indeed exist for frequencies in few THz region. Therefore the damping deo not seem to be effective. How this is possible? As an innocent layman I also wonder how this kind of mechanism can be selective: it would seem that the bullet like sound wave initiates transcription at many positions along DNA. The transcription should be localized to a region assignable to single gene. What could guarantee this?

Can TGD say anything interesting about the mechanism behind transcription and replication?

1. In TGD magnetic body controls and coordinates the dynamics. The strongest hypothesis is that basic biochemical process are induced by those for dark variants of basic bio-molecules (dark variants of DNA, enzymes,...). The belief that DNA directs its own transcription translates to the statement that the dark DNA consisting most plausibly from sequences of dark proton triplets ppp at dark magnetic flux tubes controls the transcription: the transcription/replication at the level of dark DNA induces that at the level of ordinary DNA.
2. If the dark DNA codons represented as dark proton triplets (*ppp*) are connected by 3 flux tube pairs, the reverse of the reconnection should occur and transform flux tube pairs to two U-shaped flux tubes assignable to the two dark DNA strands. Dark proton sequences have positive charge +3e per dark codon giving rise to a repulsive Coulomb force between them. There would be also an attractive force due to magnetic tension of the flux tubes. These two forces would compensate each other in equilibrium (there also the classical forces due to the negatively charged phosphates associated with nucleotides but these would not be so important).

   If the flux tube pairs are split, the stabilizing magnetic force however vanishes and the dark flux tubes repel each other and force the negatively charged DNA strands to follow so that also ordinary DNA strand splits and bubble is formed. The primary wave could therefore be the splitting of the flux tube pairs: whether one can call it as a sound wave is not clear to me. Perhaps the induced propagating splitting of ordinary DNA double strand could be regarded as an analog of sound wave.

   The splitting of flux tube pairs for a segment of DNA would induces a further splitting of flux tubes since repulsive Coulomb force tends to drive the flux tubes further away. The process could be restricted to DNA if the "upper" end of the split DNA region has some dark DNA codons which are not connected by flux tubes pairs. This model reason why for dark proton sequences.
3. This model does not yet explain how the propagating splitting wave is initiated. Could a quantum phase transition increasing the value of h_{eff} associated with the flux tube pairs occur for some minimal portion of dark DNA "below" the region associated with gene and lead to the propagating wave induced by the above classical mechanism? That the wave propagates in one direction only could be due to chirality of DNA double helix.

An interesting question is how the RNA world vision (see `http://tinyurl.com/gpmxcmk`) relates to this general picture.

1. There are strong conditions on the precedessor of DNA and RNA satisfies many of them: reverse transcription to DNA making possible transition to DNA dominated era is possible. Double stranded RNA exists `http://tinyurl.com/y9mex4v7` in cells and makes possible RNA genome: this would however suggest that cell membrane came first. RNA is a catalyst. RNA has ability to conjugate an amino-acid to the $3'$ end of RNA and RNA catalyzes peptide bond formation essential for translation. RNA can self-replicate but only relatively short sequences are produced.
2. TGD picture allows to understand why only short sequences of RNA are obtained in replication. If the replication occurs at the level of dark ppn sequences as it would occur for DNA in TGD framework, long RNA sequences might be difficult to produce because of the stopping of the propagation of the primary wave splitting the flux tube pairs. This could be due to the neuron pairs to which there is associated no Coulomb repulsion essential for splitting.
3. In TGD framework RNA need not be the precedessor of DNA since the evolution would occur at the level of dark nucleon strings and DNA as the dark proton string is the simpest dark nucleon string and might have emerged first. Dark nuclear strings would have served as

templates and biomolecules would have emerged naturally via the transcription of their dark counterparts to corresponding bio-polymers.

Is bio-catalysis a shadow of dark bio-catalysis based on generalization of genetic code?

Protein catalysis and reaction pathways look extremely complex (see `http://tinyurl.com/kp3sdlm`) as compared to replication, transcription, translation, and DNA repair. Could simplicity emerge if biomolecules are identified as chemical shadows of objects formed from dark nuclear strings consisting of dark nucleon triplets and their dynamics is shadow of dark stringy dynamics very much analogous to text processing?

What if bio-catalysis is induced by dark catalysis based on reconnection as recognition mechanism? What if contractions and expansions of U-shaped flux tubes by h_{eff} increasing phase transitions take that reactants find each other and change conformations as in the case of opening of DNA double strand? What if codes allowing only the dark nucleons with same dark nuclear spin and flux tubes spin to be connected by a pair of flux tubes?

This speculation might make sense! The recognition of reactants is one part of catalytic action. It has been found in vitro RNA selection experiments that RNA sequences are produced having high frequency for the codons which code for the amino-acid that these RNA molecules recognize (`http://tinyurl.com/kp3sdlm`. This is just what the proposal predicts!

Genetic codes DNA to RNA as $64 \rightarrow 64$ map, RNA to tRNA as $64 \rightarrow 40$, tRNA to amino-acids with $40 \rightarrow 20$ map are certainly not enough. One can however consider also additional codes allowed by projections of $(4 \oplus 2_1 \oplus 2_2) \otimes (5 \oplus 3(\oplus 1))$ to lower-dimensional sub-spaces defined by projections preserving spins. One could also visualize bio-molecules as collections of pieces of text attaching to each other along conjugate texts. The properties of catalysts and reactants would also depend by what texts are "visible" to the catalysts. Could the most important biomolecules participating biochemical reactions (proteins, nucleic acids, carbohydrates, lipids, primary and secondary metabolites, and natural products, see `http://tinyurl.com/jlfxags`) have dark counterparts in these sub-spaces.

The selection of bio-active molecules is one of the big mysteries of biology. The model for the chemical pathway leading to the selection of purines as nucleotides [L45] assumes that the precedessor of purine molecule can bind to dark proton without transforming it to ordinary proton. A possible explanation is that the binding energy of the resulting bound state is higher for dark proton than the ordinary one. Minimization of the bound state energy could be a completely general criterion dictating which bio-active molecules can pair with dark protons. The selection of bio-active molecules would not be random after all although it looks so. The proposal for DNA-nuclear/cell membrane as topological quantum computer with quantum computations coded by the braiding of magnetic flux tubes connecting nucleotides to the lipids wlead to the idea that flux tubes being at O=-bonds [K4].

Comparing TGD view about quantum biology with McFadden's views

McFadden [I22] has very original view about quantum biology: I have written about his work for the first time for years ago, much before the emergence of ZEO, of the recent view about self as generalized Zeno effect, and of the understanding the role of magnetic body containing dark matter [?]. The pleasant surprise was that I now understand McFadden's views much better from TGD viewpoint.

1. McFadden sees decoherence as crucial in biological evolution: here TGD view is diametric opposite although decoherence is a basic phenomenon also in TGD.
2. McFadden assumes quantum superpositions of different DNAs. To me this looks an unrealistic assumption in the framework of PEO. In ZEO it is quite possible option.
3. McFadden emphasizes the importance of Zeno effect (in PEO). In TGD the ZEO variant of Zeno effect is central for TGD inspired theory of consciousness and quantum biology. Mc Fadden suggests that quantum effects and Zeno effect are central in bio-catalysis: the repeated measurement keeping reactants in the same position can lead to an increase of reaction rate by factors of order billion. McFadden describe enzymes as quantum mousetraps catching the

reactants and forcing them to stay in same position. The above description for how catalysis catches the reactants using U-shaped flux tube conforms with mousetrap picture.

McFadden discusses the action of enzymes in a nice manner and his view conforms with TGD view. In ZEO the system formed by catalyst plus reactants could be described as a negentropically entangled sub-self, and self indeed corresponds to a generalized Zeno effect. The reactions can proceed in shorter scales although the situation is fixed in longer scales (hierarchy of CDs): this would increase the length of the period of time during which reactions can proceed and lead to catalytic effect. Zeno effect in ZEO plus hierarchies of selves and CDs would be essentially for the local aspects of enzyme action.

4. Protons associated with hydrogen bonds and electronic Cooper pairs play a universal role in McFadden's view and the localization of proton in quantum measurement of its position to hydrogen bond is the key step of enzyme catalysis. Also TGD dark protons at magnetic flux tubes giving rise to dark nuclear strings play a key role. For instance, McFadden models enzyme catalysis as injection of proton to a very special hydrogen bond of substrate. In TGD one has dark protons at magnetic flux tubes and their injection to a properly chosen hydrogen bond and transformation to ordinary proton is crucial for the catalysis. Typical places for reactions to occur are C=O type bonds, where the transition to C-OH can occur and would involve transformation of dark proton to ordinary proton. The transformation of dark proton to ordinary one or vice versa in hydrogen bonds would serve as a biological quantum switch allowing magnetic body to control biochemistry very effectively.

   What about electronic Cooper pairs assumed also by McFadden. They would flow along the flux tube pairs. Can Cooper pairs of electrons and dark protons reside at same flux tubes? In principle this is possible although I have considered the possibility that particles with different masses (cyclotron frequencies) reside at different flux tubes.

McFadden [I22] has proposed quantum superposition for ordinary codons: This does not seem to make sense in PEO since the chemistries of codons are different) but could make sense in ZEO. In TGD one could indeed imagine quantum entanglement (necessary negentropic in p-adic degrees of freedom) between dark codons. This NE could be either between additional degrees of freedom or between spin degrees of freedom determining the dark codons. In the latter case complete correlation between dark and ordinary DNA codons would imply also the superposition of their tensor products with ordinary codons.

The NE between dark codons could also have a useful function: it could determine physically gene as a union of disjoint mutually entangled portions of DNA. Genes are known to be highly dynamical units, and after pre-transcription splicing selects the portions of the transcript translated to protein. The codons in the complement of the real transcript are called introns and are spliced out from mRNA after the pre-transcription (see `http://tinyurl.com/gmphzzy`).

What could be the physical criterion telling whether a given codon belongs to exonic or intronic portion of DNA? A possible criterion distinguish between exons and introns is that exons have NE between themselves and introns have no entanglement with exons (also exons could have NE between themselves). Introns would not be useless trash since the division into exonic and exonic region would be dynamical. The interpretation in terms of TGD inspired theory of consciousness is that exons correspond to single self.

Is there a connection between geometric model of harmony and nuclear string model of genetic code?

There should exists a connection between the geometric model of harmony and genetic code and the model of genetic code discussed.

1. Dark DNA strands could be connected by color flux tubes to form a double strand by reconnections of U-shaped color flux tubes. What would induce a codon-wise or letter-wise pairing of DNA codons and their conjugates represented as dark quark triplets to form double DNA strand? Cyclotron resonance could accompany reconnection (magnetic field strength would be identical and reconnection could occur).
2. One has the correspondence codon $\leftrightarrow$ state of dark nucleon or codon $\leftrightarrow$ state of dark nucleon triplet. The geometric model of harmony and genetic code [L22] represents the codons as

3-chords. The 3-chord would be represented in terms of cyclotron frequencies of dark photons assignable to the 3 dark quarks (nucleons) in the state. Each quark-color bond pair (including the pion-like bond) could be in 12 states with corresponding cyclotron frequency mappable to the basic octave. The cyclotron frequency triplets would be same for codons and conjugates. The only manner to understand the scale is in terms of spectrum of magnetic field strengths for U-shaped flux tube pairs.

This would require 3 pairs of flux tubes between the dark codons of DNA strands. If the quarks inside linear dark proton are connected by color flux tubes (like protons in the model of dark nucleus). Reconnection for U-shaped flux tube connecting quarks would give rise to the double strand formed by dark proton strings. The magnetic field strength of the 3-flux tubes would be determined by the state of dark proton and would be same for DNA and RNA codons and also for RNA codons and corresponding tRNA-amino-acid complexes. The cyclotron frequencies would define a scaled up variant of Pythagorean scale projected to the basic octave [L22]. This option does not favor the idea about separater 4-letter code.

3. The geometric model for harmony is formulated in terms of orbits of the subgroups of the isometry groups of tetrahedral and icosahedral geometries. The DNAs coding particular amino-acid correspond correspond to the orbit of the triangle of icosahedron corresponding to the amino-acid. The decomposition $60 \rightarrow 20+20+20$ suggests strongly decomposition of I to 20 Z_3 cosets containing 3 elements each other and in correspondences with the triangular faces of icosahedron.

4. The model of the genetic code just discussed relies on the model of dark nucleon based on group theory. The symmetric groups of Platonic solids are in turn associated with inclusion of hyperfinite factors and appear in Mc Kay correspondence, whose proof involves decompositions of SU(2) representations to the representations of the discrete subgroups of Platonic solids. A further observation is that the numbers of elements for isometries of icosahedron and tetrahedron are 60 and 4 respectively: the sum is 64. Could the action of Z_3 leaving face invariant could be posed as an additional condition on amino-acids and reduce the amino-acid representation to $4 \otimes 5$.

5. In the geometric model of harmony genetic icosahedral 20+20+20 part of the code involves a combination of three different Hamilton's cycles mapping 60 DNAs to 20 amino-acids: in terms of icosahedral group I and its coset space I/Z_3 these maps correspond to coset projections. Could the decomposition $(4 \oplus 2_1 \oplus 2_2) \otimes (5 \otimes 3)$ be understood in terms of a reduction to icosahedral and tetrahedral subgroups of rotation group or of their spin coverings.

   In this process finite-dimensional representation of $SO(3)$ decomposes to a direct sum of representations of the discrete subgroup if its dimension is larger than any of the dimensions of representations of the finite sub-group (for basic facts about these see `http://tinyurl.com/ho4onbs`). One might hope that the decomposition of the representations of SO(3) appearing in the above formula under icosahedral group and or tetrahedral group could allow to understand the emergence of DNA, RNA, tRNA, and amino-acids as kind of symmetry breaking.

6. In the geometric model of harmony 64-codon code [L22] is obtained as a fusion 60-codon code assignable to icosahedron + 4 codon code assignable to tetrahedron. There are actually two codes corresponding to tetrahedron and icosahedron as disjoint entities and tetrahedron glued to icosahedron along one face. The model explains the two additional amino-acids Pyl and Sec coded for a variant of the genetic code.

How could these two successful models relate to each other? In p-adic physics of cognition Platonic solids and polygons can be seen as discrete approximation for sphere [L46] and biomolecules could be understood as cognitive representation in the intersection of real and p-adic space-time surface consisting of algebraic points. Could one assign icosahedron and tetrahedron to a codon in some concrete manner? Could the attachment of tetrahedron to icosahedron along one face have concrete meaning? The answer seems to be negative.

1. One can about the interpretation of the 12 vertices of the icosahedron - how number 12 could be assigned with the genetic code? The vertices correspond to notes perhaps represented as magnetic field strength at the flux tubes assignable to color bonds. This field strength should

be determined by the spin state of dark 3-nucleon. No concrete nuclear string counterpart seems to exist for the closed Hamiltonian cycle consisting of 12 notes and in case of tetrahedral extension of 13 notes. 12 vertices of icosahedron correspond to 12 notes and 20 faces to 3-chords so that there is not need for more concrete correspondence.

2. The attachment of tetrahedron to icosahedron would bring in further note very near to one of the notes of Pythagorean scale and corresponding 3-chords. This has concrete interpretation and there is no need to make this more concrete at the level of geometry of DNA. If icosahedron and tetrahedron are disjoint one obtains four additional codons. It seems that all these 4 3-chords be assigned with the 3 color bonds, one note for each of them. What distinguishes at the level of dark nucleon string the situations in which tetrahedron is attached and non-attached to the color bond? In presence of attachment there would be 1 shared 3-chord corresponding to stop codon assignable with the shared face. The 13:th note appearing in 4 3-chords differs very little from one of the notes of the icosahedral scale: this corresponds to the fact that 12 perfect quints do not quite give 7 octaves as already Pythagoras realized. Crazy question: Could this small difference relate to the small relative mass difference $(m_p - m_n)/m_p \simeq .0014$ making itself possible visible in cyclotron frequency scale? The idea does not seem plausible: $[(3/2)^{12} - 2^7]/2^7 \simeq .014$ is 10 times larger than $(m_p - m_n)/m_p \simeq .0014$.

The conclusion is that genetic code can be understand as a map of stringy nucleon states induced by the projection of all states with same spin projections to a representative state with the same spin projections (total quark spin and total flux tube spin). Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin.

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Chapter 5

Cold Fusion Again

5.1 Introduction

Despite the fact that NASA is funding cold fusion research, cold fusion research is still regarded as almost criminal activity amongst people enjoying monthly salary as research professionals. The impossibility to communicate with so called respected scientists implies that cold fusion researchers do not receive healthy criticism. It is only human that cold fusion researchers tend to act reactively in this kind of situation. Defensive and reactive attitudes also imply that the research standards cannot be as high as they could be.

Cold fusion research is often carried out by companies with the goal of developing a commercial product. Funding is essential for achieving this and the reports about achievements tend to look like commercials. For an outsider it is very difficult to get information about what has been really achieved.

A serious problem is that a real theory of cold fusion is lacking and the standards of the theorizing carried out by experimenters are not too high. Fashionable pseudo-scientific notions like zero point energy (ZPE) having no mathematical justification and lacking real explanatory power plague the theorizing.

Before joining to the crowd labelling cold fusion researchers bad boys of science, one should realize that the battle for getting funding is merciless. Hot fusion research is an instutionalized branch of science but has failed to achieve its goal and there are a lot of researchers who want their funding to continue and fight desperately to prevent outsiders from entering their territory. The last 30 years of superstring hegemony is an excellent example of the same phenomenon.

Why I am writing about cold fusion? If I were standard career builder, I would of course dismiss the cold fusion research altogether since anything positive that I say about this kind of topics can be used against me. The new physics implied by TGD could however make possible phenomena explaining cold fusion and my research ethics does not allow me to make the standard choice concerning my attitudes to cold fusion. I have already earlier discussed cold fusion [K103, L4, K42, K40, L31].

This particular work was inspired by a comment to my blog article (see `http://tinyurl.com/zvqfqkt`) providing very interesting links to cold fusion related work that I was not aware of (thanks to Axil!). Reading this material led to much more precise formulation of one of the models for cold fusion that I had proposed in [L31] with inspiration coming from the model of fourth phase of water discovered by Pollack's. I also became finally convinced that cold fusion is real science.

The basic idea of TGD based model is that cold fusion occurs in two steps. First dark nuclei (large $h_{eff} = n \times h$) with much lower binding energy than ordinary nuclei are formed at magnetic flux tubes possibly carrying monopole flux. These nuclei can leak out the system along magnetic flux tubes. Under some circumstances these dark nuclei can transform to ordinary nuclei and give rise to detectable fusion products. An essential additional condition is that the dark protons can decay to neutrons rapidly enough by exchanges of dark weak bosons effectively massless below atomic length scale. Also beta decays in which dark W boson decays to dark electron and neutrino can be considered. This allows to overcome the Coulomb wall and explains why final state nuclei are stable and the decay to ordinary nuclei does not yield only protons. Thus it seems that this model combined with the TGD variant of Widom-Larsen model [K42] could explain nicely the existing data.

Before continuing it is good the sharpen the view about what the loose term *cold fusion* means as a term (see `http://coldfusionnow.org/what-is-cold-fusion/`). According to this reference:

Cold fusion describes a form of energy generated when hydrogen interacts with various metals like nickel and palladium. Cold fusion is a field of condensed matter nuclear science CMNS, and is also called low-energy nuclear reactions LENR, lattice-assisted nuclear reactions LANR, low energy nanoscale reactions LENR, among others. Cold fusion is also referred to as the Anomalous Heat Effect AHE, reflecting the fact that there is no definitive theory of the elusive reaction.

Beloved child is said to have many names but the many names does not imply being beloved!

One can find an article about cold fusion in Wikipedia (`https://en.wikipedia.org/wiki/Cold_fusion`). Although cold fusion has become legitimate science and cold fusion researchers are no more treated as criminals, the hostile tone of the article has not changed. The article even forgets to mention at all that NASA is one of the prestigious organizations studying cold fusion. This tells about the ethical and intellectual standards of the academic science nowadays.

Many non-standard mechanisms claimed to lead to nuclear fusion have been proposed and not all of them can be regarded as cold fusion. In the following I will describe the steps leading to the TGD inspired model for cold fusion combining the earlier TGD variant [K42] of Widom-Larsen model [C13] (`http://newenergytimes.com/v2/sr/WL/WLTheory.shtml`) with the model [L31] inspired by the TGD inspired model of Pollack's fourth phase of water [L24] using as input data findings from laser pulse induced cold fusion discovered by Leif Holmlid and collaborators [C23] (see popular article `http://tinyurl.com/nbephxb`). I consider briefly also alternative options (models assuming surface plasma polariton and heavy electron). After that I apply TGD inspired model in some cases (Pons-Fleischman effect, bubble fusion, and LeClair effect (see `https://nanospireinc.com/Fusion.html`)).

5.2 TGD Inspired Proposal For The Mechanism Of Cold Fusion

In TGD inspired model of cold fusion the basic new physics elements are following.

1. p-Adic length scale hypothesis [K70, K61] allowing to consider the possibility that given particle can exists in several phases with the p-adic prime $p \simeq 2^k$ and having mass scale proportional to $2^{-k/2}$. For instance, electron having usually $k = 127$ could exist in phase $k = 113$ assignable to atomic nuclei or even $k = 107$ assignable to hadrons.
2. Hierarchy of Planck constants $h_{eff}/h = n$ labelling the phase of dark matter with magnetic flux tubes possibly carrying monopole fluxes identified as as carriers of dark matter. Key idea is that dark protons and even dark deuteriums and even heavier nuclei can form dark variants of nuclei with appropriately scaled down binding energy. This step could be present also in the ordinary hot nuclear fusion.

The basic challenges of any model of cold fusion (LENR) are very demanding.

1. One must understand how Coulomb wall can be overcome. If LENR is in question, it seems that new physics is unavoidable.
2. The isotope ratios and also the composition of nuclei should be near to those appearing in natural environment.
3. In the original cold fusion experiments neither neutrons and gamma rays were detected and there were also other deviations from standard nuclear physics. One should also understand why the energy yield is so small and why the production rate of the nuclei is so modest.
4. There is evidence that only stable isotopes (at least stable with respect to weak decays) are produced or at least detected.

There are three basic models, which could satisfying the constraints.

1. Dark scaled up variants of weak bosons can make weak interactions as strong as em interactions below atomic scale. The transformation of protons to neutrons by exchange of dark weak boson or by dark weak decay allows to overcome Coulomb wall and explain why only nuclei stable against beta decays are produced.

2. p-Adically scaled up variant of electron considerably heavier than electron is possible and leads to the analog of muon-catalyzed fusion. This could help to overcome Coulomb wall but fails to explain how neutron containing nuclei could be obtained from dark proton sequences and why the final state nuclei seem to be stable.

3. Dark fusion could be the fundamental process and take place at magnetic flux tubes and leads to dark nuclei, which under some circumstances can transform to ordinary nuclei liberating nuclear binding energy. The leakage of the produced dark nuclei from system along magnetic flux tubes explains why the production rates of nuclei and energy are so modest and why gamma rays, neutrons and other nuclei are not detected. Also ordinary hot nuclear fusion would rely on this mechanism and the high temperature in Sun would be generated by the transformation to ordinary nuclei - perhaps in the collisions of dark nucleus beams leaking out of the system along magnetic flux tubes with dense targets. Universal abundances and isotope ratios are predicted. This model combined with the generalization of Widom-Larsen model is strongly favored.

The combination of first and third mechanisms satisfies the basic conditions if also hot fusion proceeds by this mechanism. Thus dark variants of nuclei and weak interactions would become an essential part of nuclear physics.

5.2.1 TGD Variant Of Widom-Larsen Model

Widom and Larsen (for articles see the Widom Larsen LENR Theory Portal [C13] (see `http://tinyurl.com/boq2u2z`) have proposed a theory of cold fusion (LENR) (see `http://tinyurl.com/y8ejwxom`) [C11], which claims to predict correctly the various isotope ratios observed in cold fusion and accompanying nuclear transmutations. The ability to predict correctly the isotope ratios suggests that the model is on the right track. A further finding is that the predicted isotope ratios correspond to those appearing in Nature which suggests that LENR is perhaps more important than hot fusion in solar interior as far as nuclear abundances are considered. TGD leads to the same proposal and Lithium anomaly could be understood as one implication of LENR [L4]. The basic step of the reaction would rely on weak interactions: the proton of hydrogen atom would transform to neutron by capturing the electron and therefore would overcome the Coulomb barrier.

It is difficult to understand how this step could be fast enough and this is certainly the weak point of Widom-Larsen model. The TGD inspired solution of the problem [K42] could be that weak interactions are mediated by dark variants of weak bosons such that weak scale is scaled up to $L(k)$ by scaling with h_{eff}/h. $k=137$ would correspond to atomic length scale and $k=127$ to electron's p-adic length scale. The latter option is suggested by the superdense matter proposal of Holmlid. Weak bosons would behave like massless bosons below $L(k)$. This would make weak interactions as strong as electromagnetic interactions and the crucial weak interaction step could proceed swiftly.The dark variant of weak interactions would apply below $L(k)$ and make weak gauge bosons effectively massless below $L(k)$ characterizing the flux tube (electronic p-adic length scale in the model considered). Only exchanges of W bosons and dark beta decays (if possible) make this happen fast: ordinary beta decays would be as slow as in standard model since W bosons would be massive above $L(k)$.

This makes possible the exchange of effectively massless dark W bosons between dark protons at flux tube and dark nuclei at second flux tube. This exchange allows to get rid of Coulomb wall by transforming proton to neutrons and the formation of dark nuclei can proceed. Exchange of dark W bosons also leads to a rapid decay of dark nuclei to nuclei stable with respect to weak interactions: observed final state nuclei are indeed stable. Dark beta decay makes possible simpler transformation to beta-stable dark nuclei.

5.2.2 Could TGD Allow Heavy Electron As Exotic State Of Electron?

There exists evidence that neutrino mass scale can vary. TGD explanation is that the p-adic mass scale associated characterized by $p \simeq 2^k$, can vary. There would be several values of k and the value of k would depend on the environment of neutrino. resides.

This allows to play with the possibility large effective mass of electron used routinely in condensed matter models in some situations corresponds to a real mass. The p-adic mass scale $L(k) \propto 2^{k/2}$ assignable to Mersenne prime $p = M_{127} = 2^{127}-1$ with $k = 127$ characterizing electron would be reduced from that associated with $k = 127$ to some smaller value of k. One possibility is the scale $L(k = 113)$ associated the Gaussian Mersenne $p = M_{G,113} = (1 + i)^{113} - 1$ characterizing the size scale of atomic nuclei. Second possibility is the Mersenne prime $2^{107} - 1$ characterizing nucleons so that electron mass is scaled up by $2^{(127-k)/2}$. For $k = 127 \rightarrow k = 107$, mass (size) would be scaled up (down) by a factor $2^{10} = 1024$ ($2^{-10} = 1/1024$). For $k = 127 \rightarrow k = 113$, mass (size) would be scaled up (down) by a factor $2^7 = 128$ ($2^{-7} = 1/128$).

This option can be considered as a way to overcome Coulomb wall but it does not explain why only stable nuclei are produced in cold fusion.

5.2.3 Cold Fusion Of Dark Protons To Dark Nuclei At Dark Magnetic Flux Tubes Followed By Transformation To Ordinary Nuclei

The TGD inspired quantum model for living matter in terms of magnetic flux tubes (magnetic bodies) carrying dark matter as large h_{eff} phases leads to the model of dark cold fusion suggesting in turn a model for cold fusion [L31].

1. Pollack's exclusion zones (EZs) [L24] are negatively charged regions of water giving rise to what Pollack calls the fourth phase of water. In TGD inspired model [K85, K86, K40] [L24] it is assumed that water molecules form inside EZs a phase with effective stoichiometry $H_{1.5}O$ with each hydrogen bonded pair of water molecules losing one proton, which becomes dark proton at magnetic flux tube. The dark protons can form string like objects at flux tubes identifiable as dark nuclei. The simplest assumption is that the binding energy of dark nuclei scales as $1/h_{eff}$ and would be much lower than ordinary nuclear binding energy. In biological applications it has been assumed that this energy is in the range of bio-photon energies covering visible and UV energies. The distance between dark protons would be about 1 nm.

   Dark nuclear binding energy would be liberated in the formation of dark nuclei and the emitted dark photons with energy of order O-H bond energy about 5 eV would kick protons from further water molecules. Dark cold fusion would proceed as a chain reaction much like the ordinary fusion. This could happen also for dark variants of deuterons since deuterons could be regarded as elementary particle like entities corresponding to p-adic prime $k = 109$ whereas protons would correspond to $k = 107$. Even nuclei could appear as building bricks of nuclei made from nuclei. Mathematician would unashamedly generalize this to a fractal hierarchy of nuclei formed from nuclei formed from...

2. Could dark nuclei transform to ordinary ones? If they do so, large energies in the range 1-7 MeV per nucleon are liberated and the system ends up to a high temperature. This could make possible ordinary nuclear fusion and I have proposed that biofusion - for which evidence exists - is preceded by dark cold fusion [L31].

   One can wonder whether also the ordinary fusion involves dark cold fusionas as the first step. Or could all nuclei be produced via dark fusion of protons to light dark nuclei, which in turn coud fuse to heavier dark nuclei followed by beta decays and whether the distributions of elements are determined already at this level? High temperature could be seen as a consequence of the transformation of dark nuclei to ordinary nuclei rather than a prerequisite of hot fusion. This would predict universal composition present also in natural environment and suggested by the cold fusion experiments.

3. The mechanism leading to cold fusion would be very general. Charge separation in which protons are transformed to dark protons at magnetic flux tubes would be enough. This could take be achieved by irradiation by visible or IR light as in Pollack's experiments. Oscillating water bubble, cavitation, laser pulses inducing Coulomb explosion, and strong electric fields

used in electrolysis could induce charge separation and dark fusion inducing ordinary fusion might take place in all these situations.

This kind of charge separation occurs also in rotating magnetic systems as was observed already by Faraday and these systems indeed exhibit free energy anomalies not easy to understand in standard physics. The space-energy generator of Tewari [H3] is an example of this kind of system [L33] [K8]. The rotating F_0 machine analogous to the generator of electric power plant and transforming ADP to ATP in mitochondria might use dark nuclear fusion as power source in some situations and could be behind the reported biofusion. The transformation of large $h_{eff}/h \sim 10^6$ dark nuclei with size of about 10 nm to ordinary nuclei could be of course quite too slow.

5.2.4 Fusion Induced By Coulomb Explosions As A Way To Fix The Details Of TGD Inspired Model

Leif Holmlid has introduced the notion of fusion induced by Coulomb explosion of ultradense deuterium (see popular article `http://tinyurl.com/nbephxb`). The slides of the talk by Sweinn Olaffsson (see `http://tinyurl.com/j3csy53`) give a more technical representation about the subject. Also ultradense variant of hydrogen can be considered. The article *Laser-driven nuclear fusion D+D in ultra-dense deuterium: MeV particles formed without ignition* (see `http://tinyurl.com/pm56kk3`) gives a more detailed representation about the idea [C23].

The abstract of article provides a summary of the idea.

The short D-D distance of 2.3 pm in the condensed material ultra-dense deuterium means that it is possible that only a small disturbance is required to give D+D fusion. This disturbance could be an intense laser pulse. The high excess kinetic energy of several hundred eV given to the deuterons by laser induced Coulomb explosions in the material increases the probability of spontaneous fusion without the need for a high plasma temperature. The temperature calculated from the normal kinetic energy of the deuterons of 630 eV from the Coulomb explosions is 7 MK, maybe a factor of 10 lower than required for ignition. We now report on experiments where several types of high-energy particles from laser impact on ultra-dense deuterium are detected by plastic scintillators. Fast particles with energy up to 2 MeV are detected at a time-of-flight as short as 60 ns, while neutrons are detected at 50 ns time-of-flight after passage through a steel plate. A strong signal peaking at 22.6 keV u1 is interpreted as due to mainly T retarded by collisions with H atoms in the surrounding cloud of dense atomic hydrogen.

What is important that fusion products assignable to Coulomb explosions have been indeed observed. Also kaons, pion, muons, and their decay products have been detected. It is amusing that Coulomb explosion could occur in the explosive reaction of alkali metals with water familiar from school days (see `http://tinyurl.com/ybxbfoo2`).

One can of course challenge the notion of superdense hydrogen/deuterium.

1. The kinetic temperature assignable to the average kinetic energy of 630 eV of deuterium atoms resulting in Coulomb explosion is about one order of magnitude lower than the temperature $T = 10^7$ K $\simeq 1$ keV in the solar core and one can argue that ordinary fusion is impossible. Even the solar fusion proceeds very slowly.

2. Laser beam is assumed to generate ultradense deuterium with density which is about million times higher than the density of normal deuterium phase. The distance between deuterium atoms would be 2.3 pm and about 100 times shorter than than the distance between ordinary deuterium atoms (which should be 2.3 Angstroms). Charge separation occurs since the electric field of laser beam strips of electrons and the highly charged superdense deuterium explodes and produces very energetic deuterium ions. The average energy is measured to be about 630 eV and equating this energy with the repulsing Coulomb interaction energy of deuteron atoms one obtains the estimate for the distance between deuteron atoms. The Coulombic energy generated by the compression should come from the laser pulse.

TGD suggests a one-dimensional variant of this model in which the compression occurs only in the direction of laser beam and generates a string of dark deuterium nuclei at magnetic flux tube. Deuterium nuclei themselves would be unchanged: only their Compton lengths scale up by $h_{eff}/h = 2^{10}$ and they would form dark analogs of ordinary nuclear strings formed from D-D units. Similar model applies to dark proton strings.

1. The momentum given by the laser pulse to the nuclei forces compression in the normal direction and for large enough compression a new phase consisting of dark nucleons at magnetic flux tubes parallel to the laser beam is formed. For this phase large Coulomb energy would be compensated by scaled up variant of nuclear binding energy if it behaves like $1/h_{eff}$. The scaling of the p-adic length scale $L(107)$ of nucleon to effective p-adic length scale $L(127)$ is an attractive guess gives a scaling by factor 10^3 in normal direction. Nuclear binding energy scale 1 MeV scales down to of 1 keV. By the effective 1-dimensionality density would increase by factor 10^3 rather than 10^6 as assumed by Holmlid and collaborators [C23].

2. What is remarkable that in Sun the nuclear fusion takes place at temperature of 1.5 keV although the rate is extremely slow. This is thought to be made possible by tunnelling. The notion of tunneling in potential is of course an effective description based on the use of non-relativistic potential model treating nuclei as point-like objects. TGD suggests that tunneling should be replaced by two steps. In the first a phase transition forming dark nuclei with $h_{eff}/h = 2^{10}$ and nuclear size $L(k = 127) \simeq 2.5$ pm rather near to the claimed D-D distance 2.3 pm. At the second step a phase transition to ordinary nucleons with standard value of $h_{eff}/h = 1$ or to ordinary bound state of nucleons would occur as the counterpart of tunnelling.

3. Dark nuclear binding energy should not only compensate the dark Coulomb energy but also liberate energy contributing to the kinetic energy of nuclei produced in Coulomb explosion. Coulomb explosion involves both the decay to back ordinary nucleons and nuclear strings representing heavier nuclei [L4]. This process would liberate energy of order nuclear binding energy per nucleon: for nuclei heavier than D this is around 7 MeV. The energy gain would be much higher than in hot fusion.

4. One can estimate the lower bound for the Coulomb interaction energy in the first approximation as sum of interaction energies with the nearest neighbors divided by two. For flux dark proton strings along flux tube parallel to laser beam one would have 2 neighbours. This would give $E_c > \alpha\hbar/r$. Distance of $L(137) = 1/1.28$ Angstrom corresponds to Coulomb energy $E_c = \alpha(\hbar/r)$, giving $E_c > 92$ eV.

   For $k = 127$ (electron's p-adic length scale) instead of $k = 137$ Coulomb energy would be by a factor 32 higher and the lower bound for Coulomb energy is about $E_c = 3$ keV which happens to correspond to the temperature in solar core. Taking into account the interactions with all neighbors along the nuclear flux tube gives coefficient $x = (1+1/2+1/3+...)$. There is some maximal value of deuterium nuclei for which the Coulombic energy can be compensated by scaled up nuclear binding energy per nucleon. For dark alpha particle one has $x = 1$. The value of 6.3 keV of average kinetic energy is higher than the estimate for Coulomb energy and suggests that liberated dark nuclear binding energy contributes to the kinetic energy of deuteron atoms in the final state.

   For Helium formed as D-D composite the average binding energy per nucleon is 7 MeV scaling down to 7 keV. Hence the Coulomb energy is more than compensated by nuclear binding energy for dark $k = 127$ D-D but for heavier nuclei nuclear binding energy wins Coulombic interaction energy. In solar interior the temperature is about 1.5 keV and the reactions so slow that hot fusion at these temperatures is not practical at Earth (see `http://tinyurl.com/ceu7yxn`). The formation of dark nuclei could increase the fusion rate since the reactants would spend a longer time near each other.

   Coulomb potential transforms from infinite high potential to triangular potential in 1-D case and nucleon size is of order of their mutual distance during this period. This could favor the occurrence of reactions at quark level. In D-D dark cold fusion only decomposable to ordinary deuteron nuclei and having Z=N are formed and beta decays can lead to other nuclei. Since deuteron is stable, this could allow to understand why neutrons are not observed in the experiments. A more convincing explanation is that they are dark and leak out from the system along dark magnetic flux tubes.

The nuclei formed by fusing dark variants deuterium nuclei are very special and cold fusion experiments suggests that all nuclei an be produced. Hence on must consider also the formation of dark nuclei for which the initial state consists of a sequence of dark protons: this nuclear string can decay only to ordinary protons unless some protons can be transformed to neutrons in fast enough manner. Ordinary weak interactions are too slow to allow this.

1. For deuterium the average binding energy per nucleon is 1 MeV scaling down to 1 keV assuming $1/h_{eff}$ scaling so that the total binding energy is 2 keV. The estimate for Coulomb energy is 3 keV and higher than the total binding energy of dark deuteron. Therefore it seems that the basic step in dark fusion is impossible! For higher nuclei however the binding energy wins unless the proton string is not too long (Coulomb energy depends non-linearly on the number of strings). Dark proton string would however decay to protons rather than ordinary nuclei containing always neutrons. Same must be true for dark nuclei.

   The problem is that ordinary weak interactions are too slow to transform dark nuclei to ordinary ones by beta decays or W exchanges with neutron containing nuclei possibly at other strings consisting of nuclei or with neutron strings.

2. The only solution of the problem is based on the combination of the model with the TGD variant of Widom-Larsen modeling in which dark W exchange or dark beta decay allows to transform incoming proton to neutron to overcome Coulomb wall. The model assumes that weak bosons are dark and therefore effectively massless below p-adic length scale $L(r \equiv 2k+89) = (h_{eff}/h)L(89)$, $h_{eff} = 2^k$, where p-adic length scale $L(r)$ must be equal or longer than atomic length scale $L(k = 137)$. Weak exchanges would proceed as fast as electromagnetic interactions below $L(r)$. For $r = 137$ corresponding to atomic length scale this requires $h_{eff}/h = 2^{137-89)/2} = 2^{24} \simeq 1.6 \times 10^7$. For $r = 127$ corresponding to electron's p-adic length scales predicting the density of dark protons to be roughly the density reported by Holmlid one would have $h_{eff}/h = 2^{127-89)/2} = 2^{19} \simeq .5 \times 10^6$.

   Dark weak boson exchanges and dark beta decays occur fast and allow to transform protons to neutrons and vice versa by weak boson exchange between proton of protonic dark nuclear string with dark nuclear string consisting of nuclei containing neutrons. Dark nuclei would also decay rapidly to nuclei stable with respect to weak interactions. The selection rules for the formation of stable nuclei would be simple. If the dark nucleus candidate contains two neighboring protons they cannot belong to the same final state nucleus. This implies that the neutron number of finals state nuclei tends to be large than proton number and that stable nuclear strings tend to consist of neutron sequences with single proton between them. This selection rule specifies the decay products of given given dark nucleon sequence.

   A variant of this picture is inspired by the model for both ordinary and dark nuclear strings, which assumes that they consist of nucleons connected by color bonds having quark and antiquark at their ends [L4]. Four different quark pairs with em charges +1 ($u\overline{d}$, -1 ($\overline{u}d$), and 0 ($u\overline{d}$ and $d\overline{d}$) are possible. The beta decay of quark at the end of color bond reducing the charge by one unit $u \to d + W^+$ or $\overline{d} \to d\overline{u}$ reduces the charge of dark proton sequence by one unit and effectively corresponds to the ordinary weak decay $p \to n$. The dark weak boson W^+ can decay to dark pair $e^+\nu_e$ which then transforms to ordinary $e^+\nu_e$ pair: the time scale of this transformation does not matter. The final state nucleus would have proton number larger than its charge. Also some ordinary nuclei could be like this. This kind of decays anomalous from the point of view of ordinary nuclear physics has been recently observed for ordinary nuclei [C59] (see also `http://tinyurl.com/jaqrmdx`). The neutrino energies are around 5 MeV. For TGD inspired model see [L47].

   There is experimental support for this picture. In heavy electron induced fusion performed ib NASA (see `http://tinyurl.com/6qku783`) the system was bombarded with neutrons. This made possible to achieve production of stable nuclei. The interpretation is that the exchange of dark W bosons with added neutrons allowed to transform dark protons to dark neutrons by dark weak exchanges and dark beta decays to overcome the Coulomb wall and achieve beta stability.

3. There is an interesting connection with biology. I have proposed dark variants of weak interactions as an explanation for the large parity breaking effects in living matter implying chiral selection of biomolecules, and the proposed mechanism makes the model quantitative. Indeed, DNA would be accompanied by dark proton sequences with dark proton size of order 1 nm. The amazing observation made years ago was that the states of dark nucleons are in 1-1 correspondence with the DNA, RNA, amino-acids, and tRNA and realize genetic code at the

level of dark nuclei [L4, K51]. In this framework it would seem that genes could correspond to dark nuclear strings consisting of neutron sequences having single proton between them. If two dark protons follow each other the gene ends or begins.

The rate for the phase transition to ordinary nuclei is an important factor.

1. If this rate is low, dark nuclei could escape the system along dark magnetic flux tubes and the reaction yield would be small as also the energy yield. One might hope that the attachment of the dark magnetic flux tubes to some target could lead to collisions with ordinary nuclei inducing the decay of dark nuclei to ordinary nuclei.

2. Gamma rays produced in ordinary nuclear fusion would be replaced by dark X rays with energies in few keV range produced in dark nuclear reactions and could leak out of the system along the dark magnetic flux tubes and remain undetected. In the phase transition transforming dark nuclei to ordinary nuclei ordinary gamma rays or bunches of dark X rays could be produced. The fact that the observed gamma ray yield is small suggests that if dark nuclei decay rapidly to ordinary ones, the emission of bunches of dark X rays dominates in this process.

5.2.5 Phase transition temperatures of 405-725 K in superfluid ultra-dense hydrogen clusters on metal surfaces

I received very helpful comment to my blog posting (see `http://tinyurl.com/j6nn4xz`) telling about the work of Prof. Leif Holmlid related to cold fusion [C23] (the relation of TGD based model of cold fusion to Holmlid's work is discussed in this chapter and also in the article [L27]). The basis idea of Holmlid is that cold fusion is preceided by a formation of ultradense protonium or deuterium matter for which distance between protons/deuterium nuclei is about 2.3 pm, which is of the same order of magnitude electron Compton length 2.42 pm.

This helped to find a new article of Holmlid and Kotzias with title "Phase transition temperatures of 405-725 K in superfluid ultra-dense hydrogen clusters on metal surfaces" published towards the end of April [L48] (see `http://tinyurl.com/hxbvfc7`). The article provides very valuable information about the superdense phase of hydrogen/deuterium that he postulates to be crucial for cold fusion.

The postulated supra dense phase would have properties surprisingly similar to the phase postulated to be formed by dark magnetic flux tubes carrying dark proton sequences generating dark beta stable nuclei by dark weak interactions. My original intuition was that this phase is not superdense but has a density nearer to ordinary condensed matter density. The density however depends on the value of Planck constant and with Planck constant of order $m_p/m_{\simeq}2^{11} = 2000$ times the ordinary one one obtains the density reported by Holmlid so that the models become surprisingly similar. The earlier representation were mostly based on the assumption that the distance between dark protons is in Angstrom range rather than picometer range and thus by a factor 32 longer. The modification of the model is straightforward: one prediction is that radiation with energy scale of $1 - 10$ keV should accompany the formation of dark nuclei.

In fact, there are also similarities about which I did not know of!

1. The article tells that the structures formed from hydrogen/deuterium atoms are linear string like structures: this was completely new to me. The support comes from the detection of what is interpreted as decay products of these structures resulting in fragmentation in the central regions of these structures. What is detected is the time-of-flight distribution for the fragments. In TGD inspired model magnetic flux tubes carrying dark proton/D sequences giving rise to dark nuclei are also linear structures.

2. The reported superfluid (superconductor) property and the detection of Meissner effect for the structures were also big news to me and conforms with TGD picture allowing dark supraphases at flux tubes. Superfluid/superconductor property requires that protons form Cooper pairs. The proposal of Holmlid and Kotzias that Cooper pairs are pairs of protons orthogonal to the string like structure corresponds to the model of high Tc superconductivity in TGD inspired model of quantum biology assuming a pair of flux tubes with tubes containing the members of the Cooper pairs. High Tc would be due to the non-standard value of $h_{eff} = n \times h$. This

finding would be a rather direct experimental proof for the basic assumption of TGD inspired quantum biology [K85, K86].

3. In TGD model it is assumed that the density of protons at dark magnetic flux tube is determined by the value of h_{eff}. Also ordinary nuclei are identified as nuclear strings [L4] and the density of protons would be the linear density protons for ordinary nuclear strings scaled down by the inverse of h_{eff} - that is by factor $h/h_{eff} = 1/n$.

   If one assumes that single proton in ordinary nuclear string occupies length given by proton Compton length equal to (m_e/m_p) time proton Compton length and if the volume occupied by dark proton is 2.3 pm very nearly equal to electron Compton length 2.4 pm in the ultra-dense phase of Holmlid, the value of n must be rather near $n \simeq m_p/m_e \simeq 2^{11} \simeq 2000$ as the ratio of Compton lengths of electron and proton. The physical interpretation would be that the p-adic length scale of proton is scaled up to essentially that of electron which from p-adic mass calculations corresponds to p-adic prime $M_{127} = 2^{127} - 1$ [K61]. The ultra dense phase of Holmlid would correspond to dark nuclei with $h_{eff}/h \simeq 2^{11}$.

   My earlier intuition was that the density is of the order of the ordinary condensed matter density. If the nuclear binding energy scales as $1/h_{eff}$ (scaling like Coulomb interaction energy) as assumed in the TGD model, the nuclear binding energy per nucleon would scale down from about 7 MeV to about 3.5 keV for $k = 127$. This energy scale is same as that for Coulomb interaction energy for distance of 2.3 pm in Holmlid's model (about 5 keV). It must be emphasized that larger values of h_{eff} are possible in TGD framework and indeed suggested by TGD inspired quantum biology. Amusingly, my original too restricted hypothesis was that the values of n comes as powers of 2^{11}.

4. In TGD based model scaled down dark nuclear binding energy would (more than) compensate for the Coulomb repulsion and laser pulse would induce the phase transition increasing the density of protons and increasing also Planck constant making protons dark and leading from the state of free protons to that consisting of dark purely protonic nuclei in turn transforming by dark weak interactions to beta stable nuclei and finally to ordinary nuclei liberating essentially ordinary nuclear binding energy. In TGD based model the phase transition would give rise to charge separation and the transition would be highly analogous to that occurring in Pollack's experiments [L24] [L24].

It seems that the model of Holmlid and TGD based model are very similar and Holmlid's experimental findings support the vision about hierarchy of dark matter as phases of the ordinary matter labelled by the value of $h_{eff}/h = n$. There are also other anomalies that might find explanation in terms of dark nuclei with $n \simeq 2^{11}$. The X rays from Sun have been found to induce a yearly variation of nuclear decay rates correlating with the distance of Earth from Sun [C74, C116, E26].

1. One possible TGD based explanation relies the nuclear string model [L4]. Nucleons are assumed to be connected by color flux tubes, which are usually neutral but can be also charged. For instance, proton plus negative charged flux tube connecting it to the neighboring nucleon behaves effectively as neutron. This predicts exotic nuclei with the same chemical properties as ordinary nuclei but with possibly different statistics. X rays from Sun could induce transitions between ordinary and exotic nuclei affecting the measured nuclear reaction rates which are averages of all states of nuclei. A scaled down variant of gamma ray spectroscopy of ordinary nuclei would provide an experimental proof of TGD based model.

2. The fact that the energy scale is around 3 keV suggests that X rays could generate transitions of dark nuclei. If so, the transformations of dark nuclei to ordinary ones would affect the measured nuclear transition rates. There are also other anomalies such as those reported by Rolfs *et al* [C83, C84], which might find explanation in terms of presence of dark variants of nuclei ordinary nuclei.

5.2.6 Do All Variants Of Cold Fusion Reduce To Dark Bubble Fusion?

During years I have many times tried to understand what happens in electrolysis and every time I have been forced to to admit that I do not! Very embarrassing observation. I have tried to gain wisdom from an old chemistry book with 1000 pages again and again but always in vain. This is especially embarrassing because a unified theory builder to be taken seriously is expected to build brave new brane worlds in 11 or 12 dimensions to possibly explain a possible detected particle at mass 750 GeV at LHC instead of trying to understand age old little problems solved aeons ago. The wau-coefficient of chemistry is zero as compared to the awesome 10^{500} of M-theory.

Energetics has been my personal problem (besides funding). I learn from chemistry book that an electric field - say voltage of 2 V per 1 mm splits molecules to ions. The bond energies of molecules are in few eV range. For instance, O-H bond has 5 eV energy. $V = 2\text{V/mm}$ electric field corresponds to electrostatic energy $E = eVd \sim 2^{-10}$ eV energy gain for a unit charge moving from the end of the bond to the other one. This is incredibly small energy and to my understanding should have absolutely no effect to the state molecule. Except that it has!

A heretic thought: could it be that chemists have just accepted this fact (very reasonable!) and built their models as mathematical parameterizations without any attempt to understand what really happens? Could the infinite vanity of theoretical physicists have prevented them from lowering themselves to the intellectual level of chemists and prevented them from seeing that electrolysis is not at all understood?

In order that this kind of energy would have so drastic effect as splitting molecule to pieces, the system molecule + yet unidentified "something" must be in critical state. Something at the top of hill so that even slightest perturbation makes it fall down. The technical term is criticality or even quantum criticality.

1. Biological systems are critical systems extremely sensitive to small changes. Criticality means criticality against molecular ionization - charge separation basically. Also in electrolysis this criticality is present. Both DNA and cell are negatively charged. Inside cells there are various kinds of ions. In TGD Universe all matter is quantum critical.

2. Charge separation occurs also in Pollack's experiments [L24] in which the fourth phase of water is generated. This phase contains negatively charged regions with effective $H_{1.5}O$ stoichiometry (hydrogen bonded state of two water molecules which has lost proton). Positive charge associated with lost protons has gone outside these regions.

What produces quantum criticality against charge separation? What is this unidentified "something" besides the system? Magnetic body carrying dark matter! This is the answer in TGD Universe. The TGD inspired model [L31] assumes that the protons transform to dark protons at dark magnetic flux tubes possibly carrying monopole flux. If these protons form dark nuclei the liberated dark nuclear energy can split further O-H bonds and transform protons to dark phase. The energy needed is about 5 eV and is in the nuclear binding energy scale scaling as $1/h_{eff}$ (like distance) if the size scale of dark protons proportional to h_{eff}/h is 1 nm. One would have $h_{eff}/h \simeq 10^6$: the size scale of DNA codons - not an accident in TGD Universe [L4, K51]. The liberated dark nuclear energy can ionize other molecules such as KOH, NaOH, HCl, $Ca(OH)^2$, CaO,... Entire spectrum of values of h_{eff}/h is possible. For laser pulse induced fusion assumed to induce longitudinal compression one would have $h_{eff}/h \simeq 10^3$. Dark nuclear physics with non-standard values of Planck constant would be a crucial element of electrolysis. Condensed matter physics and nuclear physics would not live in totally separate compartments and dark matter an ordinary matter would interact! How humiliating for theoreticians! I do not hear the derisive laughter of superstring theoreticians anymore!

Ordinary electrolysis would thus produce dark nuclei. The problem is that most of them would leak out from the system along dark flux tubes and potentially available nuclear energy is lost! As also various elements so badly needed by modern techno-society! For instance, in the splitting of water to hydrogen, the flux tubes assignable to the beam containing hydrogen would take the dark nuclei away. Could one transform dark nuclei to ordinary ones?

1. If this beam collides with say metal target, some fraction of the dark nuclei could however transform to ordinary nuclei and liberate really huge energy: the difference between nuclear binding energies of initial and finals state would be essentially that of the final state unlike in ordinary nuclear fusion.

2. In particular, electrodes could induce transformation of the dark nuclei to ordinary ones. Even in the experiments of Pons and Fleichman [C101] the role of porous Pd target could be secondary: it would be only a target allowing the dark nuclei produced by bubble fusion

to transform to ordinary nuclei and the large surface area would help in this respect. Same applies to Rossi's E-Cat [C102].

3. So called Brown's gas (see `http://tinyurl.com/gotxwa8`) generated in the splitting of water is claimed to be able to melt metals although its temperature is relatively low- around 100 Celsius. The claims is of course taken not seriously by a "serious" scientists as the Wikipedia article so clearly demonstrates. It could be however understood if the melting is caused the transformation of dark nuclei to ordinary ones. The corrosion of the metallic surface in the presence of cavitating water would be also due to the dark nuclear energy. Not all of the energy would be used to produce corrosive effects, and I have in some discussions been told that in electric plants an anomalous production of energy assignable to corrosive effects in turbine has been observed. Electric plants could have served secretly as dark nuclear plants! Unfortunately, I do not have reference to this claim. LeClair effect to be discussed later affects aluminium disks inside cavitating water corrosively: LeClair might have reinvented Brown's gas!

   But why metals? The surface of metal in external electric field carries negative charge density of conduction electrons. Could it be that they attract the positively charged dark nuclei from the magnetic flux tubes back to the visible world, and help them to tranform back to ordinary nuclei? Conductors in electric fields would thus help to transform dark nuclei to ordinary matter.

4. Brown's gas is reported to have no effect on living matter? Why? If living matter uses dark nuclear physics as a basic tool, it should have developed tools to avoid the transformation of dark nuclei to ordinary nuclei in uncontrollable manner. What aspect of quantum biophysics could make this possible? Negentropy Maximization Principle [K65] defining the basic variational principle of TGD inspired theory of consciousness could be the general reason preventing this transformation [L31]. The negentropy characterizing negentropic entanglement serving as a measure for potentially conscious information assignable to non-standard values of h_{eff} would be reduced if h_{eff} is reduced. But how to understand this at a more detailed level? Could the fact that bio-molecules are mostly insulators rather than electronic conductors explain this?

One can imagine also an alternative and simpler mechanism transforming dark nuclei to ordinary ones. The dark nuclei are attracted from magnetic flux tubes to the negatively charged EZ from the magnetic flux tube and transform to ordinary nuclei. The bubbles in the electrolyte near the catode would serve as seats of the dark nuclei and flux tubes could entere to the negatively charged catode. The large surface area of Pd would make it as ideal target for the ends of the magnetic flux tubes.

5.2.7 Surface Plasmon Polaritons And Cold Fusion

It has been proposed that so called surface plasmon polaritons (SPPs, see `http://tinyurl.com/y7attmf7`) are important for cold fusion. In TGD framework the question is whether they are important for dark nuclear fusion or for the transformation of dark nuclei to ordinary ones.

1. SPPs involve localized surface plasmons - electron waves localized near the interface of two phases (now surface of pores of Pd target) - accompanied by polaritons, which are electromagnetic waves concentrated near the interface surface. The density of electrons varies periodically in the direction of the propagating wave. At low frequencies the dispersion relation is the linear dispersion relation for photons with light velocity determined by di-electric constant whose real part changes sign at the surface between two phases. At large wave vectors dispersion relation approaches to

$$\omega = \frac{\omega_P}{\sqrt{\epsilon_1+\epsilon_2}} \quad , \quad \omega_P = \sqrt{n_e e^2/m_{eff}} \tag{5.2.1}$$

   ω_P is the bulk plasma frequency for $\epsilon = 1$ characterizing also 3-D plasma waves. The wave vector dependent part coming from large wave vectors in the dispersion relation is inversely proportional to the effective mass of electron, and it it is large the frequency is essentially constant and the time dependence and spatial dependence separate into a product and no propagation happens. The wave consists of constant rapidly spatially varying part and slowly spatially varying part for which frequencies are not constant.

2. SPPs could either help formation of dark nuclei at Pd surface or their transformation to ordinary nuclei. It is difficult to see how SPPs could help to compress Pd nuclei to much denser Pd strings at flux tubes: bubble collapse and formation of EZs would allow to achieve this. Dark weak physics allows to overcome Coulomb wall and to explain why only stable final state nuclei are produced so that SPPs are not promising candidates for dark fusion.

3. If bubble fusion is responsible for the production of dark nuclei, SPPs at Pd surface could facilitate the transformation of dark nuclei arriving at them along flux tubes to ordinary nuclei. Pd is a conductor and generates in electric field electronic surface charge density, whose sign is determined by the sign of the normal component of the field. Polariton would provide the electric field. SPP is a wave involving both electric field and electric charge density induced by it on the surface of Pd target and varying periodically along the Pd surface and making it locally positively or negatively charged. Strong negative charge density could draw the positively charged dark nuclei from magnetic flux tubes and in this manner transform them to ordinary nuclei.

5.2.8 Heavy Electron Induced Cold Fusion Is Not Promising In TGD Framework

Muon-catalyzed fusion (`http://tinyurl.com/n7sbo5o`) was predicted by A Sakharov and F. C. Frank before 1950. L. Alvarez *et al* observed observed muon-catalyze fusion. Muon-catalyzed fusion takes place at temperatures considerably lower than needed for ordinary fusion. The isotope ratios are same as for hot fusion since muonium atoms acting as analogs of hydrogen atoms act as catalysts only. For instance, in muon-catalyzed D-T fusion muonium and D, and T nuclei form a D-muonium-T molecule, whose size is smaller than the size of D-H-T molecule by a factor $m_e/m_\mu \simeq 1/207$ of electron and muon masses. This makes the Coulomb wall narrower and tunneling makes it easier to achieve nuclear fusion. Unfortunately, muon-catalyzed fusion is not of practical value. Muons are not stableandmust be produced and muons get stuck to the outgoing nucleus produced in nuclear fusion.

Heavy electron catalyzed fusion can be seen as a variant of muon-catalyzed fusion. In condensed matter physics one introduces the notion of effective electron mass, which can be considerably larger than the mass of free electron and one speaks of heavy electrons (see `http://tinyurl.com/j5vnvqu`). The mass can become even thousand times larger than electron mass. This effective mass allows a phenomenological description of the effects of the condensed matter environment on electron's interactions. If effective mass is large, the interactions with lattice make the response of the electron to external forces slower.

If it makes sense to speak of atoms formed from nuclei and heavy electrons, it might be possible to speak also about the heavy analog of hydrogen atom H_{heavy}. In this case interactions with lattice would make the response of heavy electron to the Coulomb force of nucleus slower. The size of this heavy analog of hydrogen atom, call it H_{heavy} would be proportional to $m_{e,heavy}$. For $m_e/m_{e,heavy} = 10^3$ the size of the H_{heavy} would be about 10^{-14} meters, the size scale of nucleus. The small size would make Coulomb wall between exotic atoms of this kind narrower and make cold fusion easier. One can also consider the analog of D-H_{heavy}-T molecule and the analog of muon-catalyzed fusion. I am not enough condensed matter physicist to tell whether this idea is realistic. Certainly the role of the condensed matter environment would be crucial for the process.

Around 2012 NASA published a video (see `http://tinyurl.com/6qku783`). It was told that NASA has applied patent for a method producing heavy electrons. Zawodny, who works as senior researcher tells that it has demonstrated ability to produce excess amounts of energy cleanly without hazardous ionizing radiation without producing nasty waste. In the video Zawodny stated that NASA's method for enhancement of surface plasmon polaritons (SPPs) (see `http://tinyurl.com/y7attmf7`) to initiate and sustain LENR releases energy by adding neutrons. When enough neutrons are added they spontaneously decay into something of the same mass but another element.

No details were revealed but the announcement suggest that the mechanism assumed to make possible LENR is based on this mechanism. As already explained, the role of SPPs would be same as in muon-catalyzed fusion. If the effective mass of electrons is high enough this could make possible heavy electron catalyzed fusion by creating analogs of atoms with small size forcing the deuterium nuclei nearer to each other and making possible formation of dark deuterium strings.

In TGD framework this mechanism could be also realized if it is possible to change the p-adic length scale of electron and if the heavy electron is stable enough. This option however fails to explain why the produced final state nuclei are stable and how some protons of dark proton sequence would transform to neutrons. One can wonder about the role neutrons in the experiment. In the model based on dark weak physics their role is easy to understand.

5.3 Examples About Cold Fusion Like Processes

In the following examples of claimed cold fusion like processes are discussed in TGD framework. The discussion of fusion induced by Coulomb explosions allowed to identify the most plausible TGD inspired model of cold fusion. The model assumes the formation of dark nuclei with $h_{eff}/h = 2^9$ scaling nucleon size scale from $L(107)$ to the length scale $L(127) = 2^{10}L(107)$ of electron and temperature scale $T \sim 1$ keV near to the temperature 1.5 keV prevailing in Sun with dark weak bosons in atomic length scale allowing to transform protons to neutrons to overcome the Coulomb wall to build dark nuclei. Second possibility would be nuclear length scale $L(113)$ involving $h_{eff}/h = 2^3$ giving temperature $T = 128$ keV making possible hot fusion in earthly conditions requiring temperature in the range $10 - 10^2$ keV. All these scales correspond to Mersenne primes or Gaussian Mersennes assigned to charged leptons, hadron physics, and nuclear physics. Weak bosons are assumed to be dark and massless below atomic length scale $L(137)$ or longer p-adic length scale and are essential for getting neutron containing final state nuclei and to explain why only stable final state nuclei are produced.

5.3.1 Pons-Fleichman Effect

Pons and Fleichman announced 1989 [C101] the production of heat of with unknown origin in an electrolytic system using palladium metal as catode immersed in heavy water (D_2O). The heat production was assigned to cold fusion. The prevailing interpretation has been that electrolysis brings deuterium to the porous surface of Palladium and at some critical doping ratio near to 1:1 cold fusion at Pd target becomes possible.

The E-Cat of Andrea Rossi [C102] can be also classified as cold fusion device although the mechanism of the claimed fusion is still unknown. Several objections against Rossi's E-Cat are represented: I have discussed the objections from TGD viewpoint in [K42]. For instance, isotope ratios for Cu produced in the process are same as the natural isotope ratios and that only stable isotopes are present. This has been interpreted by skeptics in an easy-to-guess manner: the Cu isotopes are added by hand. This requires that cold fusion mechanism is very similar to the standard nuclear fusion or behind it.

Criticality could be a prerequisite for both the generation of dark variants of particles and their transformation to ordinary nuclei. At critical doping fraction either a transformation of deuterium to dark deuterium or of the dark nuclei generated in dark bubble fusion to ordinary ones in electrolyte could take place. Therefore TGD allows to consider two alternative models and also their hybrid in these situations.

1. The earlier arguments suggest that the critical doping fraction makes it possible for the incoming dark nuclei generated in the bubble fusion in the electrolyte to transform to ordinary nuclei in especially effective manner. The dark bubble fusion near Pd surface or inside pores of the Pd target could dominate and give rise to dark sequences of D nuclei (heavy water was used by Pons and Fleichman). Large fraction of the dark nuclei from the electrolyte far from electrodes could leak out from the system.

   As already explained, SPPs would help to generate strong negative local charge density at the surface of Pd attracting the positively charged dark nuclei and inducing their transformation to ordinary nuclei.

2. Second option is that dark fusion occurs mostly at the pores of Pd surface at critical doping fraction. It is not however not easy to identify for this any other mechanism than bubble

collapse in the pore. Pd catalyst could make dark bubble fusion especially effective by forcing also the Pd nuclei at Pd surface to the compressed dark phase. SPPs at the surface of Pd catalyst could in turn attract the dark nuclei and force them to transform to ordinary ones. Criticality would act in both directions.

(a) It is known that deuterium nuclei are gradually adsorbed at the surface of Palladium catalyst, where they have a high mobility. Bubble collapse could draw these highly mobile Pd nuclei to the dark nuclei at flux tubes.

(b) The larger the density of deuterons at Pd surface, the better the changes to achieve the generation of dark nuclei. It takes quite a long time before heat production begins, which suggests that the critical doping fraction implies quantum criticality making possible effective beneration of dark nuclei and their transformation back to ordinary nuclei. This argument makes sense also when bubble collapse in pores induces the dark fusion.

(c) If only the production of dark nuclei takes place at Pd surface, heat production could be due to the emission of keV dark photons transforming to ordinary X rays. The dark nuclei could leak out of the system and remain undetected. Dark nuclei could also remain in the Palladium or Nickel target and be rather long-lived against transformation to ordinary nuclei so that their presence would eventually prevent the generation of new dark nuclei. It would be also easy to understand why dark nuclei do not leak out out so easily in cold fusion with Pd and Nickel targets as in say bubble fusion. The production of heat is indeed observed to occur periodically. The dead times between heat production periods give idea about the lifetime of dark nuclei.

(d) SPPs could also attract dark nuclei and transform them to ordinary nuclei and enhance production of heat and ordinary nuclei.

The cautious conclusion would be following. The production of dark nuclei occurs always as dark bubble fusion but the dark nuclei generated in electrolyte tend to leak out from the system. Metal surfaces in electric fields inducing negative charge density could help to transform dark nuclei to ordinary ones. Mobile D-nuclei at the surface of Pd electrode could make dark fusion more effective in the pores. SPPs at Pd surface cold also make the transformation of dark nuclei to ordinary nuclei more effective.

5.3.2 Solution Of The Ni62 Mystery Of Rossi's E-Cat

In my blog (see `http://tinyurl.com/zvqfqkt`) a reader calling himself Axil made a highly interesting comment. He told that in the cold fusion ashes from Rossi's E-Cat there is 100 micrometer sized block containing almost pure Ni62 isotope. This is one of Ni isotopes but not the lightest Ni58, whose isotope fraction 67.8 per cent. Axil gave a link providing additional information (see `http://tinyurl.com/zsv8jfe`) and I dare to take the freedom to attach it here.

Ni62 finding looks really mysterious. One interesting finding is that the size 100 micrometers of the Ni62 block corresponds to the secondary p-adic length scale for W bosons. Something deep? Let us however forget this clue.

One can imagine all kinds of exotic solutions but I guess that it is the reaction kinetics "dark fusion + subsequent ordinary fusion repeated again and again", which leads to a fixed point, which is enrichment of Ni62 isotope. This is like iteration. This guess seems to work!

1. The reaction kinematics in the simplest case involves three elements.

   (a) The addition of protons to stable isotopes of Ni. One can add $N = 1, 2, ...$ protons to the stable isotope of Ni to get dark nuclear string NiX+N protons. As such these are not stable by Coulomb repulsion.

   (b) The allowed additional stabilising reactions are dark weak decays and dark W boson exchanges, which transfer charge between separate dark nuclear strings at flux tubes. Ordinary beta decays are very slow processes since outgoing W boson decaying to electron and neutrino is very massive. One can forget them.

   (c) The generation of dark nuclei and their transformation to ordinary nuclei occurs repeatedly. Decay products serve as starting point at the next round. One starts from stable isotopes of NiX, $X = 58, 60, 61, 62, 64$ and adds protons some of which can by dark W exchange transform to neutrons. The process produces from isotope NiX heavier isotopes NiY, $Y = X + 1, X + 2, ..$ plus isotopes of Zn with $Z = 30$ instead of $Z = 28$, which are stable against ordinary beta decays in the time scale considered. They can however decay by dark beta decay to a possibly stable isotope of Ni.

2. The key observation is that this iterative kinematics increases necessarily mass number!! The first guess is that starting from say $X = 58$ one unavoidably ends up to the most massive stable isotope of Ni! The problem is however that Ni62 is not the heaviest stable isotope of Ni: it is Ni64!! Why the sequence does not continue up to Ni64?

   The problem can be solved. The step Ni62 $\rightarrow$ Ni62+p leads to Cu63, which is the lightest stable isotope of Copper. No W exchanges or beta decays anymore and the iteration stops! It works!

3. But how so huge pieces of Ni62 are possible? If dark W bosons are effectively massless only below atomic length scale - the minimal requirement - , one cannot expect pieces to be much larger than atomic length scale. Situation changes if the Planck constant for dark weak interactions is so large that the scaled up weak scale corresponds to secondary p-adic length scale. This requires $h_{eff}/h \sim 2^{45} \simeq 3.2 \times 10^{13}$. The values of Planck constant in living matter are of this order of magnitude and imply that 10 Hz EEG photons have energies in visible and UV range and can transform to ordinary photons identifiable as bio-photons ideal for the control of bimolecular transitions! 100 micrometers in turn is the size scale of large neuron! So large value of h_{eff}/h would also help to understand why large breaking of parity symmetry realized as chiral selection is possible in cellular length scales.

Clearly, this kind of fixed point dynamics is the unique feature of the proposed dark fusion dynamics and provides an easily testable prediction of TGD based model. Natural isotope fractions are not produced. Rather, the heaviest stable isotope dominates unless there is lighter stable isotope which gives rise to stable isotope by addition of proton.

5.3.3 Sonofusion

In sonoluminescence (see `http://tinyurl.com/pqwovda`) external sound source induces oscillation of the radius of a bubble of water containing possibly noble gas atoms. The unexpected observation is generation of radiation even at gamma ray energies and it is proposed that nuclear fusion might take place.

The term sonofusion or bubble fusion is used about this effect (`http://tinyurl.com/n6kms75`). Taleyarkhan and collaborators [C90] claimed of having observed sonofusion and also neutrons expected to be emitted in the process in 2002 but the experiments could not be replicated. The claim was met with allegations ranging from experimental error to academic fraud, and Taleyarkhan lost his professorship. It is very difficult for an academic outsider to tell what the truth is since the tone of Wikipedia article is extremely hostile.

In standard physics framework one could try to understand sonofusion in terms of very dense phase resulting in bubble collapse making possible high local temperature and the analog of hot fusion. In the master dissertation of M. C. Ramsey spherically symmetric cavitation is modelled using hydrodynamics and also studied experimentally (see `http://tinyurl.com/hspj78t`). The conclusion is that temperatures higher than 10^4 K can be achieved but there is no evidence for extreme temperatures of order 10^7 K required to initiate thermonuclear fusion reactions in Sun (proceeding extremely slowly!).

In TGD framework the low temperature need not be a problem.

1. Also now the model based on dark nuclei at magnetic flux tubes looks natural. Flux tubes would be now radial flux tubes and probably carry monopole flux so that they should return along some axis and thus form the TGD analog of Dirac monopole possible also in Maxwell's electrodynamics albeit asa singular object. In the case of water dark hydrogen strings and even dark oxygen strings can be considered.

2. Dark nucleus phase would be formed during the contraction of the bubble. Since the dark nuclei receive momentum in radial direction, one expects that they continue to travel along the magnetic flux tubes and leak out from the system: a collision with a target might change the situation. The transformation of the nuclei to a string of dark nuclei would involve

emission of dark photons with energies corresponding to scaled down binding energies which are in keV range for $k = 127$ and transforming to ordinary photons heating the system. The transformation to ordinary nuclei could generate gamma rays. If the lifetimes of dark nuclei are relatively long as suggested by the observations of cold fusion in Pd target, the observation of reaction products inside bubbles would be difficult.

5.3.4 Leclair Effect

The original idea of cavitation induced fusion differs from bubble induced fusion in that the bubbles are not assumed to be completely spherical and the expansion is like explosion producing jets. Asymmetric cavitation leads to a situation in which the expansion of the bubble takes place in asymmetric manner and jets are created. Microjets are a real phenomenon (see `http://tinyurl.com/oopu3p2`), they accompany cavitation, and are proposed as an explanation of the corrosive effects produced by cavitation to metal surfaces. The physical mechanism causing the effects remains however open. Also cold fusion experimenters report similar effects. The interpretation would be as effects caused by the energy liberated in cold fusion: in TGD framework the fusion could have produced dark nuclei and their collisions with the target could have transformed them to ordinary nuclei liberating large energies and leading to corrosion.

LeClair has studied the possibility that microjets associated with cavitation of water could lead to cold fusion (see `http://tinyurl.com/y786gy89`). What would be remarkable the simplicity of the approach. Only water would be needed to build all elements and also produce nuclear energy. In [L31] I considered this possibility in the framework of TGD based model for the Pollack's fourth phase of water involving charge separation (negatively charged exclusion zones). Also LeClair reports charge separation and also the geometry of the cross section of jets resembles that of the EZs .

Consider first the claimed findings.

1. Three separate independent scanning electron microscope elemental analysis of the transmuted material were carried out. Also analysis known as XPS and SEM were performed. According to these analysis, the nuclei of almost all elements were produced. The composition transmuted materials followed the same patter as supernova nucleosynthesis, mostly carbon and oxygen with decreasing amounts of the heavier elements. The elemental distribution followed the saw-tooth shaped astronomers's odd-even rule, elements because of the dominance of alpha particle fusion.

   All rare earth metals, precious metals, and many other key elements are reported to be produced in high concentrations, greater than typically seen in the naturally occurring ores. The surface of the reactor was covered with diamonds. These claims sound like commercials and it is difficult to take them seriously.

   Some cold fusion researchers have commented the data and say that the reports about production of heavier nuclei can be true but that they would not try to replicate the experiments. What raises doubts that despite the claimed dramatic successes LeClair did not continue the experimentation (see `http://tinyurl.com/q3fzrzq`). Since public documents are missing, skeptics consider even the possibility of fraud.

   In TGD framework the claim about production of all nuclei could be challenged. If dark nuclei consist of protons and if beta decays of dark protons are not fast enough (they could be rather stable, and neutron containing nuclei would be produced only in the collision with the reaction core leading to the decay of unstable nuclei consisting of protons either decaying to protons. Of course, also dark nuclei containing only protons could be unstable. Dark nuclei could however stabilize themselves rather rapidly by dark beta decays of protons to neutrons if weak bosons are dark and thus effectively massless in the scale $L(127)$.

2. Detailed claims about the shape of jets are made and told to resemble bacteriophages(!) (see `http://tinyurl.com/kl9t2hx`) with head and tail. Head is reported to be positively charged and tail negatively charged. The cylindrical structure is reported to have a cross section consisting of triangles forming hexagons. Inside the negatively charged exclusion zones (EZs) associated with the fourth phase of water discovered by Pollack [L24] obeys effective stoichiometry $H_{3/2}O$ and consists of layers having hexagonal structure. Could jets

represent fourth phase of water discovered by Pollack. Personally I would take these claims very cautiously but I am not experimentalist.

3. There are also claims about a corrosion like effects in the nearby environment. These claims sound outlandish but if the dark nuclei indeed transform to ordinary one liberating large nuclear binding energy in collisions with say walls, this could happen. LeClair also tells about radiation sickness: also this claim could make sense after all.

Unfortunately, the situation is not improved by the fact that the theoretical claims of LeClair do not make much sense. Experimentalists should avoid theorizing as too risky business and leave it to theoreticians who are allowed to be wrong (it would be nice if they would be allowed to be also right!).

1. LeClair interprets the jets as crystal like particle moving with supersonic velocities accelerating to relativistic velocities at which Coulomb wall can be overcome and ordinary nuclear reactions become possible in collisions with aluminium sheets forming the core of the fusion reactor. The reported trenches in the sheet would be due to the collision of jets with the sheet and if the collision is not orthogonal to the sheet a trench is produced.

   The model of bubble fusion involving dark nuclei leaking out from the bubble would allow to interpret the jets as dark matter. They could move with super-sonic velocities since the scale for kinetic energies would be $k = 127$ in the proposed model. The velocities would be of order $v/c = \sqrt{2E/mc^2} \sim 10^{-3}$ for kinetic energy scale $E \sim$ keV. In TGD framework the dark nuclear fusions would have occurred in the bubble and only the decays to ordinary nuclei would occur at the target. The target would be heated but probably and one cannot exclude that ordinary nuclear fusions occur also in the target.

   The claim about relativistic velocities is non-sensical since the energy needed to achieve them would be a considerable fraction of the mass of the crystal. If the crystal has size of order 1 μm the energy would be about 10 Joules and about thousand times larger than the energy liberated in cold fusion if all the protons in this volume fuse to heavier nuclei.

2. LeClair introduces also ZPE as the source of energy and says that nuclear fusion is actually un-necessary. Also Casimir effect is introduced as interaction between the shock bow and jet with Coulomb attraction somehow giving rise to the acceleration of the jet. This s does not make sense to me.

3. LeClair talks about bow shock associated with the moving crystal and carrying negative charges. The geometry of the crystal would resemble bacteriophage having positively charged tail and negatively charged tail. I cannot comment these claims since I do not know about the possibilities to make so detailed conclusions and do not really understand what is meant. The motivation of LeClair probably comes from nuclear fusion believed to occur in the shock wave zones of supernovas and he claims that the situation is scaled down variant of this situation.

   The idea about the role of shock waves could make sense in TGD framework: shock wave would create in the direction of propagation of shock wave $k = 127$ dark nuclei at flux tubes in its propagation direction. In the recent case it does not seem to make sense since the dark nuclei would be generated during the contraction phase of the bubble.

As already noticed, the TGD inspires proposal electrolysis reduces to bubble fusion would suggest that LeClair has rediscovered Brown's gas and its effects on metals having interpretation as a transformation of dark nuclei to ordinary ones (see `http://tinyurl.com/gotxwa8`) .

The conclusion of skeptic on basis of these objections would be rather obvious. However, in TGD framework the cavitation induced fusion is essentially identical with the bubble fusion except that the reactor core of LeClair might make possible the transformation of the produced dark nuclei to ordinary nuclei so that they would not leak out from the system. If the results of LeClair survive his arrangement allows to transform the dark nuclei generated in bubble fusion and to ordinary nuclei and liberate also large energy. This would be an enormous technological breakthrough.

5.3.5 Is cold fusion becoming a new technology?

The progress in cold fusion research has been really fast during last years and the most recent news might well mean the final breakthrough concerning practical applications which would include not only wasteless energy production but maybe also the production of elements such as metals. The popular article titled "Cold Fusion Real, Revolutionary, and Ready Says Leading Scandinavian Newspaper" (see `http://tinyurl.com/huqc34y`) tells about the work of Prof. Leif Holmlid and his student Sinder-Zeiner Gundersen. For more details about the work of Holmlid *et al* see `http://tinyurl.com/nbephxb` and `http://tinyurl.com/j3csy53`, `http://tinyurl.com/pm56kk3` and [C23].

Gundersen revealed the details of an operating cold fusion reactor in Norway reported to generate 20 times more energy than required to activate it. The estimate of Holmlid is that Norway would need 100 kg of deuterium per year to satisfy its energy needs (this would suggest that the amount of fusion products is rather small to be practical except in situations, where the amounts needed are really small). The amusing co-incidence is that I constructed towards the end of the last year a detailed TGD based model of cold fusion and the findings of Leif Holmlid already discussed served as an important guideline although the proposed mechanism is different.

Histories are cruel, and the cruel history of cold fusion begins in 1989, when Pons and Fleichmann reported anomalous heat production involving palladiums target and electrolysis in heavy water (deuterium replacing hydrogen). The reaction is impossible in the world governed by text book physics since Coulomb barrier makes it impossible for positively charged nuclei to get close enough. If ordinary fusion is in question, reaction products should involve gamma rays and neutrons and these have not been observed.

The community preferred text books over observations and labelled Pons and Fleichman and their followers as crackpots and it became impossible to publish anything in so called respected journals. The pioneers have however continued to work with cold fusion and for few years ago American Chemical Society had to admit that there might be something in it and cold fusion researchers got a status of respectable researcher. There have been several proposals for working reactors such as Rossi's E-Cat and NASA is performing research in cold fusion. In countries like Finland cold fusion is still a cursed subject and will probably remain so until cold fusion becomes the main energy source in heating of also physics department.

The model of Holmlid for cold fusion

Leif Holmlid is a professor emeritus in chemistry at the University of Gothemburg. He has quite recently published a work on Rydberg matter in the prestigious journals of APS and is now invited to tell about his work on cold fusion to a meeting of American Physical Society.

1. Holmlid regards Rydberg matter (see `http://tinyurl.com/y7jxfnup`) as a probable precursor of cold fusion. Rydberg atoms have some electrons at very high orbitals with large radius. Therefore the nuclei plus core electrons look for them like a point nucleus, which charge equal to nuclear charge plus that of core electrons. Rydberg matter forms layer-like structures with hexagonal lattice structure.

2. Cold fusion would involve the formation of what Holmlid calls ultra-dense deuterium having Rydberg matter as precursor. If I have understood correctly, the laser pulse hitting Rydberg matter would induce the formation of the ultra-dense phase of deuterium by contracting it strongly in the direction of the pulse. The ultra-dense phase would then suffer Coulomb explosion. The compression seems to be assumed to happen in all directions. To me the natural assumption would be that it occurs only in the direction of laser pulse defining the direction of force acting on the system.

3. The ultra-dense deuterium would have density about $.13\times 10^6 kg/m^3$, which is 1.3×10^3 times that of ordinary water. The nuclei would be so close to each other that only a small perturbation would make possible to overcome the Coulomb wall and cold fusion can proceed. Critical system would be in question. It would be hard to predict the outcome of individual experiment. This would explain why the cold fusion experiments have been so hard to replicate. The existence of ultra-dense deuterium has not been proven but cold fusion seems takes place.

   Rydberg matter, which should not be confused with the ultra-dense phase would be the precursor of the process. I am not sure whether Rydberg matter exists before the process or whether it would be created by the laser pulse. Cold fusion would occur in the observed microscopic fracture zones of solid metal substances.

Issues not so well-understood

The process has some poorly understood aspects.

1. Muons as also of mesons like pion and kaon are detected in the outgoing beam generated by the laser pulse. Muons with mass about 106 MeV could be decay products of pions with mass of 140 MeV and kaons but how these particles with masses much larger than scale of nuclear binding energy per nucleon of about 7-8 MeV for ligher nuclei could be produced even if low energy nuclear reactions are involved? Pions appear as mediators of strong interaction in the old-fashioned model of nuclear interactions but the production on mass shell pions seems very implausible in low energy nuclear collisions. Something very strange seems to be occurring.
2. What is even stranger that muons produced even when laser pulse is not used to initiate the reaction. Holmlid suggests that there are two reaction pathways for cold fusion: with and without the laser pulse. This forces to ask whether the creation of Rydberg matter or something analogous to it is alone enough to induce cold fusion and whether the laser beam actually provides the energy needed for this so that ultra-dense phase of deuterium would not be needed at all. Coulomb wall problem would be solve in some other manner.
3. The amount of gamma radiation and neurons is small so that ordinary cold fusion does not seem to be in question as would be implied by the proposed mechanism of overcoming the Coulomb wall. Muon production would suggest muon catalyzed fusion as a mechanism of cold fusion but also this mechanism should produce gammas and neutrons.

TGD inspired model of cold fusion

It seems that Holmlid's experiments realize cold fusion and that cold fusion might be soon a well-established technology. A real theoretical understanding is however missing. New physics is definitely required and TGD could provide it.

1. TGD based model of cold fusion relies on TGD based view about dark matter. Dark matter would correspond to phases of ordinary matter with non-standard value of Planck constant $h_{eff} = n \times h$ implying that the Compton sizes of elementary particles and atomic nuclei are scaled up by n and can be rather large - of atomic size or even larger.

   Also weak interactions can become dark: this means that weak boson Compton lengths are scaled up so that they are effectively massless below Compton length and weak interactions become as strong as electromagnetic interactions. If this happens, then weak interactions can lead to rapid beta decay of dark protons transforming them to neutrons (or effectively neutrons as it turns out). For instance, one can imagine that proton or deuteron approaching nucleus transforms rapidly to neutral state by exchange of dark W bosons and can overcome the Coulomb wall in this manner: this was my original proposal for the mechanism of cold fusion.
2. The model assumes that electrolysis leads to a formation of so called fourth phase of water discovered by Pollack. For instance, irradiation by infrared light can induce the formation of negatively charged exclusion zones (EZs) of Pollack. Maybe also the laser beam used in the experiments of Holmlid could do this so that compression to ultra-dense phase would not be needed. The fourth phase of water forms layered structures consisting of 2-D hexagonal lattices with stoichiometry $H_{1.5}O$ and carrying therefore a strong electric charge. Also Rydberg matter forms this kind of lattices, which suggests a connection with the experiments of Holmlid.

   Protons must go somewhere from the EZ and the interpretation is that one proton per hydrogen bonded pair of water molecules goes to a flux tube of the magnetic body of the system as dark proton with non-standard value of Planck constant $h_{eff} = n \times h$ and forms sequence of dark protons forming dark nucleus. If the binding energy of dark nucleus scales like $1/h_{eff}$ (1/size) the binding energy of dark nucleus is much smaller than that for ordinary nucleus. The liberated dark nuclear binding energy in the formation would generate further EZs and one would have a kind of chain reaction.

   In fact, this picture leads to the proposal that even old and boring ordinary electrolysis involves new physics. Hard to confess, but I have had grave difficulties in understanding why ionization should occur at all in electrolysis! The external electric field between the electrodes is extremely weak in atomic scales and it is difficult to understand how it induce ionization needed to load the electric battery!

3. The dark proton sequences need not be stable - the TGD counterpart for the Coulomb barrier problem. More than half of the nucleons of ordinary nuclei are neutrons and similar situation is the first expectation now. Dark weak boson (W) emission could lead to dark beta decay transforming proton to neutron or what looks like neutron (what this cryptic statement means would requires explanation about nuclear string model). This would stabilize the dark nuclei.

   An important prediction is that dark nuclei are beta stable since dark weak interactions are so fast. This is one of the predictions of the theory. Second important prediction is that gamma rays and neutrons are not produced at this stage. The analogs of gamma rays would have energies of order dark nuclear binding energy, which is ordinary nuclear energy scale scaled down by $1/n$. Radiation at lower energies would be produced. I have a vague memory that X rays in keV range have been detected in cold fusion experiments. This would correspond to atomic size scale for dark nuclei.

4. How the ordinary nuclei are then produced? The dark nuclei could return back to negatively charged EZ (Coulomb attraction) or leave the system along magnetic flux tubes and collide with some target and transform to ordinary nuclei by phase transition reducing the value of h_{eff}. It would seem that metallic targets such as Pd are favorites in this respect. A possible reason is that metallic target can have negative surface charge densities (electron charge density waves are believed by some workers in the field to be important for cold fusion) and attract the positively charged dark nuclei at magnetic flux tubes.

   Essentially all of the nuclear binding energy would be liberated - not only the difference of binding energies for the reacting nuclei as in hot fusion. At this stage also ultra-dense regions of deuterium might be created since huge binding energy is liberated and could induce also ordinary fusion reactions. This process would create fractures in the metal target.

   This would also explain the claimed strange effects of so called Brown's gas generated in electrolysis on metals: it is claimed that Brown's gas (one piece of physics, which serious academic physicists enjoying monthly salary refuse to consider seriously) can melt metals although its temperature is not much more than 100 degrees Celsius.

5. This model would predict the formation of beta stable nuclei as dark proton sequences transform to ordinary nuclei. This process would be analogous to that believed to occur in supernova explosions and used to explain the synthesis of nuclei heavier than iron. This process could also replace the hypothesis about super-nova nucleosynthesis: indeed, SN1987A did not provide support for this hypothesis.

   The reactor of Rossi is reported to produce heavier isotopes of Ni and of Copper. This would strongly suggest that protons also fuse with Ni nuclei. Also heavier nuclei could enter to the magnetic flux tubes and form dark nuclei with dark protons transformed partially to neutral nucleons. Also the transformation of dark nuclei to ordinary nuclei could generate so high densities that ordinary nuclear reactions become possible.

6. What about the mysterious production of pions and mesons producing in turn muons?

   (a) Could the transformation of nuclei to ordinary nuclei generate so high a local temperature that hadron physics would provide an appropriate description of the situation. Pion mass corresponds to 140 MeV energy and huge temperature about .14 GeV. This is much higher than solar temperature and looks totally implausible.

   (b) The total binding energy of nucleus with 70 nucleons (average binding energy per nucleon around 7 MeV) as single meson would generate energy of the order of magnitude of kaon mass. Dark nuclei are quantum coherent structures: could this make possible this kind of "holistic" process in the transformation to ordinary nucleus. This might be part of the story.

   (c) How the mesons are created? The first option is that the transformation of dark nucleus to ordinary one creates few mesons: the binding energy of the ordinary nucleus would be liberated as meson. This would conform with the holistic nature of the process occurring as phase transition rather than as transformation of individual dark nucleons to ordinary ones. The completely mysterious looking emission of mesons from usually detected in hadronic reactions in much higher energy scale would be a direct signature of the process. Or could the transformation to ordinary nucleus involve the emission of dark W boson with mass about 80 GeV decaying to dark quark pairs binding to dark mesons transforming eventually to ordinary mesons? Could dark W boson emission occur quantum coherently so that the amplitude would be sum over the emission amplitudes, and one would have an amplification of the decay rate so that it would be proportional to the square of dark nuclear charge? The effective masslessness below atomic scale would make the rate for this process high. The emission would lead directly to the final state nucleus by emission of on mass shell mesons.

(d) One objection against the proposed model of cold fusion is that the energy liberated in the transformation of dark nuclei to ordinary ones is so large that it should have been detected. A possible explanation is that most of the energy is liberated as mesons and leaks out of the system. Fusion products would be however detected.

5.3.6 Could Pollack effect make cell membrane a self-loading battery?

The so called Clarendon dry pile is 175 years old battery still working. The current is very weak (nano Ampere) but the working of the battery is claimed to be not well-understood. The TGD inspired model for cold fusion leads to the proposal that Pollack effect is part of electrolysis. This inspires the idea that Pollack effect and possibly also the associated cold fusion could make Clarendon dry pile a self-loading battery. Cell membrane can be regarded as the analog of self-loading battery, and in TGD framework also as a generalised Josephson junction. Hence one can ask whether also cell membrane could be seen as a self-loading battery utilizing Pollack's mechanism. This would also allow to understand why hyperpolarization stabilizes the membrane potential and why depolarization generates nerve pulse.

Clarendon pile: 175 years old battery still working

Elemer Rosinger had a Facebook link to an article telling about Clarendon dry pile, a very long-lived battery providing energy for an electric clock (see http://tinyurl.com/zeut69y, http://tinyurl.com/jhrww2a, and http://tinyurl.com/gvbrhra). This clock known also as Oxford bell has been ringing for 175 years now and the article suggests that the longevity of the battery is not really understood. The bell is not actually ringing so loud that human ear could hear it but one can see the motion of the small metal sphere between the oppositely charged electrodes of the battery in the video.

The function principle of the clock is simple. The gravitational field of earth is also present. When the sphere touches the negative electrode, it receives a bunch of electrons and gives the bunch away as it touches positive electrode so that a current consisting of these bunches is running between electrons. The average current during the oscillation period of 2 seconds is nanoampere so that nanocoulomb of charge is transferred during each period (Coulomb corresponds to a 6.242×10^{18} elementary charges (electrons)).

The dry pile was discovered by priest and physicist Giuseppe Zamboni at 1812 (see http://tinyurl.com/jkvtj6f). The pile consists of 2,000 pairs of pairs of discs of tin foil glued to paper impregnated with Zinc sulphate and coated on the other side with manganese dioxide: 2,000 thin batteries in series. The operation of battery gradually leads to the oxidation of Zinc and the loss of magnase dioxide but the process takes place very slowly. One might actually wonder whether it takes place too slowly so that some other source of energy than the electrostatic energy of the battery would be keep the clock running. Karpen pile is analogous battery discover by Vasily Karpen (see http://tinyurl.com/jpzcs32). It has now worked for 50 years.

Cold fusion is associated with electrolysis. Could the functioning of this mystery clock involve cold fusion taken seriously even by American Physical Society thanks to the work of the group of prof. Holmlid. Electrolytes have of course been "understood" for aeons. Ionization leads to charge separation and current flows in the resulting voltage. With a feeling of deep shame I must confess that I cannot understand how the ionization is possible in standard physics. This of course might be just my immense stupidity - every second year physics student would immediately tell that this is "trivial" - so trivial that he would not even bother to explain why. The electric field between the electrodes is immensely weak in the scale of molecules. How can it induce the ionisation? Could ordinary electrolytes involve new physics involving cold fusion liberating energy? These are the questions which pop up in my stupid mind. Stubborn as I am in my delusions, I have proposed what this new physics might be with inspiration coming from strange experimental findings of Gerald Pollack, cold fusion, and my own view about dark matter has phases of ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant. Continuing with my weird delusions I dare ask: Could cold fusion provide the energy for the "miracle" battery?

What batteries are?

To understand what might be involved one must first learn some basic concepts. I am trying to do the same.

1. Battery (see `http://tinyurl.com/8xqsnab`) consistes of two distinct electrochemical cells (see `http://tinyurl.com/jq8ljmo`). Cell consists of electrode and electrolyte. The electrodes are called anode and catode. By definition electron current along external wire flows to catode and leaves anode.
2. There are also ionic currents flowing inside the battery. In absence of the ionic currents the electrodes of the battery lose their charge. In the loading the electrodes get their charges. In the ideal situation the ionic current is same as electron current and the battery does not lose its charging. Chemical reactions are however taking place near and at the electrodes and in their reversals take place during charging. Chemical changes are not completely reversible so that the lifetime of the battery is finite.

   The ionic current can be rather complex: the carriers of the positive charge from anode can even change during the charge transfer: what matters that negative charge from catode is transferred to anode in some manner and this charge logistics can involve several steps. Near the catode the currents of positive ions (cations) and electrons from the anode combine to form neutral molecules. The negative current carriers from catode to the anode are called anions.
3. The charge of the clectrochemical cell is in the electrolyte near the surface of the electrode rather than inside it as one might first think and the chemical processes involve neutralization of ion and the transfer of neutral outcome to or from the electrode.
4. Catode - or better, the electrochemical cell containing the catode - can have both signs of charge. For positive charge one has a battery liberating energy as the electron current connecting the negative and positive poles goes through the load, such as LED. For negative charge current flows only if there is external energy feed: this is loading of the battery. External voltage source and thus energy is needed to drive the negative charges and positive charges to the electrodes. The chemical reactions involved can be rather complex and proceed in reverse direction during the loading process. Travel phone battery is a familiar example.

   During charging the roles of the anode and catode are changed: understanding this helps considerably.

Could dark cold fusion make possible self-loading batteries?

Could cold fusion help to understand why the Clarendon dry pile is so long lived?

1. The battery is series of very many simpler batteries. The mechanism should reduce to the level of single building brick. This is assumed in the following.
2. The charge of the battery tends to be reduced unless the ionic and electronic currents are identical. Also chemical changes occur. The mechanism involved should oppose the reduction of the charging by creating positive charge to the catode and negative charge to the anode or induce additional voltage between the electrodes of the battery inducing its loading. The energy feed involved might also change the direction of the basic chemical reactions as in the ordinary loading by raising the temperature at catode or anode.
3. Could be formation of Pollack's exclusion zones (EZs) in the elecrolytic cell containing the anode help to achieve this? EZs carry a high electronic charge. According to TGD based model protons are transformed to dark protons at magnetic flux tubes. If the positive dark

charge at the flux tubes is transferred to the electrolytic cell containing catode and transformed to ordinary charge, it would increase the positive charge of the catode. The effect would be analogous to the loading of battery. The energy liberated in the process would compensate for the loss of charge energy due to electronic and ionic currents.

4. In the ordinary loading of the battery the voltage between batteries induces the reversal of the chemical processes occurring in the battery. This is due to the external energy feed. Could the energy feed from dark cold fusion induce similar effects now? For instance, could the energy liberated at the catode as positively charged dark nuclei transform to ordinary ones raise the temperature and in this manner feed the energy needed to change the direction of the chemical reactions.

Cell membrane as self-loading battery and how nerve pulse is generated?

This model might have an interesting application to the physics of cell membrane.

1. Cell membrane consisting of two lipid layers defines the analog of a battery. Cell interior plus inner lipid layer (anode) and cell exterior plus outer lipid layer (catode) are analogs of electrolyte cells.

   What has been troubling me for two decades is how this battery manages to load itself. Metabolic energy is certainly needed and ADP-ATP mechanism is essential element. I do not however understand how the membrane manages to keep its voltage.

   Second mystery is why it is hyperpolarization rather than polarization, which tends to stabilize the membrane potential in the sense that the probability for the spontaneous generation of nerve pulse is reduced. Neither do I understand why depolarization (reduction of the membrane voltage) leads to a generation of nerve pulse involving rapid change of the sign of the membrane voltage and the flow of various ionic currents between the interior and exterior of the cell.

2. In the TGD inspired model for nerve pulse cell interior and cell exterior or at least their regions near to lipid layers are regarded as super-conductors forming a generalized Josephson junction. For the ordinary Josephson junction the Coulombic energy due to the membrane voltage defines Josephson energy. Now Josephson energy is replaced by the ordinary Josephson energy plus the difference of cyclotron energies of the ion at the two sides of the membrane. Also ordinary Josephson radiation can be generated. The Josephson currents are assumed to run along magnetic flux tubes connecting cell interior and exterior. This assumption receives support from the strange finding that the small quantal currents associated with the membrane remain essentially the same when the membrane is replaced with polymer membrane.

3. The model for Clarendon dry pile suggests an explanation for the self-loading ability. The electrolytic cell containing the anode corresponds to the negatively charged cell interior, where Pollack's EZs would be generated spontaneously and the feed of protonic charge to the outside of the membrane would be along flux tubes as dark protons to minimize dissipation. Also ions would flow along them. The dark protons driven to the outside of the membrane transform to ordinary ones or remain dark and flow spontaneously back and provide the energy needed to add phosphate to ADP to get ATP.

4. The system could be quantum critical in the sense that a small reduction of the membrane potential induces nerve pulse. Why the ability to generate Pollack's EZs in the interior would be lost for a few milliseconds during nerve pulse? The hint comes from the fact that Pollack's EZs can be generated by feeding infrared radiation to a water bounded by gel. Also the ordinary Josephson radiation generated by cell membrane Josephson junction has energy in infrared range!

   Could the ordinary Josephson radiation generate EZs by inducing the ionization of almost ionized hydrogen bonded pairs of water molecules. The hydrogen bonded pairs must be very near to the ionization energy so that ordinary Josephson energy of about .06 eV assignable to the membrane voltage is enough to induce the ionization followed by the formation of $H_{3/2}O$. The resulting EZ would consist of layers with the effective stoichiometry $H_{3/2}O$.

   As the membrane voltage is reduced, Josephson energy would not be anymore enough to induce the ionization of hydrogen bonded pair of water molecules, EZs are not generated, and the battery voltage is rapidly reduced: nerve pulse is created. In the case of hyperpolarization the energy excees the energy needed for ionization and the situation becomes more stable.

5. This model could also allow to understand the effect of anesthetes [K84] [L34]. Anesthetes could basically induce hyperpolarization so that Josephson photons would continually generate Pollack's EZ:s and creating of dark particles at the magnetic flux tubes. This need not mean that consciousness is lost at the cell level. Only sensory and motor actions are prevented because nerve pulses are not possible. This prevents formation of sensory and motor mental images at our level of hierarchy.

   Meyer-Overton correlation states that the effectiveness of the anesthete correlates with its solubility to the lipid membrane. This is the case if the presence of anesthete in the membrane induces hyperpolarization so that the energies of the photons of Josephson radiation would be higher than needed for the generation of EZs accompanied by magnetic flux tubes along which ionic Josephson currents would flow between cell interior and exterior. For these quantal currents evidence exists [K88]. In the case of battery these dark ions would flow from the cell containing anode to that containing catode. For depolarization the energy of Josephson photons would be too low to allow the kicking off protons from hydrogen bonded pairs of water molecules so that EZs would not be created and self-loading would stop and nerve pulse would be generated.

5.4 Could cold fusion solve some problems of the standard view about nucleosynthesis?

The theory of nucleosynthesis involves several uncertainties and it is interesting to see whether interstellar cold fusion could provide mechanisms allowing improved understanding of the observed abundances. There are several problems: D abundance is too low unless one assumes the presence of dark matter/energy during Big Bang nucleosynthesis (BBN); there are two Lithium anomalies; there is evidence for the synthesis of boron during BBN; for large redshifts the observed metallic abundances are lower than predicted. The observed abundances of light nuclei are higher than predicted and require that so called cosmic ray spallation producing them via nuclear fission induced by cosmic rays. The understanding of abundances of nuclei heavier than Fe require supernova nucleosynthesis: the problem is that supernova 1987A did not provide support for the r-process.

The idea of dark cold fusion could be taken more seriously if it helped to improve the recent view about nucleosynthesis. In the sequel I try to develop a systematic view about how cold fusion could help. I take as a starting point the model for cold dark fusion already discussed. This model could be seen as generalization of supernova nucleosynthesis in which dark variant of neutron and proton capture gives rise to more massive isotopes. Also a variant allowing the capture of dark alpha particle can be considered.

5.4.1 Standard view about nucleosynthesis

To learn some background it is good to read Wikipedia articles about stellar nucleosynthesis (see `http://tinyurl.com/j9ytvsx`) and abundances of the chemical elements (see `http://tinyurl.com/7hgjxya`).

There are several contributions to nucleosynthesis in the standard model. The first contribution comes from Big Bang (BBN), second contribution from supernova nucleosynthesis and the third from cosmic ray spallation.

Nuclear fusion during Big Bang

Big Bang nucleosynthesis (BBN) lasting from 10 seconds to 20 minutes after Big Bang produced stable light elements up to $7Li$. Also unstable ^7Be decaying to ^7Li and ^3H decaying to ^3He was produced.

1. ^1H ja ^4He nuclei dominate and the remaining nuclei give only fraction of order .01 per cent. The value of n/p ratio at the moment when $n \leftrightarrow p$ transformations ceased to occur is decisive since all neutrons and protons, which could recombine to ^4He did so after this moment. For

$n/p \simeq 1/7$ a correct relative abundance for ^4He is obtained. This can be understood quite concretely: 4 of 12+4 nucleons could combine to ^4He and did so. For ^4He particle number fraction was $1/13 \simeq 7.7$ per cent and mass fraction 25 percent. For protons the particle number fraction was $12/13 \simeq 92.3$ and mass fraction 75 percent.

2. BBN produces also deuterium. The amount of D produced is highly sensitive to the initial conditions since deuterium is only marginally stable unlike ^4He . Part of D could have combined to ^4He. There is sensitivity to the baryon density and to the expansion rate of the Universe determined by the total mass density. The observed finite amount of D implies finite age of Universe unless there are some other mechanisms producing deuterium.

3. If the Universe consisted of protons and neutrons only during fusion to ^4He, the density of nucleons would have been be so high that all D would have burned to ^4He. Nuclear fusion (temperature should be at critical range to not produce deuterium) in stars cannot produce deuterium and the production by nuclear fission is also difficult. This has forces to assume the presence of dark matter at the time of BBN. Also dark energy could be in question. Cosmic ray spallation was proposed as source of D but failed to explain its abundance. It is however suggested do explain the abundances of the other elements.

4. Also small fractions of ^7Li and ^7Be were produced but no heavier elements was produced. The reason was the absence of stable nuclei with 8 or 5 nucleons. This severely limited the amounts of ^7Li and ^9Be (unstable) nuclei produced. In stars triple alpha process produces carbon but the rate is so slow that it could not yield significant amount of carbon during BBN. In stars ^7Li burns to more massive nuclei.

   There is however a problem. The abundances of ^7Li predicted by BBN and deduced from WMAP/Planck and the abundance derived from population II stars (see `http://tinyurl.com/qczc8ty`). The predicted abundance is by a factor 2.2-4.3 higher than the observed one [C131] (see `http://tinyurl.com/ycnrljls`). The abstract of the article summarizes lithium anomalies.

   The measured abundance for ^7Li is within a factor of two agreement with the standard Big Bang Nucleosynthesis (BBN) models, however for the more fragile ^6Li, its abundance has been observed at a level three orders of magnitude above those predicted by standard BBN model. These discrepancies are known as the Lithium Anomaly. The standard BBN model predicts an abundance ratio for $[^7Li/^6Li]$ of the order of a 1000 or greater. Precise measurements of isotopic ratio indicate that $[^7Li/^6Li] = 12.3$. This discrepancy is the Strong Lithium Anomaly. The measured abundance $[^7Li/^1H] = (1.5 + 0.3) \times 10^{|10}$ is a factor of two lower than the abundance $[^7Li/^1H] = (3.82 + 0.70) \times 10^{-10}$ predicted by the standard BBN calculations, and this discrepancy is the Weak Lithium Anomaly. A quick review will be done of the reactions that have been included in the BBN calculations of Lithium-6 abundance. I will discuss an experiment to address the Lithium Anomaly, via the ^7Li (^3He, ^4He)^6Li reaction using the TACTIC detector at TRIUMF.

5. Some old stars are found to contain boron, which suggests that also Boron was produced during BBN. Standard BBN does not allow it but the fact that resonant alpha capture by ^7Li producing Boron has been observed [C127] suggests that Boron is actually produced during BBN.

Stellar nucleosynthesis

Elements lighter than Fe are formed by stellar nucleosynthesis (`http://tinyurl.com/j9ytvsx`). Binding energy begins to decrease after Fe and the buildup of these nuclei requires energy and it seems that stellar fusion cannot provide it.

1. Proton-proton chain reaction (`http://tinyurl.com/yazrzeez`) produces ^3He and to ^3He:s fuse to $^4He + 2p$. The direct fusion of ^3He or ^3H to ^4He is would require energy so that fusion of two ^3He:s is necessary. Both hydrogen and ^3He nuclei are depleted.

2. Lithium burning (see `http://tinyurl.com/oyjck6v`) depletes lithium and ^4He is generated. The observed lithium should come from Big Bang in standard cosmology. The abundance of ^7Li is by a factor 2/3 smaller than the predicted abundance whereas the abundance of ^6Li is too high by several orders of magnitude [C131].

3. Triple alpha process (see http://tinyurl.com/lvjafqo) was discovered by Hoyle. Hoyle started from the empirical fact that carbon must have been produced abundantly. On the other, hand there seemed to be a bottleneck preventing production of ^{12}C by alpha capture. The fusion of two ^4He to unstable ^8Be requires at least the energy of 91.8 keV and occurs slightly faster than its reversal after hydrogen has transformed to ^4He. To produce C another fusion is needed and since triple alpha process is unlikely, it would take long time to produce the needed amount of carbon. Hoyle made a brave hypothesis: carbon must have a resonant state with energy very near to that of $^8Be +^4 He$. If this is the case the process can proceed resonantly. It turned out that this hypothesis was correct!

4. Once C is generated alpha process (see http://tinyurl.com/yc3u8kjr) adds ^4He repeatedly and builds heavier nuclei up to Fe. The first heavy nucleus is ^{16}O.

5. CNO cycle converts four protons to helium in 4 steps. It starts from C and proceeds by fusion proton with the heavier C, N, or O nucleus and by beta decays and ends with alpha decay of O to C as the last step (see http://tinyurl.com/qfcmo5c).

6. Other important burning processes take lace in stars considerably heavier than Sun are carbon burning (see http://tinyurl.com/y7wor4ur), oxygen burning (see http://tinyurl.com/y866yjkr), and neon burning: (see http://tinyurl.com/y88eazhc).

Supernova fusion

Stellar nucleosynthesis leads to explosive oxygen burning and silicon burning the elements silicon, sulfur, chlorine, argon, sodium, potassium, calcium, scandium, titanium and iron peak elements: vanadium, chromium, manganese, iron, cobalt, and nickel. These elements known as "primary elements" can be fused from pure hydrogen and helium in massive stars. As a result of their ejection from supernovae, their abundances increase within the interstellar medium.

Elements heavier than nickel are believed to be created primarily by supernova nucleosynthesis (see http://tinyurl.com/y74rh5rw). The processes involved are slow neutron capture (s-process, see http://tinyurl.com/ybbnwkpd, fast neutron capture (r-process, see http://tinyurl.com/hs3x3se), and fast proton capture (r-p-process, see http://tinyurl.com/y8gysoqg). The most important process is r-process. The resulting elements are much less abundant than the primary chemical elements. Other processes thought to be responsible for some of the nucleosynthesis of under-abundant heavy elements, notably a proton capture process known as the rp-process and a photodisintegration process known as the gamma (or p) process. The latter would synthesize the lightest, most neutron-poor, isotopes of the heavy elements.

Interestingly (and rather alarmingly!), the only modern nearby supernova SN1987A, has not revealed r-process enrichments (see http://tinyurl.com/y74rh5rw). Modern thinking is that the r-process yield may be ejected from some supernovae but swallowed up in others as part of the residual neutron star or black hole.

Remark: The production of elements heavier than Fe might be a weak point of standard model. The proposed cold fusion by absorption of dark protons and possibly also neutrons is remarkably similar to the supernova fusion process. The failure to observe r-process in SN1987A raises the question whether the analog of supernova cold fusion could occur in interstellar space as cold fusion in TGD sense.

Cosmic ray spallation

Stellar nuclear fusion does not produce stable isotopes ^3He, ^7Li, ^9Be, ^{10}B, and ^{11}B. These isotopes have been however observed. The process known as cosmic ray spallation (CRB, see http://tinyurl.com/zaa49s6) has been proposed as a mechanism producing these nuclei. The collision of highly energetic charged cosmic ray induces nuclear fission to larger number of lighter fragments and in this manner gives rise to a synthesis of lighter elements. CRB would also explain the presence of a beta-unstable nuclei such as ^7Be in environment with lifetime of 53.6 d. Also tritium and isotopes of aluminium, carbon (^{14}C), chlorine, iodine and neon are formed in CRB.

Remark: Cold fusion in TGD sense does not produce beta-instable elements and this might allow to disentangle the predictions of CRB model from those of cold fusion model.

5.4.2 Could cold fusion help?

TGD based model of cold fusion [C101, C102] relies on two new physics elements: the hierarchy of Planck constants and the notion of magnetic body. Cold fusion would occur in two steps. First dark nuclei (large $h_{eff} = n \times h$) with much lower binding energy than ordinary nuclei are formed at magnetic flux tubes possibly carrying monopole flux, and are transformed by dark beta decay and W exchange to beta-stable dark nuclei. These nuclei can leak out the system along magnetic flux tubes but in presence of metallic surfaces in negative potential can suffer a phase transition to ordinary nuclei and liberate nuclear binding energy.

An essential condition is that the dark protons can decay to neutrons rapidly enough by exchanges of dark weak bosons effectively massless below atomic length scale. Also beta decays in which dark W boson decays to dark electron and neutrino can be considered. This allows to overcome the Coulomb wall and explains why final state nuclei are stable and the decay to ordinary nuclei does not yield only protons.

The model is motivated by several experimental findings about cold fusion.

1. Leif Holmlid has introduced the notion of fusion induced by Coulomb explosion of ultra-dense deuterium (see popular article `http://tinyurl.com/nbephxb`). The slides of the talk by Sweinn Olaffsson (see `http://tinyurl.com/j3csy53`) give a more technical representation about the subject. Also ultradense variant of hydrogen can be considered. The article *Laser-driven nuclear fusion D+D in ultra-dense deuterium: MeV particles formed without ignition* (see `http://tinyurl.com/pm56kk3`) gives a more detailed representation about the idea [C23]. The TGD based model for the findings assumes that laser pulse induces a compression in longitudinal direction and formation of large h_{eff} phase on magnetic flux tube in the direction of laser pulse.
2. The TGD inspired model [L24] for what Pollack [L24] calls the fourth phase of water involving negatively charged exclusion zones (EZs) plays central role in TGD inspired quantum biology [L31] and also serve as the starting point for the model of cold fusion. The basic idea is that the protons disappearing from EZ become dark protons at dark magnetic flux tubes and form sequences identifiable as dark nuclei [L4]. Ordinary nuclei would result in the phase transition reducing Planck constant to its ordinary value.
3. The earlier TGD based model [L4] modifying the cold fusion model of Widom and Larsen [C13] (`http://tinyurl.com/boq2u2z`) provides also an important ingredient. In Widom-Larsen model weak boson exchange transforming the proton approaching the target nucleus to neutron allows to overcome Coulomb wall. The extremely slow rate for weak boson exchange is the weak point of the model.

   This exchange is fast if weak bosons are dark and thus effectively massless in the length scale considered: this length scale would be $h_{eff}/h = n$-multiple of weak scale and could be as long as 100 microns but atomic length scale is in principle enough. In the recent model W emission and W exchanges would transform dark proton sequences to dark nuclei containing also neutrons so that Coulomb instability could be overcome. Dark nucleosynthesis in living matter (biofusion has been reported to occur) would also explain why parity breaking effects are large in cell scale.
4. The so called Brown's gas [H19] regarded by skeptics as pseudoscience (see `http://tinyurl.com/gotxwa8`) can be interpreted in terms dark fusion products leaking out of the system along flux tubes. Both the claimed ability of Brown's gas to melt metals although itself at temperature of order 100 Celsius and the claims of the article summarizing the findings of LeClair (see `http://tinyurl.com/y786gy89`) suggest that the presence of metallic surface could prevent the dark nuclei from escaping by inducing a phase transition reducing the value of Planck constant to its ordinary value. This can be understood if the metallic surface is negatively charged and attracts the positively charge dark nuclei at the flux tubes and forces the phase transition to occur.

   The phase transition would liberate an energy, which is essentially the total nuclear binding energy (if the dark nuclear binding energy scales like $1/h_{eff}$ it would be rather small in nuclear energy scale) and thus larger than liberated in ordinary nuclear fusion or fission. LeClair also claims that the nuclei produced are beta stable and the spectrum is same as for the nuclei produced by supernova nucleosynthesis: if true this would suggest that capture of neutrons or protons would be the basic mechanism. It is easy to challenge LeClair's claims and this has been done but they seem to conform with the predictions of the TGD model: I realized this only when learning about what supernova nucleosynthesis is. Also a recent very strange finding about spectrum of Ni isotopes produced in E-Cat reactor conform with the predictions of TGD based model [L27].

The basic prediction is that the process cannot produce beta-unstable isotopes, which should be thus produced by cosmic ray spallation. Dark cold fusion might provide insights to the problems of standard model of nucleosynthesis.

Let us consider first a model of nucleosynthesis in which the binding energies of dark nuclei are obtained by a simple universal scaling from the ordinary binding energies so that kinematical constrains remain the same as in ordinary nuclear fusion. Let us also assume that absorption of two dark protons by same dark nucleus to give dark nuclear string is a slow process.

With these assumptions the absorption of dark protons (and possibly also dark neutrons) would be a process very much analogous to r-p process but restricted to occur only between beta stable isotopes and involving rapid stabilizing dark beta decays. Also the analogs of s- and r-processes a possible but would not happen if the formation of EZs is behind the cold fusion.

In the following considerations I have used the excellent tables of an old text book "Nuclear Physics" of Robert Howard about nuclear physics [C137]. One can certainly find from web more modern representations but I have somehow become attached to this nice old-fashioned book.

1. Interstellar dark nuclear fusion involving dark matter in TGD sense could generate deuterium, ^3He, and ^4He from hydrogen. The ordinary fusion of proton and ^4He to ^5He via beta decay or to ^5Li does not occur spontaneously. Whether the dark counterparts of these processes are possible depends on the binding energy of dark ^4He. If one believes in ultra naïve scaling of binding energies then dark variants of these processes could not take place and one would have only the sequence $H \rightarrow D \rightarrow ^3He \rightarrow ^4He$. The chain stops at ^4He and only the densities of lightest elements up to ^4He would be affected.

2. D abundance is predicted to be too low unless the presence of dark matter is assumed during BBN: the reason is that D nuclei fuse to $4He$ nuclei. Dark energy can can do same trick as dark matter and TGD indeed predicts its presence in the early cosmology. One can of course consider also a scenario without primordial dark energy/matter. This would require that there is a mechanism producing deuterium. Cosmic ray spallation can generate ^3He, Be, and B but not D (because of its marginal stability). Here interstellar cold fusion could come in rescue. This option does not look plausible to me.

3. Traces of boron have been found in some old stars (see `http://tinyurl.com/qczc8ty`). This might be called boron anomaly. One can wonder whether high nucleon densities could have made the alpha captures $^6Li +^4 He \rightarrow ^{10}B$ and $^7Li +^4 He \rightarrow ^{17}B$ possible and produced boron. Resonant alpha capture $^7Li(\alpha, \gamma)$ is indeed known to take place [C69] (see `http://tinyurl.com/z6clc79`) and one can wonder whether it could take place during BBN. Mechanism would be a copy of the mechanism proposed by Hoyle to produced carbon.

4. Lithium anomaly involves actually two anomalies. The observed ^7Li abundance is lower than predicted and the observed $^6Li/^7Li$ ratio is higher than predicted by orders of magnitude. If the resonant alpha capture by ^7Li giving rise to B takes place early cosmology it could have reduced ^7Li abundance already at that time. The absence of resonant alpha capture for ^6Li could in turn explain its recent over abundance with respect to ^7Li as present already primordially.

5. How cold fusion could affect the BBN abundances of lithium, B and Be? In the pessimistic scenario (exact scaling of binding energies) one would have only single step $^6Li \rightarrow ^7Li$. Some fraction of ^6Li would transformed to ^7Li. Cosmic ray spallation would be needed to produce B and Be. The presence of beta unstable isotopes with relatively short life time (such as tritium) gives support for the occurrence of cosmic ray spallation since the presence of tritium cannot be explained by dark cold fusion.

6. The sequence $^9Be \rightarrow ^{10}B \rightarrow ^{11}B \rightarrow ^{12}C \rightarrow ^{13}C \rightarrow ^{14}N \rightarrow ^{15} ... ^{36}A$ of beta stable nuclei would be very long and mean flow from low mass numbers to higher ones. Also the sequence of beta stable nuclei starting from ^{39}K would extend to ^{64}Zn.

The above sketchy model involves strong simplifying assumptions, which can be criticized.

1. The naïve scaling of binding energy could be of course too strong an assumption. Also the assumption that two subsequent absorptions of dark proton has a low rate is only the first guess. For instance, the steps $^4He \rightarrow ^6Li$ and $^7Li \rightarrow ^9Be$ would require fusion of 2 protons to already existing nucleus. Dark variants of beta un-stable isotopes ^5He, ^5Li and ^nBe, $n = 6, 7, 8$ could appear as dark intermediate states if they are stable enough against dark variants of strong interactions the rates for the $n = 2$ steps would be higher.

2. One can consider also the possibility that the capture of ^4He nuclei transforming to dark nuclei is involved so that one would obtain nuclei consisting of ^4He nuclei plus some protons and neutrons. As a matter of fact, nuclear string model [L4] assumes that there is a kind of fractal structure involved in which ^4He nuclear strings become building bricks of higher level nuclear strings (flux tubes inside flux tubes). ^4He nuclei could be first generated by dark fusion if the formation of EZs is the basic mechanism. This would bring in dark variants of the basic mechanisms of stellar nuclear fusion and suggests fusion product spectrum probably resembling that produced in stellar nuclear fusion inside stars. It would also allow resonant transformation of ^7Li to ^{10}B and in this manner might help to understand Lithium anomalies.

One can challenge also the supernova fusion believed to produce elements heavier than Fe. r- and s-processes involving absorption of neutron and rp-process involving absorption of proton in general require energy in the case of nuclei heavier than Fe and the energy liberated in supernova collapse could provide this energy. An alternative mechanism is by interstellar dark fusion involving absorption of dark protons and also neutrons by heavy nucleus. One can consider the possibility that no external energy feed is needed. At least the energy feed would be by about factor 10^{-5} smaller if the proposed model is qualitatively correct. The rapidly occurring beta decays would allow only beta stable outcomes and this could serve as a signature of the process.

There is evidence that the abundances of metals in the early universe for redshifts 2-3 are lower than predicted [C127]. For instance, for one particular case with $z = 2.7276$ for which rather reliable data exist, the abundances of N, Mn, Fe, Ni are below predicted. Same is true for O, Mg, Si, P, and S as figure 4 of [C127] (see `http://tinyurl.com/y78o5jrt`) demonstrates. N abundance is especially low in this example. The proposed cold fusion mechanism would induce the flow of nuclei to higher mass numbers and increase the abundances at later times. If the density of protons was larger at the end of BBN period as absence of dark matter at that time demands, dark cold fusion could have induced a flow of baryon number to the direction of higher mass numbers.

There are also indications for CF in Earth, quite recently (May 2022) I learned an interesting piece of fact related to nuclear physics anomalies. It has been found that the amount of ^{3}He in the Earths' atmosphere is ten times higher than expected `https://cutt.ly/WHx7FUz`).

The result is not deduced by measuring the amount ^{3}He but that of ^{4}He. The amount of the latter is too high and since ^{4}He produces ^{3}He, the amount of ^{3}He must be higher than normal if we believe in standard nuclear physics.

The first report by Goldman and Fleisch about "cold fusion" was the claim that ^{4}He is produced by fusion of two deuterium nuclei(`https://cutt.ly/xHx7Mjl`). "Cold fusion" was labelled as pseudoscience first but now "cold fusion" is accepted as a real science and cold fusion researchers are not regarded as science criminals anymore.

Could this extra ^{4}He be produced by "cold fusion" so that no extra ^{3}He, not produced in "cold fusion", would be needed?

1. The TGD based model for "cold fusion" [L27, L103, L117] relies on the notion of dark nuclei and one of the basic predictions is that heavier nuclei can be produced outside stellar cores at much lower temperatures than in the Sun. In the TGD framework, prestellar evolution would start by "cold fusion" and lead eventually to such a high temperature that ordinary fusion would start.

2. "Cold fusion" solves many problems of the standard nuclear physics based view. For instance, the production of nuclei heavier and iron is poorly understood: the hypothesis that Supernovae might have produced them remains unproven. Also the abundances of many light nuclei, such as Lithium, are poorly understood. Also the model for solar fusion has an anomaly discovered a few years ago. There is also evidence that living matter produces nuclei such as Calcium by some unknown mechanism.

5.4.3 Heavy element surprise

Again a surprise in astrophysics (see the popular articles at http://tinyurl.com/y2yexqq4 and http://tinyurl.com/yybbcz6e). It is really amazing how little we actually know about the mechanism producing heavier elements.

1. Big bang produces H, He, and also Be but in trace amounts. Heavier elements are absent and are believed to be produced in stars. How the heavier elements are formed? This is the problem. One proposal is that during super-nova explosions so called r-process produces heavier elements outside supernova but SN1987A did not provide support for this (see http://tinyurl.com/hs3x3se). Second proposal is that the heavier elements are produced in the collisions of neutron stars. There is also a proposal is that they are produced in collapsing accreting disk when neutron star collapses to blackhole (see http://tinyurl.com/y6cvldwm).
2. Standard hypothesis is that so called population III stars produce elements heavier than Be. These stars would be very large and very short lived - age would have been around $10^5 - 10^6$ years. Not a single population III star has been however observed but one could blame their short ages as a reason for this. So called population II stars would be their successors and have been observed. The amount of heavier elements in them is still much lower than in Sun.
3. Astrophysicists Frebel and Ezzeddine [E18] (see http://tinyurl.com/y6bopwfo and also the slides at http://tinyurl.com/y6gupmzk) have studied the spectral signatures of a population II star HE 1327-2326 and discovered it to contain unusually large amount of Zinc heavier than iron. This looks very strange since elements heavier than Fe should be produced much later.

It has been proposed that the first stars did not explode in a spherically symmetric manner but generated jets in opposite directions, and Frebel and Ezzeddine suggests that this might explain the strange findings. Jets would have distributed heavier elements from population III stars stars to surroundings in a very undemocratic manner. Although the total amount of heavier elements would have been small, the density of heavier elements in the birthplaces of population II stars along the jets would have been much higher than spherically symmetric model predicts.This could explain the high amount of Zinc.

While reading the article, I realized that the jetty picture is very natural in TGD framework.

1. Asymmetric jets are very natural in TGD vision about the formation of galaxies as tangles associated with long cosmic string known to form linear structures [L68]. This picture solves the galactic dark matter problem: dark matter and energy reside at cosmic strings thickened to flux tubes and create just the desired gravitational potential to explain flat velocity spectrum of distant stars. That there would be no dark matter halo conforms with the various findings strongly suggesting that this halo does not exist.

   Flux tubes of long cosmic strings are what I call wormhole magnetic fields that is have same M^4 projection except in the regions, where there are galaxies and stars. Wormhole magnetic field portions outside galaxies would be essentially dark energy since test particles do not experience the associated magnetic and electric fields. However, long range gravitational fields are created and make themselves visible as flat velocity spectrum around spiral galaxies [L83, L104].

   The cosmic strings would have thickened and liberated energy in the process and given rise to ordinary visible matter: this would be analogous to the decay of inflaton field except that the magnetic energy and volume energy characterized by length scale dependent cosmological constant would replace energy of inflaton field.

   The topology of tangles consisting of a looped monopole flux tube carrying monopole flux resembled the field line topology of dipole magnetic field. Stars and eventually even planets would have ormed as sub-tangles around the flux tubes. Universe would be like highly neural network with quantum coherence even in cosmic scales instead of uncorrelated galaxies and stars.
2. The explosion of very earlier star like entity would have automatically created jets propagating along the flux tubes emanating from so that instead of being distributed in a spherically symmetric manner the elements in the earlier star would have propagated directly to the birth places of new stars along the flux tube having the exploded star as tangle. This would changes completely the view about star formation.

But what these very earlier stars might have been?

1. TGD based view about dark suggests a new mechanism for the production of heavier elements [L54, L27]. What I call dark nuclei (having non-standard value $h_{eff} = n \times h_0$ of Planck constant) would be dark protons sequences along flux tubes and have nuclear binding energy much smaller than ordinary nuclei.

   Pollack effect [L24] would give rise to these dark nuclei and they would be present in living matter and give a fundamental realization of genetic code: ordinary matter with ordinary value of Planck constant would mimic the dynamics of magnetic body having higher "IQ" (higher evolutionary level in number theoretical evolutionary hierarchy defined by extensions of rationals) definable as $h_{eff}/h_0 = n$ and identifiable as dimension of extension of rationals.

   The connection between biology and astrophysics looks of course strange but this is what the fractality of TGD Universe predicts. Same cosmic strings thickened to flux tubes are in all length scales and basic mechanisms are the same.

2. Dark nuclei would have been formed first and caused pre-heating during the pre-stellar phase [L54, L27]. As the temperature became high enough, ordinary fusion reactions started and stars were born. The spontaneous transformation to ordinary nuclei liberating almost all nuclear binding energy would have also occurred and is proposed as a model for "cold fusion" reported to produce heavy elements.

3. One can ask why so much Zn in HE 1327-2326. Was "cold fusion" involved already at that time as TGD based model indeed proposes? Could the postulated but unseen population III stars be pre-stellar objects generating heavy elements by "cold fusion" and spraying them along flux tubes directly to the new stars rather than dispersing them to all possible directions? The Universe would have been a network analogous to neural system rather than soup and the formation of stars would have been a collective process with correlations in super-astrophysical length scales.

   This is the also the picture about living mater provided by TGD, where flux tube network makes possible for reacting molecules to find each other and also provides a mechanism of catalysis based on the reduction of h_{eff} liberating energy allowing to overcome the potential walls preventing the chemical reactions.

5.4.4 What is the IQ of neutron star?

"*Humans and Supernova-Born Neutron Stars Have Similar Structures, Discover Scientists*" (see `http://tinyurl.com/y7qdeuba`) is the title of a popular article about the finding that neutron stars and eukaryotic (not only human) cells contain geometrically similar structures. In cells the cytoplasma between cell nucleus and cell membrane contains a complex highly folded membrane structure known as endoplasmic reticulum (ER). ER in turn contains stacks of evenly spaced sheets connected by helical ramps. They resemble multistory parking garages (see the illustration of the popular article). These structures are referred to as parking places for ribosomes, which are the machinery for the translation of mRNA to amino-acids. The size scale of these structures must be in the range 1-100 microns.

Computer simulations for neutron stars predict geometrically similar structures, whose size is however million times larger and therefore must be in the range of 1-100 meters.The soft condensed-matter physicist Greg Huber from U.C. Santa Barbara and nuclear physicist Charles Horowitz from Indiana University have worked together to explore the shapes [I8] (see `http://tinyurl.com/js9wavq` and `http://tinyurl.com/y72o474v`).

The physical principles leading to these structures look quite different. At nuclear physics side one has strong and electromagnetic interaction at microscopic level and in the model used they give rise to these geometric structures in macroscopic scales. In living matter the model assumes basically entropic forces and the basic variational principle is minimization of the free energy of the system - second law of thermodynamics for a system coupled to thermal bath at constant temperature. The proposal is that some deeper principle might be behind these intriguing structural similarities.

In TGD framework one is forced to challenge the basic principles behind these models as really fundamental principles and to consider deeper reasons for the geometric similarity. One ends up challenging even the belief that neutron stars are just dead matter.

1. In TGD framework space-time identified as 4-D surface in $H = M^4 \times CP_2$ is many-sheeted fractal structure. In TGD these structures are topological structures for the space-time itself as a 4-surface rather than for the distribution of the matter in topologically trivial almost empty Minkowski space.

   TGD space-time is also fractal characterized by the hierarchy of p-adic length scales assignable to primes near powers of two and to a hierarchy of Planck constants. Zero energy ontology (ZEO) predicts also a hierarchy of causal diamonds (CDs) as regions inside which space-time surfaces are located.

   The usual length scale reductionism is replaced with fractality and the fractality of the many-sheeted space-time could explain the structural similarity of structures with widely different size scales.

2. Dark matter is identified as a hierarchy of phases of ordinary matter labelled by the value $h_{eff} = n \times h$ of Planck constant. In adelic physics $h_{eff}/h = n$ has purely number theoretic interpretation as a measure for the complexity of extension of rationals - the hierarchy of dark matters would correspond to the hierarchy of these extensions and evolution corresponds to the increase of this complexity. It would be dark matter at the flux tubes of the magnetic body of the system that would make the system living and intelligent. This would be true for all systems, not only for those that we regard as living systems. Perhaps even neutron stars!

3. In adelic physics [L64] p-adic physics for various primes as physics of cognition and ordinary real number based physics are fused together. One has a hierarchy of adeles defined by extensions of rational numbers (not only algebraic extensions but by those using roots of e). The higher the complexity of the extension, the larger the number of common points shared by reals and p-adics: they correspond to space-time points with coordinates in an extension of rationals defining the adele. These common points are identified as cognitive representations, something in the intersection of cognitive and sensory. The larger the number of points, the more complex the cognitive representations. Adeles define thus an evolutionary hierarchy.

   The points of space-time surface defining the cognitive representation are excellent candidates for the carriers of fundamental fermions since many-fermion states allow interpretation in terms of a realization of Boolean algebra. If so then the complexity of the cognitive representation characterized by h_{eff}/h increases with the density of fundamental fermions! The larger the density of matter, the higher the intelligence of the system if this view is correct!

This view inspires interesting speculative questions.

1. In TGD inspired theory of consciousness conscious entities form a fractal hierarchy accompanying geometric fractal hierarchies. Could the analogies between neutron stars and cells be much deeper than merely geometric? Could neutron stars be super-intelligent systems possessing structures resembling those inside cells? What about TGD counterparts of black holes? For blackhole like structures the fermionic cognitive representation would contain even more information per volume than those for neutron star. Could blackholes be super-intelligences instead of mere cosmic trashbins?

   Living systems metabolize. The interpretation is that the metabolic energy allows to increase the value of h_{eff}/h and generate negentropic entanglement crucial for cognition. Also blackholes "eat" matter from their environment: is the reason the same as in the case of living cell?

   Living systems communicate using flux tubes connecting them and serving also as correlates of attention. In TGD frame flux tubes emanates from all physical systems, in particular stars and blackholes and mediate gravitational interactions. In fact, flux tubes replace wormholes in ER-EPR correspondence in TGD framework or more precisely: wormhole contacts replace flux tubes in GRT framework.

2. Could also blackhole like structures possess the analog of endoplasmic reticulum replacing the cell membrane with an entire network of membranes in the interior of cell? Interpretation as minimal surface is very natural in TGD framework. Could the predicted space-time sheet within blackhole like structure having Euclidian signature of the induced metric serve as the analog for cell nucleus? In fact, all systems - even elementary particles - possess the space-time sheet with Euclidian signature: this sheet is analogous to the line of Feynman diagram.

Could the space-time sheet assignable to cell nucleus have Euclidian signature of the induced metric? Could cell membrane be analogous to blackhole horizon?

3. What abut genetic code? In TGD inspired biology genetic code could be realized already at the level of dark nuclear physics in terms of strings of dark protons: also ordinary nuclei are identified as strings of nucleons [L4]. Biochemical representation would be only a secondary representation and biochemistry would be a kind of shadow for the deeper dynamics of dark matter and magnetic flux tubes. Dark 3-proton states correspond naturally to DNA, RNA, tRNA and amino-acids and dark nuclei as polymers of these states [L36].

   Could neutron stars containing dark matter as dark nuclei indeed realize genetic code? This view about dark matter leads also to a proposal that the so called cold fusion could actually correspond to dark nucleosynthesis such that the resulting dark nuclei with rather small nuclear binding energy transform to ordinary nuclei and liberate most of the ordinary nuclear binding energy in this process [L54]. Could dark nucleosynthesis produce elements heavier than Fe and also part of the lighter elements outside stellar interiors. Could this happen also in the fusion of neutron stars to neutron star like entity as the recent simultaneous detection of gravitational waves (GW170817 event) and em radiation from this kind of fusion suggests [E21] [L44].

4. How can one understand cell (or any system) as a trashbin like structure maximizing its entropy on one hand and as an intelligent system on one hand? This can make sense in TGD framework where the amount of conscious information, negentropy, is measured by the sum of p-adic variants of entanglement entropies and is negative(!) thanks to the properties of p-adic norm. Neutron stars, blackholes and cells would be entropic objects if one limits the consideration to real sector of adeles but in p-adic sectors they would carry conscious information. The sum of real and p-adic entropies tends to be negative. Living cell would be very entropic object in real sense but very negentropic in p-adic sense: even more, the sum of negative p-adic negentropies associated with cognition in adelic physics would overcome this entropy [L26].

5.5 Neutron production from an arc current in gaseous hydrogen

I learned about nuclear physics anomaly new to me (actually the anomaly is 66 years old!) from an article of Norman and Dunning-Davies in Research Gate (see `http://tinyurl.com/y7jlhnx8`). Neutrons are produced from an arc current in hydrogen gas with a rate exceeding dramatically the rate predicted by the standard model of electroweak interactions, in which the production should occur through $e - +p \rightarrow n + \nu$ by weak boson exchange. The low electron energies make the process also kinematically impossible. Additional strange finding due to Borghi and Santilli is that the neutron production can in some cases be delayed by several hours. Furthermore, according to Santilli neutron production occurs only for hydrogen but not for heavier nuclei.

In the following I sum up the history of the anomaly following closely to the representation of Norman and Dunning-Davies [C129] (see `http://tinyurl.com/y7jlhnx8`): this article gives references and details and is strongly recommended. This includes the pioneering work of Sternglass in 1951, the experiments of Don Carlo Borghi in the late 1960s [C28], and the rather recent experiments of Ruggiero Santilli [C139] (see `http://tinyurl.com/y8nsh883`).

5.5.1 Experimental work

In the following the experimental support for neutron anomaly is summarized.

The pioneering experiment of Sternglass

The initial anomalously large production of neutrons using an current arc in hydrogen gas was performed by Earnest Sternglass in 1951 while completing his Ph.D. thesis at Cornell. He wrote to Einstein about his inexplicable results, which seemed to occur in conditions lacking sufficient energy to synthesize the neutrons that his experiments had indeed somehow apparently created.

Although Einstein firmly advised that the results must be published even though they apparently contradicted standard theory, Sternglass refused due to the stultifying preponderance of contrary opinion and so his results were preemptively excluded under orthodox pressure within discipline leaving them unpublished. Edward Trounson, a physicist working at the Naval Ordnance Laboratory repeated the experiment and again gained successful results but they too, were not published.

One cannot avoid the question, what physics would look like today, if Sternglass had published or managed to publish his results. One must however remember that the first indications for cold fusion emerged also surprisingly early but did not receive any attention and that cold fusion researchers were for decades labelled as next to criminals. Maybe the extreme conservatism following the revolution in theoretical physics during the first decades of the previous century would have prevented his work to receive the attention that it would have deserved.

The experiments of Don Carlo Borghi

Italian priest-physicist Don Carlo Borghi in collaboration with experimentalists from the University of Recife, Brazil, claimed in the late 1960s to have achieved the laboratory synthesis of neutrons from protons and electrons. C. Borghi, C. Giori, and A. Dall'Olio published 1993 an article entitled "Experimental evidence of emission of neutrons from cold hydrogen plasma" in Yad. Fiz. 56 and Phys. At. Nucl. 56 (7) [C28].

Don Borghi's experiment was conducted via a cylindrical metallic chamber (called "klystron") filled up with a partially ionized hydrogen gas at a fraction of 1 bar pressure, traversed by an electric arc with about 500V and 10mA as well as by microwaves with 10^{10} Hz frequency. Note that the energies of electrons would be below .5 keV and non-relativistic. In the cylindrical exterior of the chamber the experimentalists placed various materials suitable to become radioactive when subjected to a neutron flux (such as gold, silver and others). Following exposures of the order of weeks, the experimentalists reported nuclear transmutations due to a claimed neutron flux of the order of 10^4 cps, apparently confirmed by beta emissions not present in the original material.

Don Borghi's claim remained un-noticed for decades due to its incompatibility with the prevailing view about weak interactions. The process $e^- + p \rightarrow n + \nu$ is also forbidden by conservation of energy unless the total cm energy of proton and the electron have energy larger than $\Delta E = m_n - m_p - m_e = 0.78$ MeV. This requires highly relativistic electrons. Also the cross section for the reaction proceeding by exchange of W boson is extremely small at low energies (about 10^{-20} barn: barn=10^{-28} m^2 represents the natural scale for cross section in nuclear physics). Some new physics must be involved if the effect is real. Situation is strongly reminiscent of cold fusion (or low energy nuclear reactions (LENR), which many main stream nuclear physicists still regard as a pseudoscience.

Santilli's experiments

Ruggero Santilli [C139] (see `http://tinyurl.com/y8nsh883`) replicated the experiments of Don Borghi. Santilli analyzes several alternative proposals explaining the anomalyn and suggests that new spin zero bound state of electron and proton with rest mass below the sum of proton and electron masses and absorbed by nuclei decaying then radioactively could explain the anomaly. The energy needed to overcome the kinematic barrier could come from the energy liberated by electric arc. The problem of the model is that it has no connection with standard model.

Both in the experiments of Don Carlo Borghi and those of Santilli, delayed neutron synthesis was *sometimes* observed. According to Santilli:

> *A first series of measurements was initiated with Klystron I on July 28,2006, at 2 p.m. Following flushing of air, the klystron was filled up with commercial grale hydrogen at 25 psi pressure. We first used detector PM1703GN to verify that the background radiations were solely consisting of photon counts of 5-7 $\mu R/h$ without any neutron count; we delivered a DC electric arc at 27 V and 30 A (namely with power much bigger than that of the arc used in Don Borghi's tests...), at about 0.125" gap for about 3 s; we waited for one hour until the electrodes had cooled down, and then placed detector PM1703GN against the PVC cylinder. This resulted in the detection of photons at the rate of 10 - 15 $\mu R/hr$ expected from the residual excitation of the tips of the electrodes, but no neutron count at all.*

However, about three hours following the test, detector PM1703GN entered into sonic and vibration alarms, specifically, for neutron detections off the instrument maximum of 99 cps at about 5' distance from the klystron while no anomalous photon emission was measured. The detector was moved outside the laboratory and the neutron counts returned to zero. The detector was then returned to the laboratory and we were surprised to see it entering again into sonic and vibrational alarms at about 5' away from the arc chamber with the neutron count off scale without appreciable detection of photons, at which point the laboratory was evacuated for safety.

After waiting for 30 minutes (double neutron's lifetime), we were surprised to see detector PMl703GN go off scale again in neutron counts at a distance of 10' from the experimental set up, and the laboratory was closed for the day.

5.5.2 TGD based model for the neutron anomaly

The basic problems to be solved are following.

1. What is the role of current arc and other triggering impulses (such as microwave radiation or pressure surge mentioned by Santilli): do they provide energy or do they have some other role?
2. Neutron production is kinematically impossible if weak interactions mediate it. Even if kinematically possible, weak interaction rates are quite too slow. The creation of intermediate states via other than weak interactions would solve both problems. If weak interactions are involved with the creation of the intermediate states, how there rates can be so high?
3. What causes the strange delays in the production in some cases but now always? Why hydrogen gas is preferred?

The effect brings strongly in mind cold fusion (or LENR) - another process not allowed by standard model - for which TGD proposes a model [L27] in terms of generation of dark nuclei with non-standard value $h_{eff} = n \times h$ of Planck constant formed from dark proton sequences at magnetic flux tubes. The binding energy for these states replacing the scalar particle proposed by Santilli is supposed to be obtained by scaling the nuclear binding energy by $1h/h_{eff}$ and is much lower than for the ordinary nuclei. The proposal is that these nuclei decay to ordinary nuclei as the flux tubes attach to metallic targets with negative surface charge attracting positively charged magnetic flux tubes. The energy liberated would be of the essentially the ordinary nuclear binding energy. Note that the creation of dark proton sequences does not require weak interactions so that the basic objections are circumvented.

TGD explanation for anomalous neutron production could be the same for Tesla's findings [L18], for cold fusion [C23, L48] (see `http://tinyurl.com/j3csy53`), Pollack effect [L24] [L24] and for the anomalous production of neutrons. Even electrolysis would involve in an essential manner Pollack effect and new physics.

Could this model explain the anomalous neutron production and its strange features?

1. Why electric arc, pressure surge, or microwave radiation would be needed? Dark phases are formed at quantum criticality [**?**] and give rise to the characteristic long range correlations via quantum entanglement made possible by large $h_{eff} = n \times h$. The presence of electron arc occurring as di-electric breakdown is indeed a critical phenomenon Already Tesla discovered strange phenomena in his studies of arc discharges but his discoveries were forgotten by mainstream.

   Also energy feed might be involved. Quite generally, in TGD inspired quantum biology generation of dark states requires energy feed and the role of metabolic energy is to excite dark states. For instance, dark atoms have smaller binding energy and the energies of cyclotron states increase with h_{eff}/h. For instance, part of microwave photons could be dark and have much higher energy than otherwise.

   Could the production of dark proton sequences at magnetic flux tubes be all that is needed so that the possible dark variant of the reaction $e^- + p \rightarrow n + \nu$ would not be needed at all?
2. If also weak bosons appear as dark variants, their Compton length is scaled up accordingly and in scales shorter than the Compton length, they behave effectively like massless particles

and weak interactions become as strong as electromagnetic interactions. This would make possible a rapid decay of dark proton sequences at magnetic flux tubes to beta stable dark isotopes via $p \rightarrow n + e^+ + \nu$: there is indeed evidence that cold fusion produces only beta stable isotopes. Neutrons would be produced in the decays of the dark nuclei to ordinary nuclei liberating nuclear binding energy. Note however that TGD allows also to consider p-adically scaled variants of weak bosons with much smaller mass scale possible important in biology [K59], and one cannot exclude them from consideration.

3. The reaction $e^- + p \rightarrow n + \nu$ is not necessary in the model. One can however ask, whether there could exist a mechanism making the dark reaction $e^- + p \rightarrow n + \nu$ kinematically possible. If the scale of dark nuclear binding energy is strongly reduced, also $p \rightarrow n + e^+ + \nu$ in dark nuclei would become kinematically impossible (in ordinary nuclei nuclear binding energy makes n effectively lighter than p).

   TGD based model for nuclei as strings of nucleons [L4] [L27] connected by neutral or charged (possibly colored) mesonlike bonds with quark and antiquark at its ends could resolve this problem (if one wants to see it as a problem). One could have exotic nuclei in which proton plus negatively charged bond could effectively behave like neutron. Dark weak interactions would take place for neutral bonds between protons and reduce the charge of the bond from $q = 0$ to $q = -1$ and transform p to effective n. This was assumed also in the model of dark nuclei and also in the model of ordinary nuclei and predicts large number of exotic states. One can of course ask, whether the nuclear neutrons are actually pairs of proton and negatively charged bond.

4. What about the delays in neutron production occurring in some cases? Why not always? In the situations, when there is a delay in neutron production, the dark nuclei could have rotated around magnetic flux tubes of the magnetic body (MB) of the system before entering to the metal target, one would have a delayed production.

5. Why would hydrogen be preferred? Why for instance, deuteron and heavier isotopes containing neutrons would not form dark proton sequences at magnetic flux tubes. Why would be the probability for the transformation of say D=pn to its dark variant be very small?

   If the binding energy of dark nuclei per nucleon is several orders of magnitude smaller than for ordinary nuclei, the explanation is obvious. The ordinary nuclear binding energy is much higher than the dark binding energy so that only the sequences of dark protons can form dark nuclei. The first guess made in [L27] is that the binding energy is analogous to Coulomb energy and thus inversely proportional to the size scale of dark nucleus scaling like h/h_{eff}. One can however ask why D with ordinary size could not serve as sub-unit.

5.6 Cold fusion, low energy nuclear reactions, or dark nuclear synthesis?

Steven Krivit has written three books or one book in three parts [C144, C143, C145] - as you wish - about cold fusion (shortly CF in the sequel) - or low energy nuclear reaction (LENR) - which is the prevailing term nowadays and preferred by Krivit. The term "cold fusion" can be defended only by historical reasons: the process cannot be cold fusion. LENR relies on Widom-Larsen model (WL) trying to explain the observations using only the existing nuclear and weak interaction physics. Whether LENR is here to stay is still an open question. TGD suggests that even this interpretation is not appropriate: the nuclear physics involved would be dark and associated with $h_{eff} = n \times h$ phases of ordinary matter having identification as dark matter. Even the term "nuclear transmutation" would be challenged in TGD framework and "dark nuclear synthesis" looks a more appropriate term.

5.6.1 General comments

The books were a very pleasant surprise for many reasons, and I have been able to develop my own earlier overall view by adding important details and missing pieces and allowing to understand the relationship to Widom-Larsen model (WL).

What the books are about?

There are three books.

"Hacking the atom: Explorations in Nuclear Research, vol I" (see http://tinyurl.com/yb2zxpmy) considers the developments between 1990-2006. The first key theme is the tension between two competing interpretations. On one hand, the interpretation as CF involving necessarily new physics besides ordinary nuclear fusion and plagued by a direct contradiction with the expected signatures of fusion processes, in particular those of $D+D \rightarrow^4 He$. On the other hand, the interpretation as LENR in the framework of WL in which no new physics is assumed and neutrons and weak interactions are in a key role.

Second key theme is the tension between two competing research strategies.

(a) The first strategy tried to demonstrate convincingly that heat is produced in the process - commercial applications was the basic goal. This led to many premature declarations about solution of energy problems within few years and provided excellent weapons for the academic world opposing cold fusion on basis of textbook wisdom.

(b) Second strategy studied the reaction products and demonstrated convincingly that nuclear transmutations (isotopic shifts) took place. This aspect did not receive attention in public and the attempts to ridiculize have directed attention to the first approach and to the use of the term "cold fusion".

According to Krivit, CF era ended around 2006, when Widom and Larsen proposed their model in which LENR would be the mechanism [C154, C13, C11, C152, C153]. Widom-Larsen model (WL) can be however criticized for some un-natural looking assumptions: electron is required to have renormalized mass considerably higher than the real mass; the neutrons initiating nuclear reactions are assumed to have ultralow energies below thermal energy of target nuclei. This requires electron mass to be larger but extremely near to neutron-proton mass difference. The gamma rays produced in the process are assumed to transform to infrared radiation.

To my view, WL is not the end of the story. New physics is required. For instance, the work of professor Holmlid and his team [C23, L48] has provided new fascinating insights to what might be the mechanism of what has been called nuclear transmutations.

"Fusion Fiasco: Explorations in Nuclear Research, vol II" (see http://tinyurl.com/ybtvwlyz) discusses the developments during 1989 when cold fusion was discovered by Fleischman and Pons [C101] and interpreted as CF. It soon turned out that the interpretation has deep problems and CF got the label of pseudoscience.

"Lost History: Explorations in Nuclear Research, vol III" (see http://tinyurl.com/ybxrsvqk) tells about surprisingly similar sequence of discoveries, which has been cleaned away from history books of science because it did not fit with the emerging view about nuclear physics and condensed matter physics as completely separate disciplines. Although I had seen some remarks about this era I had not not become aware what really happened. It seems that discoveries can be accepted only when the time is mature for them, and it is far from clear whether the time is ripe even now.

What I say in the sequel necessarily reflects my limitations as a dilettante in the field of LENR/CF. My interest on the topic has lasted for about two decades and comes from different sources: LENR/CF is an attractive application for the unification of fundamental interactions that I have developed for four decades now. This unification predicts a lot of new physics - not only in Planck length scale but in all length scales - and it is of course fascinating to try to understand LENR/CF in this framework.

For instance, while reading the book, I realized that my own references to the literature have been somewhat random and not always appropriate. I do not have any systematic overall view about what has been done in the field: here the book makes wonderful service. It was a real surprise to find that first evidence for transmutation/isotope shifts emerged already for about century ago and also how soon isotope shifts were re-discovered after Pons-Fleischman discovery [C101]. The insistence on $D + D \rightarrow^4 He$ fusion model remains for an outsider as mysterious as the refusal of mainstream nuclear physicists to consider the possibility of new nuclear physics. One new valuable bit of information was the evidence that it is the cathode material that transforms to the isotope shifted nuclei: this helped to develop my own model in more detail.

Remark: A comment concerning the terminology. I agree with the author that cold fusion is not a precise or even correct term. I have myself taken CF as nothing more than a letter sequence and defended this practice to myself as a historical convention. My conviction is that the phenomenon in question is not a nuclear fusion but I am not at all convinced that it is LENR either. Dark nucleosynthesis is my won proposal.

What did I learn from the books?

Needless to say, the books are extremely interesting, for both layman and scientist - say physicist or chemist, or anyone involved in developing new energy technologies. The books provide a very thorough view about the history of the subject. There is also an extensive list of references to the literature. Since I am not an experimentalist and feel myself a dilettante in this field as a theoretician, I am unable to check the correctness and reliability of the data represented. In any case, the overall view is consistent with what I have learned about the situation during years. My opinion about WL is however different.

I have been working with ideas related to CF/LENR (or nuclear transmutations) but found that books provided also completely new information and I became aware about some new critical points.

I have had a rather imbalanced view about transmutations/isotopic shifts and it was a surprise to see that they were discovered already 1989 when Fleisch and Pons published their work [C101]. Even more, the premature discovery of transmutations for century ago (1910-1930) interpreted by Darwin as a collective effect, was new to me. Articles about transmutations were published in prestigious journals like Nature and Naturwissenschaften. The written history is however history of winners and all traces of this episode disappeared from the history books of physics after the standard model of nuclear physics assuming that nuclear physics and condensed matter physics are totally isolated disciplines. The developments after the establishment of standard model relying on GUT paradigm looks to me surprisingly similar.

Sternglass - still a graduate student - wrote around 1947 to Einstein about his preliminary ideas concerning the possibility to transform protons to neutrons in strong electric fields. It became as a surprise to Sternglass that Einstein supported his ideas. I must say that this increased my respect of Einstein even further. Einstein's physical intuition was marvellous. In 1951 Sternglass found that in strong voltages in keV range protons could be transformed to neutrons with unexpectedly high rate. This is strange since the process is kinematically impossible for free protons: it however can be seen as support for WL model.

Also scientists are humans with their human weaknesses and strengths and the history of CF/LENR is full of examples of both light and dark sides of human nature. Researchers are fighting for funding and the successful production of energy was also the dream of many people involved. There were also people, who saw CF/LENR as a quick manner to become millionaire. Getting a glimpse about this dark side was rewarding. The author knows most of the influential people, who have worked in the field and this gives special authenticity to the books.

It was a great service for the reader the basic view about what happened was stated clearly in the introduction. I noticed also that with some background one can pick up any section and start to read: this is a service for a reader like me. I would have perhaps divided the material into separate parts but probably a less bureaucratic choice leaving room for surprise is better after all.

Who should read these books? The books would be a treasure for any physicist ready to challenge the prevailing prejudices and learn about what science is as seen from the kitchen side. Probably this period will be seen in future as very much analogous to the period leading to the birth of atomic physics and quantum theory. Also layman could enjoy reading the books, especially the stories about the people involved - both scientists and those funding the research and academic power holders - are fascinating. The history of cold fusion is a drama in which one can see as fight between Good and Evil and eventually realize that also Good can divide into Good and Evil. This story teaches about a lot about the role of egos in all branches of sciences and in all human activities. Highly rationally behaving science professionals can suddenly start to behave completely irrationally when their egos feel being under threat.

My hope is that the books could wake up the mainstream colleague to finally realize that

CF/LENR or - whatever you wish to call it - is not pseudoscience. Most workers in the field are highly competent, intellectually honest, an have had so deep passion for understanding Nature that they have been ready to suffer all the humiliations that the academic hegemony can offer for dissidents. The results about nuclear transmutations are genuine and pose a strong challenge for the existing physics, and to my opinion force to give up the naïve reductionistic paradigm. People building unified theories of physics should be keenly aware of these phenomena challenging the reductionistic paradigm even at the level of nuclear and condensed matter physics.

The problems of WL

For me the first book representing the state of CF/LENR as it was around 2004 was the most interesting. In his first book Krivit sees 1990-2004 period as a gradual transition from the cold fusion paradigm to the realization that nuclear transmutations occur and the fusion model does not explain this process.

In his first book Krivit sees 1990-1999 period as a gradual transition from the cold fusion paradigm to the realization that nuclear transmutations occur and the fusion model does not explain this process.

The basic assumption of the simplest fusion model was that the fusion $D + D \rightarrow^4 He$ explains the production of heat. This excluded the possibility that the phenomenon could take place also in light water with deuterium replaced with hydrogen. It however turned out that also ordinary water allows the process. The basic difficulty is of course Coulomb wall but the model has also difficulties with the reaction signatures and the production rate of ^4He is too low to explain heat production. Furthermore, gamma rays accompanying ^4He production were not observed. The occurrence of transmutations is a further problem. Production of Li was observed already in 1989, and later russia trio Kucherov, Savvatinova, Karabut detected tritium, ^4He, and of heavy elements [C119]. They also observed modifications at the surface of the cathode down to depth of .1-1 micrometers.

Krivit sees LENR as a more realistic approach to the phenomena involved. In LENR Widom-Larsen model (WL) is the starting point [C154, C13, C11, C152, C153]. This would involve no new nuclear physics. I also see WL as a natural starting point but I am skeptic about understanding CF/LENR in term of existing physics. Some new physics seems to be required and I have been doing intense propaganda for a particular kind of new physics [K24].

WL assumes that weak process proton (p) $\rightarrow$ neutron (n) occurring via $e + p \rightarrow n + \nu$ (e denotes electron and ν for neutrino) is the key step in cold fusion. After this step neutron finds its way to nucleus easily and the process continues in conventional sense as analog of r-process assumed to give rise to elements heavier than iron in supernova explosions and leads to the observed nuclear transmutations. Essentially one proton is added in each step decomposing to four sub-steps involving beta decay $n \rightarrow p$ and its reversal.

There are however problems.

1. Already the observations of Sternglass suggest that $e + p \rightarrow n + \nu$ occurs. $e + p \rightarrow n + \nu$ is however kinematically impossible for free particles. e should have considerably higher effective mass perhaps caused by collective many-body effects. $e + p \rightarrow n + \nu$ could occur in the negatively charged surface layer of cathode provided the sum of the rest masses of e and p is larger than that of n. This requires rather large renormalization of electron mass claimed to be due to the presence of strong electric fields. Whether there really exists a mechanism increasing the effective mass of electron, is far from obvious and strong nuclear electric fields are proposed to cause this.

2. Second problematic aspect of WL is the extreme slowness of the rate of beta decay transforming proton to neutron. For ultraslow neutrons the cross section for the absorption of neutron to nucleus increases as $1/v_{rel}$, v_{rel} the relative velocity, and in principle could compensate the extreme slowness of the weak decays. The proposal is that neutrons are ultraslow. This is satisfied if the sum of rest masses is only slightly larger than proton mass. One would have $m_E \simeq m_n - m_p \Delta E_n$, where ΔE_n is the kinetic of neutron. To obtain correct order of magnitude for the rate of neutron absorptions ΔE_n should be indeed extremely small. One should have $\Delta E = 10^{-12}$ eV and one has $\Delta E/m_p = 10^{-21}$! This requires fine tuning and it

is difficult to believe that the electric field causing the renormalization could be so precisely fine-tuned.

ΔE corresponds to extremely low temperature about 10^{-8} K hard to imagine this at room temperature. Thermal energy of the target nucleus at room temperature is of the order $10^{-11} Am_p$, A mass number. Hence it would seem that the thermal motion of the target nuclei mask the effect.

3. One should also understand why gamma rays emitted in the ordinary nuclear interactions after neutron absorption are not detected. The proposal is that gamma rays somehow transform to infrared photons, which would cause the heating. This would be a collective effect involving quantum entanglement of electrons. One might hope that by quantum coherence the neutron absorption rate could be proportional to N^2 instead of N, where N is the number of nuclei involved. This looks logical but I am not convinced about the physical realizability of this proposal.

To my opinion these objections are really serious.

5.6.2 Comparison with TGD inspired models of CF/LENR or whatever it is

I cannot avoid the temptation to compare WL to my own dilettante models for which also WL has served as an inspiration. I have two models explaining these phenomena in my own TGD Universe. Both models rely on the hierarchy of Planck constants $h_{eff} = n \times h$ [**?**, K43] explaining dark matter as ordinary matter in $h_{eff} = n \times h$ phases emerging at quantum criticality. h_{eff} implies scaled up Compton lengths and other quantal lengths making possible quantum coherence is longer scales than usually.

The hierarchy of Planck constants $h_{eff} = n \times h$ has now rather strong theoretical basis and reduces to number theory [L63, L64]. Quantum criticality would be essential for the phenomenon and could explain the critical doping fraction for cathode by D nuclei. Quantum criticality could help to explain the difficulties to replicate the effect.

Simple modification of WL does not work

The first model is a modification of WL and relies on dark variant of weak interactions. In this case LENR would be appropriate term.

1. Concerning the rate of the weak process $e + p \rightarrow n + \nu$ the situation changes if h_{eff} is large enough and rather large values are indeed predicted. h_{eff} could be large also for weak gauge bosons in the situation considered. Below their Compton length weak bosons are effectively massless and this scale would scale up by factor $n = h_{eff}/h$ to almost atomic scale. This would make weak interactions as strong as electromagnetic interactions and long ranged below the Compton length and the transformation of proton to neutron would be a fast process. After that a nuclear reaction sequence initiated by neutron would take place as in WL. There is no need to assume that neutrons are ultraslow but electron mass remains the problem. Note that also proton mass could be higher than normal perhaps due to Coulomb interactions.
2. As such this model does not solve the problem related to the too small electron mass. Nor does it solve the problem posed by gamma ray production.

Dark nucleosynthesis

Also second TGD inspired model involves the h_{eff} hierarchy. Now LENR is not an appropriate term: the most interesting things would occur at the level of dark nuclear physics, which is now a key part of TGD inspired quantum biology.

1. One piece of inspiration comes from the exclusion ones (EZs) of Pollack [L24] [L24], which are negatively charged regions [K24] [L27, L38]. Also the work of the group of Prof. Holmlid [C23, L48] not yet included in the book of Krivit was of great help. TGD proposal [L27, L48] is that protons causing the ionization go to magnetic flux tubes having interpretation in terms of space-time topology in TGD Universe. At flux tubes they have $h_{eff} = n \times h$ and form dark variants of nuclear strings, which are basic structures also for ordinary nuclei.

2. The sequences of dark protons at flux tubes would give rise to dark counterparts of ordinary nuclei proposed to be also nuclear strings but with dark nuclear binding energy, whose scale is measured using as natural unit MeV$/n$, $n = h_{eff}/h$, rather than MeV. The most plausible interpretation is that the field body/magnetic body of the nucleus has $h_{eff} = n \times h$ and is scaled up in size. $n = 2^{11}$ is favoured by the fact that from Holmlid's experiments the distance between dark protons should be about electron Compton length.

   Besides protons also deuterons and even heavier nuclei can end up to the magnetic flux tubes. They would however preserve their size and only the distances between them would be scaled to about electron Compton length on basis of the data provided by Holmlid's experiments [C23, L48].

   The reduced binding energy scale could solve the problems caused by the absence of gamma rays: instead of gamma rays one would have much less energetic photons, say X rays assignable to $n = 2^{11} \simeq m_p/m_e$. For infrared radiation the energy of photons would be about 1 eV and nuclear energy scale would be reduced by a factor about $10^{-6} - 10^{-7}$: one cannot exclude this option either. In fact, several options can be imagined since entire spectrum of h_{eff} is predicted. This prediction is a testable.

   Large h_{eff} would also induce quantum coherence is a scale between electron Compton length and atomic size scale.

3. The simplest possibility is that the protons are just added to the growing nuclear string. In each addition one has $(A, Z) \to (A + 1, Z + 1)$. This is exactly what happens in the mechanism proposed by Widom and Larsen for the simplest reaction sequences already explaining reasonably well the spectrum of end products.

   In WL the addition of a proton is a four-step process. First $e + p \to n + \nu$ occurs at the surface of the cathode. This requires large electron mass renormalization and fine tuning of the electron mass to be very nearly equal but higher than $n - p$ mass difference.

   There is no need for these questionable assumptions of WL in TGD. Even the assumption that weak bosons correspond to large h_{eff} phase might not be needed but cannot be excluded with further data. The implication would be that the dark proton sequences decay rather rapidly to beta stable nuclei if dark variant of $p \to n$ is possible.

4. EZs and accompanying flux tubes could be created also in electrolyte: perhaps in the region near cathode, where bubbles are formed. For the flux tubes leading from the system to external world most of the fusion products as well as the liberated nuclear energy would be lost. This could partially explain the poor replicability for the claims about energy production. Some flux tubes could however end at the surface of catalyst under some conditions. Flux tubes could have ends at the catalyst surface. Even in this case the particles emitted in the transformation to ordinary nuclei could be such that they leak out of the system and Holmlid's findings indeed support this possibility.

   If there are negatively charged surfaces present, the flux tubes can end to them since the positively charged dark nuclei at flux tubes and therefore the flux tubes themselves would be attracted by these surfaces. The most obvious candidate is catalyst surface, to which electronic charge waves were assigned by WL. One can wonder whether already Tesla observed in his experiments the leakage of dark matter to various surfaces of the laboratory building. In the collision with the catalyst surface dark nuclei would transform to ordinary nuclei releasing all the ordinary nuclear binding energy. This could create the reported craters at the surface of the target and cause ehating. One cannot of course exclude that nuclear reactions take place between the reaction products and target nuclei. It is quite possible that most dark nuclei leave the system.

   It was in fact Larsen, who realized that there are electronic charge waves propagating along the surface of some catalysts, and for good catalysts such as Gold, they are especially strong. This would suggests that electronic charge waves play a key role in the process. The proposal of WL is that due to the positive electromagnetic interaction energy the dark protons of dark nuclei could have rest mass higher than that of neutron (just as in the ordinary nuclei) and the reaction $e + p \to n + \nu$ would become possible.

5. Spontaneous beta decays of protons could take place inside dark nuclei just as they occur inside ordinary nuclei. If the weak interactions are as strong as electromagnetic interactions,

dark nuclei could rapidly transform to beta stable nuclei containing neutrons: this is also a testable prediction. Also dark strong interactions would proceed rather fast and the dark nuclei at magnetic flux tubes could be stable in the final state. If dark stability means same as the ordinary stability then also the isotope shifted nuclei would be stable. There is evidence that this is the case.

Neither "CF" nor "LENR" is appropriate term for TGD inspired option. One would not have ordinary nuclear reactions: nuclei would be created as dark proton sequences and the nuclear physics involved is in considerably smaller energy scale than usually. This mechanism could allow at least the generation of nuclei heavier than Fe not possible inside stars and supernova explosions would not be needed to achieve this. The observation that transmuted nuclei are observed in four bands for nuclear charge Z irrespective of the catalyst used suggest that catalyst itself does not determined the outcome.

One can of course wonder whether even "transmutation" is an appropriate term now. Dark nucleosynthesis, which could in fact be the mechanism of also ordinary nucleosynthesis outside stellar interiors explain how elements heavier than iron are produced, might be more appropriate term.

5.6.3 More about dark nucleosynthesis

In the sequel a more detailed view about dark nucleosynthesis is developed using the information provided by the first book of Krivit. This information allows to make also the nuclear string model much more detailed and connect CF/LENR with co called X boson anomaly and other nuclear anomalies.

Not only sequences of dark protons but also of dark nucleons are involved

Are only dark protons sequences at magnetic flux tubes involved or can these sequences consists of nuclei so that one would have nucleus consisting of nuclei? From the first book I learned, that the experiments of Urutskoev [H9] demonstrate that there are 4 peaks for the production rate of elements as function of atomic number Z. Furthermore, the amount of mass assignable to the transmuted elements is nearly the mass lost from the cathode. Hence also cathode nuclei should end up to flux tubes.

1. Entire target nuclei can become dark in the sense described and end up to the same magnetic flux tubes as the protons coming from bubbles of electrolyte, and participate in dark nuclear reactions with the incoming dark nuclei: the dark nuclear energy scale would be much smaller than MeV. For heavy water electrolyte D must become dark nucleus: the distance between p and n inside D would be usual. A natural expectation is that the flux tubes connect the EZs and cathode.

   In the transformation to ordinary nuclear matter these nuclei of nuclei would fuse to ordinary nuclei and liberate nuclear energy associated with the formation of ordinary nuclear bonds.

2. The transformation of protons to neutrons in strong electric fields observed already by Sternglass in 1951 could be understood as a formation of flux tubes containing dark nuclei and producing neutrons in their decays to ordinary nuclei. The needed voltages are in kV range suggesting that the scale of dark nuclear binding energy is of order keV implying $h_{eff}/h = n \sim 2^{11}$ - roughly the ratio m_p/m_e.

3. Remarkably, also in ordinary nuclei the flux tubes connecting nucleons to nuclear string would be long, much longer than the nucleon Compton length [L4] [L50]. By ordinary Uncertainty Principle ($h_{eff} = h$) the length of flux tube to which binding energy is assigned would correspond to the size of nuclear binding energy scale of order few MeV. This would be also the distance between dark $h_{eff} = n \times h$ nuclei forming dark nuclear string! The binding energy would be scaled down by $1/n$.

   This suggests that $n \to 1$ phase transition does not affect the lengths of flux tubes but only turns them to loops and that the distance between nucleons as measured in $M^4 \times CP_2$ is therefore scaled down by $1/n$. Coulomb repulsion between proton does not prevent this if the electric flux between protons is channelled along the long flux tubes rather than along larger space-time sheet so that the repulsive Coulomb interaction energy is not affected in the phase transition! This line of thought obviously involves the notion of space-time as a 4-surface in crucial manner.

4. Dark nuclei could have also ordinary nuclei as building bricks in accordance with fractality of TGD. Nuclei at dark flux tubes would be ordinary and the flux tubes portions - bonds - between them would have large h_{eff} and ahve thus length considerably longer than in ordinary nuclei. This would give sequences of ordinary nuclei with dark binding energy: similar situation is actually assumed to hold true for the nucleons of ordinary nuclei connected by analogs of dark mesons with masses in MeV range [L4].

Remark: In TGD inspired model for quantum biology dark variants of biologically important ions are assumed to be present. Dark proton sequences having basic entangled unit consisting of 3 protons analogous to DNA triplet would represent analogs of DNA, RNA, amino-acids and tRNA [L36]. Genetic code would be realized already at the level of dark nuclear physics and biochemical realization would represent kind of shadow dynamics. The number of dark codons coding for given dark amino-acid would be same as in vertebrate genetic code.

How dark nuclei are transformed to ordinary nuclei?

What happens in the transformation of dark nuclei to ordinary ones? Nuclear binding energy is liberated but how does this occur? If gamma rays generated, one should invent also now a mechanism transforming gamma rays to thermal radiation. The findings of Holmlid provide valuable information here and lead to a detailed qualitative view about process and also allow to sharpen the model for ordinary nuclei.

1. Holmlid [L48] [L48] [K24] has reported rather strange finding that muons (mass 106 MeV) pions (mass 140 MeV) and even kaons (mass 497) MeV are emitted in the process. This does not fit at all to ordinary nuclear physics with natural binding energy scale of few MeVs. It could be that a considerable part of energy is liberated as mesons decaying to lepton pairs (pions also to gamma pairs) but with energies much above the upper bound of about 7 MeV for the range of energies missing from the detected gamma ray spectrum (this is discussed in the first part of the book of Krivit [C144]).

   As if even hadronic interactions would enter the game somehow! Already condensed matter physics and nuclear physics in the same coffee table are too much fort the mainstream physicist!

2. What happens when the liberated total binding energy is below pion mass? There is experimental evidence for what is called X boson [C68] discussed from TGD point of view in [L50]. In TGD framework X is identified as a scaled down variant $\pi(113)$ of ordinary pion $\pi = \pi(107)$. X is predicted to have mass of $m(\pi(113)) = 2^{(113-107)/2}m(\pi) \simeq 16.68$ MeV, which conforms with the mass estimate for X boson. Note that $k = 113$ *resp.* $k = 117$ corresponds to nuclear *resp.* hadronic p-adic length scale. For low mass transmutations the binding energy could be liberated by emission of X bosons and gamma rays.

3. I have also proposed that pion and also other neutral pseudo-scalar states could have p-adically scaled variants with masses differing by powers of two. For pion the scaled variants would have masses 8.5 MeV, $m(\pi(113)) = 17$ MeV, 34 MeV, 68 MeV, $m(\pi(107)) = 136$ MeV, ... and also these could be emitted and decay to lepton pairs of gamma pairs [K66]. The emission of scaled pions could be faster process than emission of gamma rays and allow to emit the binding energy with minimum number of gamma rays.

There is indeed evidence for pion like states (for TGD inspired comments see [K66]).

1. The experimental claim (see `http://tinyurl.com/ybq323yy`) of Tatischeff and Tomasi-Gustafsson is that pion is accompanied by pion like states organized on Regge trajectory and having mass 60, 80, 100, 140, 181, 198, 215, 227.5, and 235 MeV. For TGD inspired comments see [K66].

2. A further piece of evidence for scaled variants of pion comes from two articles by Eef van Beveren and George Rupp. The first article [C26] is titled *First indications of the existence of a 38 MeV light scalar boson* (see `http://tinyurl.com/yatlb97o`). Second article [C27] has title *Material evidence of a 38 MeV boson* (see `http://tinyurl.com/yczo7juy`).

The above picture suggests that the pieces of dark nuclear string connecting the nucleons are looped and nucleons collapse to a nucleus sized region. On the other, the emission of mesons suggests that these pieces contract to much shorter pieces with length of order Compton length of meson responsible for binding and the binding energy is emitted as single quantum or very few quanta. Strings cannot however retain their length (albeit becoming looped with ends very near in $M^4 \times CP_2$) and contract at the same time! How could one unify these two conflicting pictures?

1. To see how TGD could solve the puzzle, consider what elementary particles look like in TGD Universe [K66]. Elementary particles are identified as two-sheeted structures consisting of two space-time sheets with Minkowskian signature of the induced metric connected by CP_2 sized wormhole contacts with Euclidian signature of induced metric. One has a pair of wormhole contacts and both of them have two throats analogous to blackhole horizons serving as carriers of elementary particle quantum numbers.

   Wormhole throats correspond to homologically trivial 2-surfaces of CP_2 being therefore Kähler magnetically charged monopole like entities. Wormhole throat at given space-time sheet is necessarily connected by a monopole flux tube to another throat, now the throat of second wormhole contact. Flux tubes must be closed and therefore consist of 2 "long" pieces connecting wormhole throats at different parallel space-time sheets plus 2 wormhole contacts of CP_2 size scale connecting these pieces at their ends. The structure resembles extremely flattened rectangle.

2. The alert reader can guess the solution of the puzzle now. The looped string corresponds to string portion at the non-contracted space-time sheet and contracted string to that at contracted space-time sheet! The first sheet could have ordinary value of Planck constant but larger p-adic length scale of order electron's p-adic length scale $L(127)$ (it could correspond to the magnetic body of ordinary nucleon [L50]) and second sheet could correspond to $h_{eff} = n \times h$ dark variant of nuclear space-time sheet with $n = 2^{11}$ so that the size scales are same.

   The phase transition $h_{eff} \rightarrow h$ occurs only for the flux tubes of the second space-time sheet reducing the size of this space-time sheet to that of nuclear $k = 137$ space-time sheet of size of $\sim 10^{-14}$ meters. The portions of the flux tubes at this space-time sheet become short, at most of the order of nuclear size scale, which roughly corresponds to pion Compton length. The contraction is accompanied by the emission of the ordinary nuclear binding energy as pions, their scaled variants, and even heavier mesons. This if the mass of the dark nucleus is large enough to guarantee that total binding energy makes the emission possible. The second space-time sheet retains its size but the flux tubes at it retain their length but become loopy since their ends must follow the ends of the shortened flux tubes.

3. If this picture is correct, most of the energy produced in the process could be lost as mesons, possibly also their scaled variants. One should have some manner to prevent the leakage of this energy from the system in order to make the process effective energy producer.

4. The is however an important question to be answered. The basic hypothesis has been that the dark $h_{eff}(h = n$ variants of elementary particles have same masses as the ordinary elementary particles particles. Hadrons are however many-quark systems and this need not be true anymore. Could proton and neutron masses change?

   The model for Pollack effect does not allow significant change of proton mass. If also neutron mass remains un-affected and nuclear binding energies are scaled down by factor 2^{-11}, one ends up with difficulties. n-p mass difference is about 1.3 MeV and its scale would be much higher than the few keV scale for scaled down nuclear binding energies. Stable dark nuclei would consist of protons only and the transformation to ordinary nuclei would require emission of charge particles, say scaled variants of pion (which could be emitted in any way with a higher rate than gamma rays).

   If n-p mass difference is scaled down by factor 2^{-11} to .65 keV, one has scaling invariance and the spectrum of dark nuclei would be essentially similar to that of ordinary nuclei and dark beta decays would lead rapidly to beta stable dark nuclei. In particular, dark variants of beta decays involving the emission of e^+ become possible and can transform dark protons to dark neutrons. Notice, the assumption of WL about large renormalization of proton mass implying $m_{R,p} + m_e \simeq m_n$ in an excellent approximation is analogous to this hypothesis.

Dark nucleosynthesis and stellar evolution

The temperature of the solar core is rather near to the scale of dark nuclear binding energy. This co-incidence inspires interesting questions about the dark nucleosynthesis in the stellar evolution.

1. Some questions inspired by a numerical co-incidence

The temperature at solar core is about $T = 1.5 \times 10^7$ K corresponding to the thermal energy $E = 3T/2 = 2.25$ keV obtained by a scaling factor 2^{-11} energy ~ 5 MeV, which is the binding energy scale for the ordinary nuclei. That this temperature corresponds to the binding energy scale of dark nuclei might not be an accident.

That the temperature in the stellar core is of the same order of magnitude as dark nuclear binding energy is a highly intriguing finding and encourages to ask whether dark nuclear fusion could be the key step in the production of ordinary nuclei and what is the relation of dark nucleosynthesis to ordinary nucleosynthesis.

1. Could dark nucleosynthesis occur also pre-stellar evolution and thus proceed differently from the usual p-p-cycle involving fusion processes? The resulting ordinary nuclei would undergo only ordinary nuclear reactions and decouple from the dark dynamics. This does not exclude the possibility that the resulting ordinary nuclei form nuclei of nuclei with dark protons: this seems to occur also in nuclear transmutations.
2. There would be two competing effects. The higher the temperature, the less stable dark nuclei and the longer the dark nuclear strings. At lower temperatures dark nuclei are more stable but transform to ordinary nuclei decoupling from the dark dynamics. The liberated nuclear binding energy however raises the temperature and makes dark nuclei less stable so that the production of ordinary nuclei in this manner would slow down.

   At what stage ordinary nuclear reactions begin to dominate over dark nucleosynthesis? The conservative and plausible looking view is that p-p cycle is indeed at work in stellar cores and has replaced dark nucleosynthesis when dark nuclei became thermally unstable.

   The standard view is that solar temperature makes possible tunnelling through Coulomb wall and thus ordinary nuclear reactions. The temperature is few keVs and surprisingly small as compared to the height of Coulomb wall $E_c \sim Z_1 Z_2 e^2/L$, L the size of the nucleus. There are good reasons to believe that this picture is correct. The co-incidence of the two temperatures would make possible the transition from dark nucleosynthesis to ordinary nucleosynthesis.
3. What about dark nuclear reactions? Could they occur as reconnections of long magnetic flux tubes? For ordinary nuclei reconnections of short flux tubes would take place (recall the view about nuclei as two-sheeted structures). For ordinary nuclear the reactions at energies so low that the phase transition to dark phase (somewhat analogous to the de-confinement phase transition in QCD) is not energetically possible, the reactions would occur in nuclear scale.
4. An interesting question is whether dark nucleosynthesis could provide a new manner to achieve ordinary nuclear fusion in laboratory. The system would heat itself to the temperatures required by ordinary nuclear fusion as it would do also during the pre-stellar evolution and when nuclear reactor is formed spontaneously (Oklo reactor, see `http://tinyurl.com/l3h6t9v`).

2. Could dark nucleosynthesis affect the views about stellar evolution?

The presence of dark nucleosynthesis could modify the views about star formation (see `http://tinyurl.com/ybdv79gg`), in particular about energy production in protostars (see `http://tinyurl.com/l4htsob`) and pre-main-sequence stars (PMS, see `http://tinyurl.com/y8bfbvk7`) following protostars in stellar evolution.

In protostars and PMSs the temperature is not yet high enough for the burning of hydrogen to ^{4}He, and according to the standard model the energy radiated by the star consists of the gravitational energy liberated during the gravitational contraction. Could dark nucleosynthesis provide a new mechanism of energy production and could this energy be transferred from the protostar/PMS as dark energy along dark magnetic flux tubes?

Can one imagine any empirical evidence for the presence of dark nucleosynthesis in protostars and PMSs?

1. The energy and matter produced in dark nucleosynthesis could partially leak out along dark magnetic flux tubes and give rise to astrophysical jets (see http://tinyurl.com/yb7g9ryx). Astrophysical jets indeed accompany protostars and the associated planetary and bipolar nebulae as well as PMSs (T Tauri stars and Herbig-Haro objects). The jets along flux tubes associated with hot spots at which dark nucleosynthesis would take place could provide also a mechanism for the transfer of angular momentum from the protostar/PMS.
2. Spectroscopic observations of dense cores (protostar) not yet containing stars indicate that contraction occurs but the predicted expansion of the contracting region has not been observed (see http://tinyurl.com/l4htsob). The energy production by dark nucleosynthesis could increase pressure and slow down and even prevent the expansion of the contracting region.

How dark nucleosynthesis could affect the evolution of protostars and PMSs?

1. In standard model the formation of accretion disk (see http://tinyurl.com/yaax8ruq) could be understood in terms of angular momentum conservation: spherical distribution of matter transforms to a planar one does not require large changes for the velocities tangential to the plane. The mechanism for how the matter from accretion disk spirals into star is however poorly understood.
2. The TGD inspired model for galaxy formation suggests that the core region of the protostar is associated with a highly knotted cosmic string ("pearl in a necklace") forming the dark core of galaxy with constant density of dark matter [L53]. The dark matter from the cosmic string would have leaked out from the cosmic string and transformed to ordinary matter already before the annihilation of quarks and antiquarks. The CP, P, and T asymmetries predicted by twistor lift of TGD would predict that there is a net quark (antiquark) number outside (inside) the cosmic string. The locally axisymmetric gravitational potential of the cosmic string would favour disk like rather than spherically symmetric matter distribution as the initial distribution of the baryonic matter formed in the hadronization from the quarks left from the annihilation.

   Quantitative model is needed to see whether dark fusion could contribute significantly to the energy production in protostars and PMSs and affect their evolution. The nuclear binding energy liberated in dark fusion would slow down the gravitational contraction and increase the duration of protostar and PMS phases. In standard model PMS phase is possible for masses varying from 2 to 8 solar masses. Dark nucleosynthesis could increase the upper bound for the mass of PMS from that predicted by the standard model.

This is only rough overall view and it would be unrealistic to regard it as final one: one can indeed imagine variations. But even its recent rough form it seems to be able explain all the weird looking aspects of CF/LENR/dark nucleosynthesis. To pick up one particular interesting question: how significantly dark nucleosynthesis could contribute to the generation of elements heavier than Fe (and also lighter elements)? It is assumed that the heavier elements are generated in so called r-process involving creation of neutrons fusing with nuclei. One option is that r-process accompanies supernova explosions but SN1987A did not provide support for this hypothesis: the characteristic em radiation accompanying r-process was not detected. Quite recently the observation of gravitational waves from the fusion of two neutron stars generated also visible radiation, so called kilonova (see http://tinyurl.com/ycagjeau), and the radiation accompanying r-process was reported. Therefore this kind of collisions generate at least part of the heavier elements.

3. The discovery of "invisible visible matter" and more detailed view about dark pre-nuclear physics

That 30 per cent of visible matter has remained invisible is not so well-known problem related to dark matter. It is now identified and assigned to the network of filaments in intergalactic space. Reader can consult the popular article "Researchers find last of universe's missing ordinary matter" (see http://tinyurl.com/y8tj7mq4. The article "Observations of the missing baryons in the warm-hot intergalactic medium" by Nicastro *et al* [E22] (see http://tinyurl.com/ydhhuld4) describes the finding at technical level. Note that warm-hot refers to the temperature range $10^5 - 10^6$ K.

In TGD framework one can interpret the filament network as as a signature of flux tubes/cosmic string network to which one can assign dark matter and dark energy. The interpretation could be that the "invisible visible" matter emerges from the network of cosmic strings as part of dark energy is transformed to ordinary matter. This is TGD variant of inflationary scenario with inflaton vacuum energy replaced with cosmic strings/flux tubes carrying dark energy and matter.

This inspires more detailed speculations about pre-stellar physics according to TGD. The questions are following. What preceded the formation of stellar cores? What heated the matter to the needed temperatures? The TGD inspired proposal is that it was dark nuclear physics [L54] (see the article "Cold fusion, low energy nuclear reactions, or dark nuclear synthesis?" at `http://tinyurl.com/y7u5v7j4`). Dark nuclei with $h_{eff} = n \times h_0$ were formed first and these decayed to ordinary nuclei or dark nuclei with smaller value of $h_{eff} = n \times h_0$ and heated the matter so that ordinary nuclear fusion became possible.

Remark: h_0 is the minimal value of h_{eff}. The best guess is that ordinary Planck constant equals to $h = 6h_0$ [L42, L73] (see `http://tinyurl.com/goruuzm` and `http://tinyurl.com/y9jxyjns`.

1. The temperature of the recently detected missing baryonic matter is around 10^6 K and roughly 1/10:th of the temperature 10^7 K at solar core. This serves as a valuable guideline.

   I already earlier realized that the temperature at solar core, where fusion occurs happens to be same as the estimated temperature for the binding energy of dark nuclei identified as dark proton sequences with dark nucleon size equal to electron size. The estimate is obtained by scaling down the typical nuclear binding energy for low mass nuclei by the ratio 2^{-11} of sizes of ordinary and dark nuclear (electron/proton mass ratio, dark proton has same size as ordinary electron). This led to the idea that nuclear fusion in the solar core creates first dark nuclei, which then decay to ordinary nuclei and liberate essentially all of nuclear binding energy. After that ordinary nuclear fusion at resulting high enough temperature would take the lead.

2. Dark nuclear strings can correspond to several values of $h_{eff} = n \times h_0$ with size scale scaled up by n. p-Adic length scales $L(k) = 2^{(k-151)/2}L(151)$, $L(151) \simeq 10$ nm, define favoured values of n as integers in good approximation proportional to $2^{k/2}$. The binding energy scales for dark nuclei is inversely proportional to $1/n$ (to the inverse of the p-adic length scale). Could 10^6 K correspond to a p-adic length scale $k = 137$ - atomic length scale of 1 Angstrom?

   Could dark cold fusion start at this temperature and first give rise to "pre-nuclear" physics generating dark nuclei as dark proton sequences and with dark nuclear binding energy about . 1 keV with dark nuclei decaying to $k = 127$ dark nuclei with binding energy about 1 keV, and lead to heating of the matter and eventually to cold fusion at $k = 127$ and after than the ordinary fusion? Also the values intermediate in the range $[137, 127]$ can be considered as intermediate steps. Note that also $k = 131$ is prime.

3. Interestingly, the temperature at solar corona is about 1 million degrees and by factor 140-150 hotter than the inner solar surface. The heating of solar corona has remained a mystery and the obvious question is whether dark nuclear fusion giving rise to pre-nuclear fusion for $k = 137$ generates the energy needed.

4. If this picture makes sense, the standard views about the nuclear history of astrophysical objects stating that the nuclei in stars come from the nuclei from supernovas would change radically. Even planetary cores might be formed by a sequence of dark nuclear fusions ending with ordinary fusion and the iron in the Earth's core could be an outcome of dark nuclear fusion. The temperature at Earth's core is about 6×10^3 K. This corresponds to $k = 151$ in reasonable approximation. What is amusing that the earlier fractal analogy of Earth as cell would make sense in the sense that $k = 151$ corresponds to the p-adic length scale of cell membrane.

   I have also considered the possibility that dark nuclear fusion could have provided metabolic energy [L31, L70] for prebiotic lifeforms in underground oceans of Earth and that life came to the surface in Cambrian explosion [L76, L75]. The proposal would solve the hen-egg question which came first: metabolism or genetic code since dark proton sequences provide a realization of genetic code [L70].

5. One can imagine also a longer sequence of p-adic length scales starting at lower temperatures and longer p-adic length scales characterized by integer k for which prime values are the primary candidates. $k = 139$ corresponding to $T = .5 \times 10^6$ K is one possibility. For $k = 149$

and $k = 151$ (thicknesses for the lipid layer of the cell membrane and cell membrane) one would have $T \simeq 2\times 10^4$ K and $T \simeq 10^4$ K - roughly the temperature at the surface of Sun and biologically important energies $E = 2$ eV of red light and $E = 1$ eV of infrared light (quite recently it was found that also IR light can serve as metabolic energy in photosynthesis).

Could dark nuclear fusion process occur at the surface of the Sun? Could one image that the sequence of dark phase transitions proceeding to opposite directions as: $k = 137 \leftarrow 139 \leftarrow 149 \leftarrow 151 \rightarrow 149 \rightarrow 139 \rightarrow 137 \rightarrow 131 \rightarrow 127$ between dark nuclear physics corresponding to p-adic length scales $L(k)$ takes place as one proceeds from the surface of the Sun upwards to solar corona and downwards to the core. Of course, also other values of k can be considered: k:s in this sequence are primes: the ends of the warm-hot temperature range $10^5 - 10^6$ corresponds roughly to $k = 143 = 13 \times 11$ and $k = 137$.

There are indeed indications that Solar corona could serve as a seat of dark nucleosynthesis (see `http://tinyurl.com/y7g9sjfl`). The metallicity of stellar objects gives important information about its size, age, temperature, brightness, etc... The problem is that measurements give two widely different values for the metallicity of Sun depending on how one measures it. One obtains 1.3 per cent from the absorption lines of the radiation from Sun and 1.8 from solar seismic data. Solar neutrinos give also the latter value. What could cause the discrepancy?

Problems do not in general appear alone. There is also a second old problem: what is the origin of the heating of the solar corona. Where does the energy needed for the heating come from?

TGD proposal is based on a model, which emerged initially as a model for "cold fusion" (not really) in terms of dark nucleosynthesis, which produced dark scaled up variants of ordinary nuclei as dark proton sequences with much smaller binding energy [L54]. This can happen even in living matter: Pollack effect [L24] involving irradiation by IR light of water bounded by gel phase creates negatively charged regions from which part of protons go somewhere. They could go to magnetic flux tubes and form dark nuclei [L24]. This could explain the reported transmutations in living matter not taken seriously by academic nuclear physicists.

TGD proposal is that the protons transform to dark proton sequences at magnetic flux tubes with nonstandard value of Planck constant $h_{eff}/h_0 = n$. Dark nuclei with scaled up size. Dark nuclei can transform to ordinary nuclei by $h_{eff} \rightarrow h$ ($h = 6h_0$ is the most plausible option [L42, L73] and liberate almost all nuclear binding energy in the process. The outcome would be "cold fusion".

This leads to a vision about pre-stellar evolution. First came the dark nucleosynthesis, which heated the system and eventually led to a temperature at which the ordinary nuclear fusion started. This process could occur also outside stellar cores - say in planet interiors - and a considerable part of nuclei could be created outside star.

A good candidate for the site of dark nucleosynthesis would be solar corona. Dark nucleosynthesis could heat the corona and create metals also here. They would absorb the radiation coming from the solar core and reduce the measured metallicity to 1.3 per cent.

4. The connection of missing baryon number problem with the TGD view of evolution

The following argument relates the missing baryon problem to the TGD view of the evolution and also clarifies how the galactic dark matter differs from the dark matter as $h_{eff} \geq h$ phases (see this).

What is the problem of missing baryonic matter?

1. 1/7 of the matter of the Universe is dark matter in the sense of galactic dark matter. The identification of the dark matter is still a mystery. LambdaCDM people have decided dark matter to be some exotic particles forming halos around galaxies. MOND people have decided that Newtonian gravity is modified for weak fields.
2. Besides this 30 per cent of the ordinary matter, baryons, seems to be missing. This is known as the missing baryon problem (see this).

The prosaic explanation for the puzzle is that with the available technology we are not able to detect the missing part of ordinary matter and it has been argued that the missing baryonic matter can be assigned with long filamentary structures. This explanation might be correct.

What could one say about the missing baryonic matter in this framework? I have considered this question in more detail earlier [L54], and the following general comment explains why ordinary baryons should transform to dark ones during the cosmic evolution.

1. In the TGD Universe, the radiation dominated phase was preceded by cosmic string dominance. They would have decayed to ordinary matter like inflaton fields and led to the radiation dominated Universe.
2. The galactic dark matter could be actually dark energy assignable with long cosmic strings with a gigantic string tension. Monopole flux would make them stable. This dark energy would decay to ordinary matter since the cosmic strings are unstable against thickening and generation of flux tube tangles giving rise to ordinary galaxies.

   This process would be the TGD counterpart of inflation: inflaton fields would be replaced by cosmic strings. This view predicts the flat velocity spectra of galaxies using only string tension as a parameter and makes a long list of predictions allowing us to understand the anomalies of LambdaCDM and MOND.
3. TGD predicts also matter behaving like dark matter. This analog of dark matter is identifiable as $h_{eff} \geq h$ phases of THE ordinary matter and could contribute to the missing baryonic matter. I have used to talk about dark matter but this matter need not be galactic dark matter, which could be mostly dark energy for cosmic strings. The dark phases can have arbitrarily long quantum coherence scales and they play a fundamental role in living matter as controllers of the ordinary matter. In TGD inspired biology dark protons identified as this kind of phase at monopole flux tubes play an essential role.

What could one say about the missing baryonic matter in this framework?

1. Could the missing ordinary matter correspond to $h_{eff} \geq h$ phases of the ordinary matter? The intuitive view is that the density of dark protons is much smaller than the number of ordinary protons. Could this be true only in the regions containing high density of ordinary matter. Could the fraction of ordinary protons be much larger than that of dark protons only in the regions where the visible matter is concentrated.
2. Why would ordinary nucleons transform to dark nucleons? Evolution means the increase of complexity. In the TGD Universe this means the increase of h_{eff}, which corresponds to a dimension of algebraic extension of rationals characterizing polynomials which at the fundamental level characterize space-time regions. Number theoretic evolution would transform the ordinary matter to dark matter as h$_{eff} > hphasesresidingatthemonopolefluxtubes.Could30percentofordinary$

5.6.4 "Fusion fiasco" and "Lost history" from TGD perspective

In the following the second and third volume of "*Explorations in Nuclear Research*" of Krivit are discussed from TGD point of view. The intention is to use the information provided by these books in order to refine the model for dark nucleosynthesis.

Summary of the model of dark nucleosynthesis model

Before continuing it is good to recall first the basic ideas behind dark nucleosynthesis.

1. Dark nuclei are produced as dark proton sequences at magnetic flux tubes with distance between dark protons with $h_{eff}/h = 2^{11}$ (approximately proton/electron mass ratio) very near to electron Compton length. This makes possible formation of at least light elements when dark nuclei transform to ordinary ones and liberate almost entire nuclear binding energy.
2. Also more complex nuclei can form as nuclei of nuclei from ordinary nuclei and sequences of dark protons are at magnetic flux tubes. In particular, the basic rule $(A, Z) \rightarrow (A+1, Z+1)$ of Widom-Larsen model is satisfied although dark beta decays would break this rule.

   In this case the transformation to ordinary nuclei produces heavier nuclei, even those heavier than Fe. This mechanism could make possible the production of heavy nuclei outside stellar interiors. Also dark beta decays can be considered. They would be fast: the idea is that the Compton length of weak bosons is scaled up and within the region of size scale of Compton length weak interactions have essentially the same strength as electromagnetic interactions so that weak decays are fast and led to dark isotopes stable against weak interactions.
3. The transformation of dark nuclei to ordinary nuclei liberates almost all nuclear binding energy. This energy could induce the fission of the daughter nucleus and emission of neurons causing the decay of ordinary nuclei, at least those heavier than Fe.

$Element$	^4He	^3He	T	D
E_B/MeV	28.28	7.72	8.48	2.57
$\Delta E/MeV$	25.70	6.412	5.8	1.27

Table 5.1: The ordinary nuclear binding energies E_B for light nuclei and the energies ΔE liberated in dark $\rightarrow$ ordinary transition.

4. Also the dark weak process $e^- + p \rightarrow n + \nu$ liberating energy of order electron mass could kick out neutron from dark nucleus. This process would be TGD counterpart for the corresponding process in WL but having very different physical interpretation. This mechanism could explain production of neutrons which is by about 8 orders slower than in cold fusion model.

5. The magnetic flux tubes containing dark nuclei form a positively charged system attracted by negatively charged surfaces. The cathode is where the electrons usually flow to. The electrons can generate negative surface charge, which attracts the flux tubes so that flux tubes end up to the cathode surface and dark ions can enter to the surface. Also ordinary nuclei from the cathode could enter temporarily to the flux tube so that more complex dark nuclei consisting of dark protons and nuclei are formed. Dark nuclei can also leak out of the system if the flux tube ends to some negatively charged surface other than cathode.

The findings described in the two books, in particular the production of neutrons and tritium, allow to sharpen the view about dark nucleosynthesis.

1. The simplest view about dark nucleosynthesis is as a formation of dark proton sequences in which some dark protons transform by beta decay (emission of positron) to neutrons. The objection is that this decay is kinematically forbidden if the masses of dark proton and neutron are same as those of ordinary proton and neutron (n-p mass difference is 1.3 MeV). Only dark proton sequences would be stable.

   Situation changes if also n-p mass difference scales by factor 2^{-11}. The spectra of dark and ordinary nuclei would be essentially identical. For scaled down n-p mass difference, neutrons would be produced most naturally in the process $e^- + p \rightarrow n + \nu$ for dark nuclei proceeding via dark weak interactions. The dark neutron would receive a large recoil energy about $m_e \simeq .5$ MeV and dark nucleus would decay. The electrons inducing the neutron emission could come from the negatively charged surface of cathode after the flux tube has attached to it. The rate for $e^- + p \rightarrow n + \nu$ is very law for ordinary weak Planck constant. The ratio $n/T \sim 10^{-8}$ allows to deduce information about h_{eff}/h: a good guess is that dark weak process is in question.

2. Tritium and other isotopes would be produced as several magnetic flux tubes connect to a negatively charged hot spot of cathode. A reasonable assumption is that the ordinary binding energy gives rise to an excited state of the ordinary nucleus. This can induce the fission of the final state nucleus and also neutrons can be produced. Also scaled down variants of pions can be emitted, in particular the pion with mass of 17 MeV [L50].

3. The ordinary nuclear binding energy minus the n-p mass difference 1.3 MeV multiplied by the number of neutrons would be released in the transformation of dark nuclei to ordinary ones. The table 5.1 gives the total binding energies and liberated energies for some lightest stable nuclei.

   Gamma rays are not wanted in the final state. For instance, for the transformation of dark ^{4}He to ordinary one, the liberated energy would be about 25.7 MeV. If the final state nucleus is in excited state unstable against fission, the binding energy can go to the kinetic energy of the final state and not gamma ray pairs are observed. If two 17 MeV pions π_{113} are emitted the other one or both must be on mass shell and decay weakly. The decay of off-mass π_{113} could however proceed via dark weak interactions and be fast so that the rate for this process could be considerably faster than for the emission of two gamma rays.

Fusion fiasco from TGD perspective

The second volume of the book "*Explorations in Nuclear Research*" of Krivit is titled (see `http://tinyurl.com/y7tsoweh`). The book gives a very detailed view about what happened during the first years after the discovery of Pons of Fleischman of energy production in electrolysis (in 1989) not understandable in terms of chemistry. Their interpretation was as cold fusion was definitely wrong and gave an excellent weapon for those wanting to label them as crackpots.

From TGD point of view especially interesting observations related to the observations of Indian and Italian research group made immediately after the announcement of the results of Pons and Fleischman. The observations of Indian groups working in Babbha Atomic Research Center (BARC) were led by Mahadeva Shrinivasan and Padmanabha Krisnagopala Iyengar. Yengar was the director BARC and Shrinivasa the director of the physics group working in BARC. The three leading researchers in Italian ENEA-Frascati experiment were Fransesco Scaramuzzi, Antonella De Ninno and Antonio Frattolillo.

The results of both experiments were rather similar and I will summarize in the following only the findings of Indians. Tritium and neutron production were detected by 6 independent groups. The basic prediction of D+D fusion model is that equal amounts of neutrons and tritium nuclei should be produced in D+D→ n+T process occurring besides D+D $\rightarrow$ ^{4}He. These groups tested this hypothesis and found that the n/T ratio is small: in the range $(10^{-9}, 10^{-8})$ in BARC experiments so that D+D fusion hypothesis cannot be correct. What is however remarkable is that neutrons were produced and one should understand this also in TGD framework.

Milton-Roy electrolytic cell consisting of 16 Pd-Ag alloy membrane tubes with total area of 300 cm^2 was used. For instance, 30 amp current rising gradually to 60 amp was used in one of the runs using Pd as host metal. Also experiments replacing Pd with Ti as a host metal were performed. Three types of neutron detectors were used to detect cold, thermal, and high energy neutrons: BF_3 detector was used for cold neutrons, ^3He detector for thermal neutrons, and scintillation counter for high energy neutrons. Comparison with the neutron background was performed. All counters detected the neutrons simultaneously.

What was found was following.

1. During 4-hour run 4×10^7 neutrons were observed: this is considerably above background. n/T ratio was in the range $10^{-6} - 10^{-9}$ and its average was 10^{-7}. This does not conform with the D+D fusion model.
2. Two groups at BARC observed n and T bursts with 10-20 neutrons in single burst. Neutron and tritium bursts were strongly correlated suggesting that some kind of chain reaction was involved. Bursts occurred only in the first day, after few hours of charging. After that the emission of neutrons stopped.
3. The interpretation was as surface phenomenon occurring only at hot spots whereas Pons and Fleischman assumed that the process occurs in the entire cathode.

What could be the TGD interpretation?

The simplest version of dark nucleosynthesis assumes only the formation of dark proton sequences.

1. The resulting dark nuclear strings suffered dark beta decays leading to the counterparts of ordinary nuclei. These transformed to ordinary nuclei and the ordinary nuclear binding energy was liberated. The transformation to ordinary nucleus in excited state suffering fission or emitting gamma ray pair (at least) are the most plausible decay channels. Fission channel is the faster one. This could explain the production of neutrons and the low n/T branching ratio.
2. One can also consider a formation of dark nuclei containing besides dark protons also ordinary nuclei: nuclear string consisting of nuclei would be in question.
3. Dark nuclear fusion does not look so plausible option.
   (a) Could a dark version p-p cycle assumed to produce ^4He in stars like Sun be involved? This process involves several steps. p+p gives rise D and positron+ neutrino. D and p fuse to ^{3}He liberating energy. Final step would be ^{3}He+ ^{3}He $\rightarrow$ ^{4}He + p+p. Could these steps could take for dark nuclei so that scale of liberated energy would be by factor 2^{-11} smaller than for ordinary nuclear process.

(b) Also D+D, D+T, and D+^{3}He fusions could occur

- D+D $\rightarrow$ ^{4}He
- D+D $\rightarrow$ ^{3}He + n
- D+D $\rightarrow$ T + p
- D+ T $\rightarrow$ ^{4}He + n
- D+^{3}He $\rightarrow$ ^{4}He + p

D+D produces ^3He +n or T + p. D+T to produces $^4He + n$. It would seem that the number of neutrons should be larger than the number of T. This prediction does not conform with the small n/T branching fraction. These reactions could of course take place but their contribution should be rather small as compared to that assignable to the transformation of dark nuclei to ordinary ones.

Can one understand the other observations in TGD framework?

1. The production of tritium and neutrons seems to occur in hot spots at the surface of the cathode and only during the initial stages of the experiment. Hot spots could correspond to negatively charge pieces of the cathode surfaces. The negatively charged cathode surface attracts the magnetic flux tubes. As positive charge flows to the surface, the density of electrons at the surface is weakened and the process ceases to occur.
2. Neutrons were produced as bursts, say 10-20 neutrons. The decays of dark nuclei could explain these bursts but several flux tubes are required sin single flux tube is expected to produce only few neutrons. The total number of flux tubes is expected to be proportional to the area of hot spots.

The lost history from TGD perspective

The third volume in "*Explorations in Nuclear Research*" [C145] is about lost history: roughly the period 1910-1930 during which there was not yet any sharp distinction between chemistry and nuclear physics. After 1930 the experimentation became active using radioactive sources and particle accelerators making possible nuclear reactions. The lost history suggests that the methods used determine to unexpected degree what findings are accepted as real. After 1940 the hot fusion as possible manner to liberate nuclear energy became a topic of study but we are still waiting the commercial applications.

One can say that the findings about nuclear transmutations during period 1912-1927 became lost history although most of these findings were published in highly respected journals and received also media attention. Interested reader can find in the book detailed stories about persons involved. This allows also to peek to the kitchen side of science and to realize that the written history can contain surprising misidentifications of the milestones in the history of science. Author discusses in detail an example about this: Rutherford is generally regarded as tje discover of the first nuclear transmutation but even Rutherford himself did not make this claim.

It is interesting to look what the vision about the anomalous nuclear effects based on dark nucleosynthesis can say about the lost history and whether these findings can provide new information to tighten up the TGD based model, which is only qualitative. Therefore I go through the list given in the beginning of book from the perspective of dark nucleosynthesis.

1. Production of noble gases and tritium

During period 1912-1914 several independent scientists discovered the production of noble gases ^{4}He, neon (Ne), and argon (Ar) using high voltage electrical discharges in vacuum or r through hydrogen gas at low pressures in cathode-ray tubes. Also an unidentified element with mass number 3 was discovered. It was later identified as tritium. Two of the researchers were Nobel laureates. 1922 two researchers in University of Chicago reported production of ^{4}He. Sir Joseph John Thomson explained the production of ^{4}He using occlusion hypothesis. In understand occlusion as a contamination of ^{4}He to the tungsten wire. The question is why not also hydrogen.

Why noble gases would have been produced? It is known that noble gases tend to stay near surfaces. In one experiment it was found that ^4He production stopped after few days, maybe kind of saturation was achieved. This suggests that isotopes with relatively high mass numbers were produced from dark proton sequences (possibly containing also neutrons resulting in the dark

Element	*W*	*Pt*	*Au*	*Hg*	*Tl*	Pb
(Z,A)	(74,186)	(78,195)	(79,197)	(80,202)	(81,205)	(82,208)

Table 5.2: The nuclear charge and mass number (Z,A) for the most abundant isotopes of W, Pt, Au,Hg, Tl and Pb.

weak decays). The resulting noble gases were caught near the electrodes and therefore only their production was observed.

2. Production of ^4He in experiments of Wendle and Irion

In 1922 Wendle and Irion published results from the study of exploding current wires. Their arrangement involved high voltage of about 3×10^4 V and di-electric breakdown through air gap between the electrodes producing sudden current peak in a current wire made of tungsten (W with $(Z,A) = (74,186)$ for the most abundant isotope) at temperature about $T = 2 \times 10^4$ C, which corresponds to a thermal energy $3kT/2$ of about 3 eV. Production of ^{4}He was detected.

Remark: The temperature at solar core is about 1.5×10^7 K corresponding to energy about 2.25 keV and 3 orders of magnitude higher than the temperature used.

The interpretation of the experimentalists was that the observed ^{4}He was from the decay of tungsten in the hot temperature making it unstable. This explanation is of course not consistent with what we known at about nuclear physics. No error in the experimental procedure was found. Three trials to replicate the experiment of Wendle and Irion were made with a negative result. The book discusses these attempts in detail and demonstrates that they were not faithful to the original experimental arrangement.

Rutherford explained the production of ^{4}He in terms of ^{4}He occlusion hypothesis of Thomson. In the explosion the ^{4}He contaminate would have liberated. But why just helium contamination, why not hydrogen? By above argument one could argue that ^4He as noble gas could indeed form stable contaminates.

80 yeas later Urutskoev repeated the experiment with exploding wires and observed besides ^{4}He also other isotopes. The experiments of Urutskoev [H9] demonstrated that there are 4 peaks for the production rate of elements as function of atomic number Z. Furthermore, the amount of mass assignable to the transmuted elements is nearly the mass lost from the cathode. Hence also cathode nuclei should end up to flux tubes.

How dark nucleosynthesis could explain the findings? The simplest model relies on a modification of the occlusion hypothesis: a hydrogen contaminate was present and the formation of dark nuclei from the protons of hydrogen at flux tubes took place in the exploding wire. The nuclei of noble gases tended to remain in the system and ^{4}He was observed.

3. Production of Au and Pt in arc discharges in Mercury vapor

In 1924 German chemist Miethe, better known as the discoverer of 3-color photography found trace amount of Gold (Au) and possibly Platinum (Pt) in Mercury (Hg) vapor photography lamp. Scientists in Amsterdam repeated the experiment but using lead (Pb) instead of Hg and observed production of Hg and Thallium (Tl). The same year a prominent Japanese scientist Nagaoka reported production of Au and something having the appearance of Pt. Nagaoka used a an electric arc discharge between tungsten (W) electrodes bathed in dielectric liquid "laced" with liquid Hg.

The nuclear charges and atomic weights for isotopes involved are given in table 5.2 .

Could dark nucleosynthesis explain the observations? Two mechanisms for producing heavier nuclei relying one the formation of dark nuclei from the nuclei of the electrode metal and dark protons and their subsequent transformation to ordinary nuclei.

1. Dark nuclei are formed from the metal associated with cathode and dark protons. In Nagaoka's experiment this metal is W with $(Z,A) = (74,186)$. Assuming that also dark beta decays are possible this would lead to the generation of heavier beta stable elements Au with $(Z,A) = (79,197)$ or their stable isotopes. Unfortunately, I could not find what the electrode metal used in the experiments of Miethe was.

2. In the experiments of Miethe the nuclei of Hg transmuted to Au $((80,202) \rightarrow (79,197))$ and to Pt $((80,202) \rightarrow (78,195))$. In Amsterdam experiment of Pb transmuted to Hg $((82,208) \rightarrow (80,202))$ and Tl $((82,208) \rightarrow (81,205))$. This suggests that the nuclei resulted in the decay of Hg (Pb) induced by the nuclear binding energy liberated in the transformation of dark nuclei formed from the nuclei of cathode metal and dark protons to ordinary nuclei. Part of the liberated binding energy could have induced the fission of the dark nuclei. The decay of dark nuclei could have also liberated neutrons absorbed by the Hg (Pb) nuclei and inducing the decay to lighter nuclei. Thus also the analog of r-process could have been present.

4. Paneth and Peters' H→ ^4He transmutation

In 1926 German chemists Paneth and Peters pumped hydrogen gas into a chamber with finely divided palladium powder and reported the transmutation of hydrogen to helium. This experiment resembles the "cold fusion" experiment of Pons and Fleischman in 1989. The explanation would be the formation of dark ^4He nuclei consisting of dark protons and transformation to ordinary ^4He nuclei.

5.6.5 Appendix: Could dark protons and electrons be involved with di-electric breakdown in gases and conduction in electrolytes?

I have had long time the intuitive feeling that electrolytes are not really understood in standard chemistry and physics and I have expressed this feeling in the TGD model of "cold fusion" [L54]. This kind of feeling of course induces immediate horror reaction turning stomach around. Not a single scientist in the world seems to be challenging the age-old chemical wisdom. Who am I to do this? Perhaps I really am the miserable crackpot that colleagues have for four decades told me to be. Do I realize only at the high age of 68 that my wise colleagues have have been right all the time?

The question of my friend related to di-electric breakdown in gases led me to consider this problem more precisely. I will first consider di-electric breakdown and then ionic conduction in electrolytes from TGD point of view to see whether the hypothesis stating that dark matter consists of phases of ordinary matter with non-standard Planck constant $h_{eff} = nh_0$ [?] following from adelic physics [L64, L63] could provide concrete insights to these phenomena.

Ionization in di-electric breakdown

One can start from a model for the dielectric breakdown of gas (see `http://tinyurl.com/y9v9bkay`). The basic idea is that negatively charged cathode emits electrons by tunnelling in electric field and these accelerate in the electric field and ionize atoms provided they travel a distance longer than the free path $l = 1/n\sigma$ before collision. Here n is number density of atoms and σ collision cross section, in geometric approximation the cross sectional area of gas atom. This implies a lower bound on the number density n of gas atoms. On the other hand, too low density makes also ionizations rare.

The positive ions in turn are absorbed by cathode and more electrons are liberated. In gas dielectric breakdown results if the field strength is above critical value E_{cr}. For air this one has $E_{cr} = 3$ kV/mm.

1. Cathode with a sharp tip liberates electrons. The electric field near the tip is very strong an in a reasonable approximation has strength

$$E = \frac{V}{r} \ , \tag{5.6.1}$$

where r is radius of curvature of the tip and V is the voltage with respect to earth. If r is small enough, electron is able to tunnel from the metal.

2. The tunnelling current from electron can be deduced from a simple model based on Scrödinger equation in one-dimensional potential having the form $U(x) = -\Phi_w + \frac{Vx}{r}$ in the non-allowed region. One assumes that one can describe the electron using analog of plane

wave $exp(ikx)$ with kx replaced with $\int_0^x k(x)dx = i\int_0^x p(x)dx/\hbar$ with imaginary momentum $p(x) = i\sqrt{2m|E-U(x)|}$ in the non-allowed region. Tunnelling current is proportional to the exponential factor

$$R = exp(i\int k(x)dx) \tag{5.6.2}$$

having interpretation as tunneling probability.

3. Tunneling rate is highest near Fermi energy and at this energy the tunnelling rate is

$$R = exp(-8\pi\frac{\sqrt{2m\Phi_w^3}}{3hE}) \ . \tag{5.6.3}$$

Here m is electron's mass and Φ_w is work function of the metal telling the height of the potential well in which electron resides. In the model of photo-electric effect the energy of photon needed to kick out electron from metal must be above Φ_w. The exponential factor approaches extremely rapidly but for small enough curvature radii and it can be sufficiently near to unity.

Remark: Imaginary momentum does not make sense in classical mechanics. What is interesting that in classical TGD the classical conserved quantities are in general complex numbers and the analogs of virtual particles are on mass shell states with complex moments as also in twistor Grassmannian approach having 8-D generalization in TGD framework. Could tunnelling have classical space-time description in TGD framework?

4. The electric field needed in the tip cannot be much larger than

$$E_{max} = \frac{V}{r} \sim 8\pi\frac{\sqrt{2m\Phi_w^3}}{3h} \tag{5.6.4}$$

to guarantee that the exponent is not too small. If one has $h \rightarrow h_{eff} = n \times h_0 > h$ ($h = 6h_0$ is a good guess [L42, L73]) tunnelling rate increases. This effect might serve as a signature for large value of h_{eff} [L60]. Tunnelling would be to magnetic flux tubes carrying dark electrons.

What is needed is di-electric breakdown in a way already described.

1. Electrons ionize atoms and the resulting electrons cause more ionizations. Also the positive ions collide with cathode and generate new electrons. A continual discharge, arc generation, would be the outcome.

   A rough criterion for ionization is that the free path $l = 1/n\sigma$ of electron is so large that the electron gains so large energy in the electric field E that it exceeds ionization energy. The condition is $El \geq E_I$. Small density increases l but also decreases the number of collisions so that there is some optimal density and pressure for the di-electric breakdown to occur. If electrons are dark they can travel along flux tubes, which would increase the free path in electric field and increase the rate of ionization.

2. The generation of arc is described by Paschen's law giving the breakdown voltage and discovered 1989 empirically by Paschen (see `http://tinyurl.com/heezy8f`).

Do we really understand ionic conduction in electrolytes?

One must now explain why ions can act as charged carriers in relatively weak electric fields. Concerning the production of electrons at electrode the situation remains the same. In electrolyte however the free path is much shorter than in gas since the density n is orders of magnitude higher. Therefore the ionization mechanism in electrolytes must be different - at least in standard physics framework. One can of course ask whether the large value of h_{eff} might help both in the generation of dark electron at cathode and also help to increase the free path of electron so that they gain higher energy in the electric field of electrolyte typically much lower that in dielectric breakdown.

The mechanism for the dissolution of ions in water involves neither electrodes nor electric field. The ionization of NaCl in water serves as a good example.

1. Na and Cl in NaCl are already ionized since ionic bond is in question. In dissolution giving rise to Na^+ and Cl^- ions NaCl ionizes into Na^+ and Cl^- in water. The sizes of ions vary in the range .2- 2 Angstrom. The explanation is that the presence of polar water molecules of size about 3 Angstrom of which some have ionized to OH^- and H^+ leads to a competition and the presence of OH^- and H^+ breaks ionic NaCl bonds and dissolves NaCl. Approximating the situation as one-dimensional would suggest that NaCl corresponds to a potential well for e^2/r potential. From the distance r between Na and Cl one obtains an estimate for the Coulomb potential energy depending on distance. For $r = 2$ Angstrom it is about 50 eV and therefore rather high.

2. The presence of OH^- or H^+ means second potential well. The Coulomb potentials of say Cl^- and OH^- acting on H^+ sum up and double potential well is created. In the original situation Na^+ is the potential well of Cl^-. The closer the Cl^- and OH^- (or H^+ and Na^+ ions are, the lower the barrier between the two wells is and the higher the tunnelling probability for Na^+ from the potential well of Cl^- to that of OH^- is. This can make possible tunnelling of Na^+/Cl^- with subsequent formation of ionic bound state NaOH/HCl.

   The tunnelling probability is also now an exponential analogous to that appearing in the previous formula and proportional to $1/h$. Ions must however get so close that the potential barrier is low enough. The rate for close encounters must be therefore high enough.

   Is this really the case or could h_{eff} come in rescue? Could the dark protons H^+ with $h_{eff} = n \times h$ at magnetic flux tubes possibly formed in the ionization of water molecules to OH^- and H^+ play some role. Could also dark valence electrons assignable to OH play a role. Could one think that dark H^+ and e^- of H_2O can reside at long flux tubes assignable to H_2O so that H_2O would look like $OH^- + H^+$. As a matter fact, a more realistic model replaces flux tubes with flux tube pairs since there are reasons to assume that the flux tubes carry monopole flux and they must form closed units [L60]. Flux tube pairs are also central for the TGD based model of high Tc superconductivity [K85, K86].

   Same would apply to HCl and NaOH. This leads to several variants of these molecules in which proton or electron or both are dark and resides at long flux tube. External electric field could induce lengthening of this flux flux tube pairs or at least the motion of dark proton and electron along it. These molecules would look like having long charged tentacles formed by flux tube pairs parallel or antiparallel to the direction of electric field. Electric field would force the charged flux tube pair to move so that it would point to the direction to which charged particle moves in the field.

3. According to standard physics this process generates only different ionic bound states HCl and NaOH are formed from NaCl and H_2O and vice versa. One does not obtain Na^+ and Cl^- serving as charge carriers. How could the presence of the relatively weak electric field in electrolyte make possible electric currents if there are no charge carriers?

4. Are HCl and NaOH in water really what they would be in gas? Could HCl in water be a bound state of H^+ and Cl^- such that H^+ has a large value of h_{eff}. Could also Cl^- be Cl for which electron could be dark electron at flux tube? This would make the size of HCl much larger than in gas and the ions involved look like free charge carriers in much longer scale. Could same apply also to NaOH, NaCl ad H_2O.

   Could the fundamental current carriers be dark protons and dark electrons at dark flux tubes pairs? Consider a long tentacle formed by a long flux tube pair carrying dark proton or electron with the direction of flux tube pair determined by the sign of the electric force on the charge. This tentacle could reconnect with a neutral tentacle and the charge would be transferred to the latter. This flux tube pair would be in turn driven by by the field perhaps also inducing the increase of h_{eff} (requiring energy provided by the field) and therefore flux tube length so that it points to the same direction as the original long tentacle. The outcome would be conduction based on the hopping of protons and electrons over a distance of the order of tentacle length. This hopping mechanism could serve as a universal mechanism of conduction in electrolytes and also in living matter.

Chapter 6

Could TGD provide new solutions to the energy problem?

6.1 Introduction

The city of Helsinki has posed an ambitious goal to be carbon neutral before year 2035. The role of Helsinki could be therefore decisive in the fight agains climate crisis. More than half of the population of the world lives in towns and more than 2/3 of the energy is consumed by cities and are responsible for more than 70 per cent of the carbon oxide emission of the world. About 56 per cent of the carbon oxide emissions of Helsinki are due to the heating. Finding of a sustainable heating method has a decisive effect on the total amount of carbon oxide emissions of Helsinki.

Concerning heat production Helsinki is searching for new kind of thinking and internal collaboration. The goal is to search for the solutions to energy problems even in the world scale. Therefore Helsinki city as challenged innovators and the specialist of the field to sustained solutions to the production of energy in a competition. The competition "Helsinki Energy Challenge" opened February 27 2020 is international.

6.1.1 Could artificial photosynthesis or nuclear energy be a solution to the energy problem?

The requirement of carbon neutrality leaves allows renewable energy sources, energy efficiency, and concentration of pure low carbon technologies (`http://tinyurl.com/te8uhl7`). The understanding of photosynthesis could make possible to mimic it technologically and is is a promising approach. Nuclear energy is another alternative despite its problems.

The options related to nuclear energy

There are three options related to nuclear power.

1. At this moment the power plants use fission of heavy nuclei, which liberates energy because the nuclear binding energy per nucleon decreases as the mass number of the nucleus increases.

   The problem is that one obtains as a waste long-lived isotopes which are unstable against decay and produce radiation, which is dangerous for health. The storage of the waste is a problem. Furthermore, the temperature needed in fission reactors is of the same order of magnitude as in the solar core and causes serious problems in the control of fission as also the Fukushima accident demonstrated.

   Small scale fission power planets are not so dangers and work is done to develop applications in which nuclear power would be produced in small scale.

2. Second option is fusion of light nuclei, which liberates energy for nuclei lighter than iron (Fe). Also the temperature prevailing in the solar core is needed. Now the problem is plasma confinement. Magnetic bottle is the basic solution but it has instabilities: for instance magnetic bottle tends to develop a pinch. Fusion plants still do not exist despite the research which has lasted more than seven decades (`https://en.wikipedia.org/wiki/Fusion_power`).

3. The third option is non-orthodox and would be based on "cold fusion" (CF), which was reported already 1920 and 1989 by Pons ja Fleischman. Mainstream physics has had a hostile attitude to CF as becomes clear from the ultra-skeptic Wikipedia article http://tinyurl.com/8lkm6eq) but gradually the attitude has changed and CF researchers are taken seriously.

   On basis of recent understanding one can say that CF is not a proper term. Ordinary fusion cannot be in question already because it is not possible at low temperatures and because the distributions of heavier isotopes do not correspond to those assignable to ordinary fusion. Low energy nuclear reactions (LENR) or nuclear transmutations are slightly better terms. In the sequel I will use the term CF keeping however in mind that the term is only a convention.

   The book about the history of CF written by Krivit and having 3 parts [C144, C143, C145] (http://stevenbkrivit.com ,http://tinyurl.com/y7tsoweh, http://tinyurl.com/rcfokn5) provides a good overview about the situation.

To my opinion the basic problem of CF research is that theoretical understanding is missing so that the attempts to develop a technology are like searching a needle in haystack. Of course, the hostile attitude of the mainstream is second problem. The situation is not made easier by two optimistic promises in order to get funding and the underrating of theoretical understanding. Part of the problem is that the goal is to produce energy although at this stage the main emphasis should be on the understanding of the phenomenon.

Could TGD have something to give?

My own goal has been to develop theoretical understanding about CF and also about nuclear physics on basis of the new physics predicted by Topological Geometrodynamics (TGD) [K123] (http://tinyurl.com/zrx5mdz, http://www.tgdtheory.fi/tgdarticlesall.html), which can be can be regarded as my lifework hitherto. In the sequel I try to summarize this work in hope that it could help to invent the desired new technology.

The following gies a very brief summary about tGD.

1. TGD leads to an identification of dark matter as phases of ordinary matter with non-standard value $h_{eff} = n \times h_0$ of effective Planck constant, which make possible quantum coherence in arbitrarily long length scales proportional to h_{eff}. The hypothesis follows from a generalization of physics to describe correlates of cognition: number theory becomes an essental part of quantum physics [L63, L64].

2. This leads to a model of quantum biology [L77]. The coherence of living matter is the basic problem of biology: biochemistry cannot explain it. The basic problem of standard quantum biology is in turn the smallness of the ordinary Planck constant h - it is very difficult to understand the coherence of living matter as macroscopic quantum coherence. TGD would solve this problem: dark matter with genuine quantum coherence in long scales would induce coherence of ordinary matter (not quantum coherence anymore).

   Dark matter in TGD sense would provide also a starting point for the attempts to understand photosynthesis, which is now believed to involve quantum physics in an essential way. The mimicry of the photosynthesis at the level of technology would be an alternative new energy technology.

3. Dark nuclei would be in central role in the proposed model of CF [K24], which would reduce to the production of dark nuclei by feeding to the system energy increasing the value of h_{eff}. Dark nuclei for which the binding energies of basic build blocks would be very small, would decay to ordinary nuclei and liberate energy as in ordinary nuclear fusion. The key question considered is of course what dark nuclei precisely are.

   This leads also to a proposal for a theory of nuclear physics, which could replace the nuclear models, which typically explain only some aspects of nuclear physics. The birth of dark nuclei in the collisions of nuclei would replace the tunnelling phenomenon, which reduces the value of energy above which the nuclear reactions can take place from its classical estimate by factor of order 1/100. Because the energy of dark states increases with h_{eff}, this would require high collision energy and high temperature in hot fusion.

4. In CF the production of dark nuclei would require only a relatively small energy because the building bricks of dark nuclei would be free protons, deuterons, perhaps even heavier nuclei

for which one would not do anything. They would form dark nuclei as string like entities assignable to flux tubes and the binding energy for the interaction between basic building bricks would be much smaller than that in ordinary nuclei and assignable to flux tube bonds between them. The increase of h_{eff} to produce dark nuclei from - say - deuterons would require only a small energy because the binding energy of dark nucleus would reduce the needed energy. For instance, laser beam could be enough as the researchers like Holmlid indeed claim [L48].

After this the dark nuclei could transform spontaneously to ordinary nuclei in the transition $h_{eff} \rightarrow h = 6h_0$ and liberate energy which is of the same order of magnitude as the binding energy of ordinary nuclei. Dark nuclei can also react - as in ordinary hot fusion - before the transformation to ordinary nuclei.

One can say, that in CF one goes to the edge of the energy cliff and jumps down. In hot fusion one jumps from the bottom to te edge and then jumps down.

5. The basic mechanism of CF and also ordinary fusion would be rely on quantum coherence provided by large h_{eff}; the notion of magnetic flux tube; quantum criticality (QC) of TGD Universe making possible flux tube contacts of small energy between reactants with various lengths as analog of long range fluctuations (this would break the limitation due to the short range of nuclear forces and Coulomb wall); the breaking of QC induced by increase of length scale dependent cosmological constant Λ for flux tubes predicted by twistor lift of TGD [L65] increasing their string tension so that the resulting force attracts reactants together and allows to overcome the Coulomb wall so that reaction can proceed: the shortening of flux tube would however involved temporary reduction of h_{eff}.

   The energy to increase Λ and string tension for the flux tube energy would come from reactant: essentially analog of metabolic energy provided by reactants would be in question. The mechanism is basically the same as in bio-catalysis [L77], where the energy wall hindering the reactions corresponds to Coulomb wall.

Energy production would not be the only application of CF. Modern technology needs various elements such as metals and there is a shortage of these. CF might allow to produce these elements in industrial scale. Also in quantum biology dark matter and dark nuclei - albeit in different scale as compared to CF - are in central role (`http://tinyurl.com/yyyk6fu8`), and might provide a theoretical basis for developing artificial photosynthesis.

Monochromatic lines around .5 MeV and 3.5-keV X rays have no standard identification. The recent findings [E10] exclude the possibility that these particles reside in the conjectured galactic dark matter halo. The detailed consideration of these findings led to an unexpected further progress in TGD based vision about nuclear physics developed in the first version of this article. A correct prediction for the energy of 3.5 eV line emerges and also the .5 MeV line is predicted correctly in terms of TGD based nuclear physics.

CVC and PCAC hypothesis, $M^8 - H$ duality, and p-adic length scale hypothesis support the view that hadron and nuclear physics could allow a description dual to QCD like picture in terms scaled down weak interaction physics. This picture finds concrete quantitative support. Several p-adic length scales would be involved and the active scale would depend on interaction energy. In particular, a pseudoscalar having interpretation as X boson with mass about 17 MeV is also predicted.

6.2 Short summary about the history of CF and about its problems

In the sequel short summary about the history of CF is given and also objections against are discussed.

6.2.1 About the history of CF

Krivit has written a book with three parts about CF [C144, C143, C145] (`http://stevenbkrivit.com` ,`http://tinyurl.com/y7tsoweh`, `http://tinyurl.com/rcfokn5`). The book gives a good overall view about a good overall view about the history of CF. I have written an article about the book in [L54] (http://tinyurl.com/y7u5v7j4). I have considered CF also from a wider perspective [K24] (http://tinyurl.com/y2v3qn6a.

CF (http://tinyurl.com/8lkm6eq) has been discovered several times during the previous century.

1. Thomas Graham observed the ability of Pd to absorb hydrogen already at 18th century. 1920 Paneth and Peters reported transmutation of hydrogen to helium as it was absorbed in a thin Pd at room temperature. Later they however ended up to the conclusion that ^{4}He was due to the background in the air.

2. 1927 Tandberg reported fusion of of hydrogen to He in electrolysis using Pd electrolyte and applied for a patent: patent application was rejected since Paneth and Peters had concluded that fusion is not in question. Tandberg did also experiments with heavy water after the discovery of deuterium (D) in 1932, and the experimental arrangement was similar to that used by Fleischman ja Pons, who were not aware of these experiments.

3. Fleischman ja Pons reported CF in 1989. The observations raised a wide interest but the negative attitude of nuclear physicists killed the interest although a small group of researchers continued to study the phenomenon.

   Fleischman ja Pons used Pd as elektrode ja heavy water as electrolyte. The experiments lasted for weeks. The temperature used was 30 ◦C. In the beginning of the run the output power as given by calorimeter was same as the input power. At some stage the temperature was suddenly raised to 50 ◦C without changes in the input power. This perio lasted for several days and repeated several times during the same run. Eventually these periods were not detected anymore.

4. CF research continued despite the fact that CF researchers became the pariah of science community. Japanese researcher Mizuno is one of the researchers taken seriously [C82]. The DOE panel in 2004 changed the situation: one can say that CF researchers were taken as normal human beings.

   In 2004 APS allow CF sessions in APS conferences. ACS followed in 2007. A new turn appeared when emeritus professor Holmlid from Island was invited to APS conference to talk about his observations.

   As far as I know, CF is under commercial development behind the scene. Quite recently an Australian startup group HB11 (http://tinyurl.com/tbloqfw) claimed that it can produce CF by using a very simple arrangement using HB11 pellets in a reactor volume and two laser beams. The first beam would be responsible for magnetic confinement and second wo would induce the compression of the pellets making possible fusion (this resembles the situation in Holmlid's experiments).

Also biofusion has been reported [C33, C150]. For instance, Ca would emerge in living organisms through nuclear transmutations. This brings in a new interesting aspect to the problem.

6.2.2 Key objections against CF

What are the key counter arguments against CF?

1. Pons ja Fleischman reported a detection of also neutrons and tritium in their experiments. Also gamma radiation predicted by ordinary fusion to ^4He was reported. These observations did not find support. The production of also heavier isotopes has been reported as also X rays.

2. Second objection is poor replicability but already the experiments of Pons ja Fleischman suggested that the phenomenon in question is critical - maybe even quantum critical - and appears therefore only at critical values of controllable parameters. That water does not freeze in 50 ° C at normal pressure does not mean that it does not freeze at all. CF could occur only whether the density of deuterium in the target is in critical range, and one can think that the repeated heat production periods correspond to the gradual stepwise penetration of D deeper to the Pd target and reaching of the critical surface density at the inner surface of the porous Pd.

3. The theoretical objection against CF is that it is no energetically possible: this would be due to the Coulomb wall requiring temperatures of order million Kelvins. Also the failure to observe the production of neutrons, tritium and ^{3}He is in conflict with ordinary fusion. CF cannot be in question and if the phenomenon is real, new physics is involved, and this option the nuclear physicists are not ready to consider.

What makes the situation intersting that already 10 years ago Asplund *et al* observed a possible anomaly in the nuclear physics of solar core [E7, E43]. This suggests that even hot fusion and nuclear physics itself is not completely understood. What was observed was that the nuclear abundances at the surface of Sun deduced from helioseismic waves and solar neutrino data were considerably higher than those deduced from the spectroscopy at photosphere and from meteorites.

Second anomaly is older. The X rays arriving from Sun have energy scale of keV. It has been found that the annual variation of the X ray intensity due to the variation of the Earth-Sun distance causes a similar variation in the rates of nuclear decays [C74]. This would suggests new nuclear physics in keV scale. Atomic nuclei would have excitations in the energy scale of keV.

What are the basic problems besides the above mentioned problems. Perhaps the worst sociological problem is reductionistic approach, which does not allow mainstream physicists to consider seriously the possibility of new physics. This would violate the belief about the glorious march of the physics towards shorter and shorter length scales. Ironically, the last step - super string models - was meant to take us directly to Planck length scale, but the outcome was a failure, which also forces to challenge the reductionistic dogma. The fact after all is that theoretical nuclear physics is a collection of models, which are more or less in harmony.

For instance, tunneling phenomenon plays a central role in the model for nuclear reactions. It makes possible reactions at temperatures which are by a factor 1/100 lower than the energy defined by Coulomb wall and energy of nuclear reactions (about 1 MeV). Coulomb wall is basic concept determined from the Coulomb potential for the nucleus and from the phenomenological potential describing strong interaction energy. The parameters of this potential are chosen so that the energy for the onset of nuclear fusion is reproduced. The models in general treat nucleons a point like objects, which are non-relativistic. A real theory of nuclear interactions is lacking.

6.3 Why TGD and what TGD is?

The following gives a brief overview about the motivations and basic ideans behind Topological Geometrodynamics (TGD) [K123] [L77, L107].

6.3.1 TGD as a solution to the energy problem of general relativity and as a generalization of super-string models

The space-time of general relativity theory (GRT) is a metric deformation of Minkowski space M^4, which is the space-time of special relativity. M^4 is flat and corresponds to empty space-time. The deformation makes it curved. The basic postulate of GRT is that the presence of matter makes space-time curved and Einstein's equations describe what this means mathematically. I this deformation however the symmetries of M^4 - Poincare invariance - are lost. Noether's theorem states that every symmetry corresponds to a conservation law. Now the laws for conservation of energy, momentum and angular momentum are lost.

One could argue, that the loss is not fatal because gravitation is extremely weak interaction. One the other hand, it as infinitely long range and is not screened like electromagnetism and color interactions. Also the attempts to quantied GRT have failed. The probably reason is that the predictions of quantum field theory are coded by S-matrix defined by using Hamilton operator, which corresponds to conserved energy, and does not exist mathematically in GRT.

Perhaps superstring theory was a mathematical success because the 2-D orbit of string was a 2-surface in 10-D space-time having 10-D Poincare symmetries. Space-time is however not 2-D so that the model is unrealistic in this sense. Also spontaneous compactification as a 10-D modification of 4-D space-time having 6 small dimensions was highly non-unique and led to landscape catastrophe and the predictability was completely lost.

The proposed solution can be seen as a generalization of string models. One replaces 2-D string world sheets with 4-D space-time surfaces interpreted as orbits of 3-D particles in some higher-D space-time $H = M^4 \times S$, so that the symmetries of M^4 and space S are symmetries of the theory and classical conservation laws are not lost. If one assumes $S = CP_2$, one obtains the symmetries of standard model and a geometrization of both gravitation and standard model interactions: the dream of Einstein would be realized in terms of sub-manifold geometry.

It turns out that $H = M^4 \times CP_2$ is a unique choice also mathematically. If one requires that TGD allows "twistor lift" replacing space-time surfaces with analogs of their 6-D twistor twistor spaces in the 6+6-D product $T(M^4) \times T(CP_2)$ of twistor spaces of M^4 and S, then M^4 and $S = CP_2$ are the only possible choices since they allow twistor spaces with Kähler structure, necessary for the formulation of the twistor lift [A21].

New view about space-time

TGD leads to a new view about space-time. Space-time is 4-D surface in space which can be obtained from empty Minkowski space M^4 by replacing its points with CP_2. The size of CP_2 is extremely small, roughly noin 10,000 kertaa Planck length. A convenient lower-dimensional analogy is glass plate whose thickness is of this order of magnitude. The analog of Einsteinian space-time is 4-surface for which M^4 projection is 4-dimensional. One could but this kind of surfaces on top of each other - obviously they are are extremely near to each other. These space-time sheets can be connected by extremely small wormhole contacts, which one sees as illustrations in popular books about GRT. I call this structure many-sheeted space-time.

The general solution of field equations for twistor lift is minimal surface having 2-D surface as singularities as singularities: these 2-D surfaces have interpretation as string world sheets and partonic 2-surfaces as I call them [L35, L100]. In geometrodynamics minimal surface property becomes the geometric counterpart for the masslessness of field. Stringy world sheets are analogous to the source of massless fields (charge densities) and the analog of string model is obtained if one leaves only these sources under consideration. One can associated to the ends of strings fundamental fermions as point-like entities and build from these elementary particles.

One obtains several solution types as simple limiting cases.

1. An important Einsteinian solution type is "massless extremal" (ME) [K7, K76], which corresponds to a radiation field consisting of analogs of plane waves propagating with light-velocity to single direction so that the shape of pulse is preserved. The solution is tube like structure with cross section having cylinder as 3-D projection. Laser beam is a good physical analogy. The linear superposition of Maxwell's equations is reduced to superposition of waves propagating in the same direction.

2. One obtains also non-Einsteinian space-time surfaces for which M^4 projection has dimension lower than 4 [K7].

   (a) If the projection is 1-D light-like geodesic line one obtains CP_2 type extremal providing a topological model of elementary particle.

   (b) If the projection is 2-D string world sheet, one obtains 4-D objects looking like string world sheet. I call this object cosmic string. Its deformations have in general 4-D M^4 projection which finite thickness. I call these deformations magnetic flux tubes.
   Magnetic flux tubes turn out be central objects in all length scales: the reason is that quite generally length scale reductionism, is replaced by fractality in all length scales. Cosmic strings dominate very early cosmology and galaxies are local tangles for the cosmic strings at which it thickes to flux tube. Also stars and planets are this kind of structures. One can talk about flux tube spaghetti [L91]. These flux tubes are also basic building brickes of hadrons, atomic nuclei, molecular bonds and biomolecules.

The new view about fields and the notion of field/magnetic body

There is no need to assume bosonic gauge fields of standard model and gravitational field as primary dynamical variables. When one knows the space-time surface, one knows all the fields of standard and also gravitational field determined by the induced metric. Geometrization of gauge potentials and - fields reduce to the induction of spinor structure so that the dream of Einstein is fulfilled.

Fundamental fermions appear in the role of fields and for the simplest option only quark fields of single fermion generation are needed [L106]. Leptons can be build as local composites of 3 quarks and baryons as their non-local composites. This means a new view about supersymmetry: LHC indeed excluded the standard proposal for what SUSY could mean at LHC energies where it was well-motivated. This leas also to a generalization of super-space: many-fermion states as quantum Boolean logic identified as "square root" of Kähler geometry: the super-analog of space-time surface in TGD sense would realize this idea concretely.

In many-sheeted space-time the classical fields associated with a given system correspond to space-time sheets carrying them: magnetic and electric fux tubes and radiation fields described by massless extremals. Many-sheetedness brings in new elements. Tue to the extreme non-linearity of field equations, the superposition of field is in general not possible but test particle as small 3-space-time surface - wormhole contact - touches all space-time surfaces having projection to given M^4 region and experiences the sum of their effects.

In Maxwellian theory this observation leads to the postulate that there exist fields, which superpose. In TGD one returns to the roots and does not assume this at fundamental level. At the quantum field theory limit of TGD one replaces many-sheeted space-time with a region of M^4 and identifies gauge potentials and the deviation of induced metric from induced metric with the sums of the corresponding induced quantities for space-time sheets.

The field carrying space-time sheets associated different systems are in general separate although they can have tiny wormhole contacts -they touching). Wormhole contacts can also serve as topological representations of elementary particles. In the wormhole contact the Minkowskian signature of space-time sheet (1 time like dimension) becomes Euclidian (all dimensions are space-like) The M^4 projection of wormhole contact is however light-like curve.

One can say that any system has field identity - field body. As a special case one can speak about magnetic body having as body parts magnetic flux tubes and - sheets. The notion of magnetic boy is central in TGD inspired quantum biology and actually in entire TGD.

6.3.2 Number theoretic physics, hierarchy of effective Planck constants, and dark matter

An important input in the development of TGD were p-adic mass calculations [K70]. The masses of elementary particles are still a mystery in mainstream physica and in standard model Higgs mechanism provides a parameterization of fermion massess: their values are fed in as couplings of Higgs f to fermions so that nothing is actually predicted.

p-Adinen thermodynamics as a generalization of standard thermodynamics - mass square replaces energy - describes particle masses as thermal masses [K27, K61]. Massless particle is mixed with its very massive excitations so that one obtains massivation. Higgs does not produce the massivation although it belongs to particle spectrum as also pseudoscalar as its partner.

The success of p-adic mass calculations led to the question, whether p-adic physics for various primes p, could be a part of TGD.

1. All p-adic number fields must be allowed, which suggests that forms from real numbers and various p-adic number fields a book-like structure. The pages of thes book would intersect at points which can be regarded as number common to reals and all p-adic number fields. Rationals are these points [L63, L64].

2. Also the extensions of p-adic number fields are possible. Every extension of rationals defines such an extension. Algebraic extensions of rationals obtained in terms of the roots of irreducible polynomials induce extensions of p-adic number fields One obtains infinite number of adelic books with back consisting of the numbers in the extension forming an entire library.

3. This picture generalizes at the level of space-time surfaces. Adelic space-time surface has infinite number of pages labelled by reals and by extensions of p-adic number fields defined by extensions of rationals. They obey formally same field equations. Number theoretical universality states that the solutions have the same form independently of the number field.

What could be the interpretation of this structure.

1. p-Adic physics differs from real physics that the solutions of field equations are not completely deterministic. For instance, the integration constants of equations of motion have vanishing derivative as in real case but this implies only that they are piecewise constants.

   In TGD inspired theory of consciousness one must ask what are the space-time correlates for sensory percepts, cognition, intentionality, and imagination. Could p-adic non-determinism correspond to the non-determinism of imagination?

2. If one accepts number theoretical universality, one can ask whether p-adic space-time surface interpreted as an imagined time evolution - intention - is realistic only if the pseudo constants are genuine constants so that p-adic space-time surface defines also real counterpart. If this is not the case, then only a part of p-adic space-time surface would correspond to real space-time surface - "reality". In neuroscience imagined sensory percepts and motor action indeed look like partially realized perceptions and motor activities.

The algebraic extensions of rationals form a hierarchy. The higher the dimensio n of the extension (degree of irreducible polynomial) is, the higher the algebraic complexity. A natural interpretation would be as an evolutionary level. In quantum jumps the dimension of the extension is bound to increase in statistical sense: this would correspond to evolution.

It turns out, that the dimension n corresponds naturally to effective Planck constant $h_{eff} = nh_0$, where h_0 is the smallest possible value of h_{eff}. Ordinary Planck constant can be argued to be equal to $h = 6h_0$ [?] [L42, L73, L122]. The higher the evolutionary level, the longer the scale of quantum coherence proportional to h_{eff}. A natural guess is that the origin of the coherence of living matter is here.

p-Adic primes label elementary particles in p-adic thermodynamics (for instance, electron corresponds to Mersenne prme $M_{127} = 2^{107} - 1$). Also for more general systems p-adic prime characterizes the size scale of the corresponding space-time sheet. What could be the number theoretical identification of the p-adic primes in terms of extension of rationals?

1. One can assign to each algebraic extension of rationals so called "ramified" primes. Their number is finite. Could they characterize the particles and systems assignable with the extension [L82, L95, L110]?

2. On the other hand, the dimension n of the extension has a product decomposition to powers of primes, and it turns out that these primes play a central role in "small" state function reductions as analogs of weak measurement producing as a by-product a physical correlated for the decomposition of n to powers of primes [L125].

Which identification is correct, is better to leave open but my personal guess is that the first option is the correct guess.

6.3.3 Quantum measurement theory based on zero energy ontology and theory of consciousness

Quantum measurement theory is the black sheep of quantum physics: the problem is that Schrödinger equations is deterministic but state function reduction is not so that the theory has internal contradiction. TGD based quantum measurement theory based on what I call zero energy ontology (ZEO), solves this problem.

The basic geometric notion of ZEO is causal diamond (CD) [K69] [L66, L105].

1. The causal diamond of M^4 - call it cd - is the intersection of the future and past directed light-cones and is therefore 4-D. CD is obtained from cd by replacing its points with CP_2 and is therefore 8-D. In TGD visualization cd would be diamond in 2-D Minkowski space M^2.

2. CD sizes (cd sizes) form a hierarchy. Number theoretic arguments suggest that the temporal distance between the tips of CD is multiple of CP_2:n size scale (divided by c). CDs can contain sub-CDs. Sub-CDs would correspond to mental images of conscious entity - "self" - assignable to CD. Sub-sub-CDs would not correspond to separate mental images but a kind of average.

3. The geometry of CD should be understood also from this point of view. CD receivers sensory information from environment- exterior of CD. It would arrive from the geometric past of CD

and the shape of CD is ideal in this respect. When the arrow of time changes in "big" state function reduction (BSFR) the former geometric future becomes geometric past and sensory information arrives also from geometric future in standard sense.

4. The input from the interior of CD - from the lower end of CD - corresponds to the information of conscious entity from its 4-D body. Also now the situation depends on the arrow of time.

ZEO based quantum measurement theory leads naturally to theory of consciousness, when "small" state function reductions (SSFRs) as analogous of "weak" measurements (`http://tinyurl.com/zt36hpb`) are identified as moments of consciousness, looks like follows.

1. In ZEO quantum zero energy states are identified superpositions of entire deterministic time evolutions as analogs of Bohr orbits. The act of free will is analogus to the starting of deterministic computer program. One selects some sub-program from a menu and starts it by clicking the icon. This is what our behavior mostly is, selections between a menu of routines.

   The routines correspond to a hierarchy space-time sheets, CDS, and of selves. The program starts in long time time scale T_{max} and implies starting of programs in shorter time scales a $T_1 < T_{max}$ ... The process from top to bottom as a cascade.

2. In ZEO one can distinguish between two kinds of state function reductions (SFRs).

   (a) "Small" SFRs (SSFRs) correspond to "weak" measurements (`http://tinyurl.com/zt36hpb`). The arrow of time does not change and and the members at the active boundary of CD changes and also the distance between the tips of CD clock time in very general sense - increases in statistical sense. The states at the passive boundary of CD are unaffected by change at the active boundary. One can say that generalized Zeno effect is in question.

   (b) "Big" (ordinary) SFR (BSFR) changes the arrow of time at magnetic body (MB) in long length scales - this induces effective change of the arrow of time at the level of ordinary matter. BSFs can change the arrow of time also at the level of ordinary matter but this happens in so short time scales that it is interpreted in terms of dissipation and second law.

   Libet's findings can be explained and they provide that free will corresponds to BSFR in macroscopic scale. The act of freed will, BSFR, changes the arrow of time and thus the arrow of causality and one can say that the final state of BSFR causes at the classical level the neural activity in geometric past (classical physics is an exact part of quantum physics in TGD). The observed has opposite time direction and it seems that the neural activity causes the experience of free will: this gives rise to the paradox.

3. The real surprise came as I developed a concrete model for the contents of consciousness of self [L125]. The basic question is: What the moment "Now" corresponds geometrically. The surprise was that "Now" seems to correspond to the time=constant M^4 hyperplane corresponding to the maximal radius of cd. This corresponds to $t = constant$ snapshot in the middle of CD, where t linear M^4 time coordinate such that time axis connects the tips of CD.

   At passive boundary of CD the members of state pairs forming zero energy states remain unaffected during SSFRs. Also passive boundary itself remains stationary except that its size increases with that of CD.

   Because the active upper boundary at which the members of state pairs state pairs change in time evolution by SFRS shifts to the direction of geometric future in statistical sense, the moments of consciousness experienced earlier move to the direction of geometric future ($M^8 - H$ duality allows to formulate this precisely [L98, L105])! Information theoretically this means that the "personal history" of self is stored to the active boundary of CD! In the second re-incarnation with reversed arrow of time this information forms the permanent part of self, "soul" one might say. naïve expectation would have been that personal memories are located in the geometric past! Only the sensory input from external world and from the body of self as CD would be from the geometric past. This picture would realize mathematically the belief called Karma's law.

What about the experimental support? Last summer I learned about the observations reported by Minev *et al* [L90] providing a strong support for ZEO at the level of atomic physics [L90] (`http://tinyurl.com/yj9prkho`).

1. Contrary to expectations it seem that state function reduction (BSFR) corresponds to a continuous deterministic time evolution leading to the final state of reduction rather than instantaneous and discontinuous quantum jump.

   ZEO explains this naturally. Quantum jump occurs instantaneously in the sense of subjective time but the final state corresponds to a superposition of classical time evolution from final state to the geometric past. The assumption that the time arrow of time is that of the experimenter creates the illusion that time evolution leads to the final state. This is only one example of causal anomalies predicted by ZEO.

2. It was also found, that even when one removed the stimulus inducing the quantum jumps, the time evolution that had already started, ledt o the final state.

   The ZEO explanation is that quantum jump had already occurred.

3. If one modified stimulation, the time evolution stopped.

   In ZEO this can be understood if the modified stimulus induced opposite quantum jump.

Libet's experiments relating to the active aspect of consciousness [J6] demonstrated, that the experience of free will was preceded (in the sense of geometric time) by neural activity in brain so that free will would be an illusion in standard ontology. In ZEO the interpretation would be that the arrow of causality change: the act of free will caused the neural activity in the brain of geometric past.

6.3.4 The new view about quantum biology

Number theoretical vision and ZEO lead to a model of quantum biology. Perhaps the key challenge of biology is the understanding of coherence of living mater. The vision about life as mere biochemistry does not explain the coherence since coherence lengths i biology are of the order of molecular size scale.

1. The natural idea is that dark matter as phases of ordinary matter characterized by the value $h_{eff} = n \times h_0$ of the effective Planck constant, produces the coherence of ordinary living matter somehow. The dark matter would reside at magnetic body (MB). The coherence at biological body (BB) would not be quantum coherence but coherence induced by MB. The coherence scale at MB - in the simplest situation proportional toh_{eff} - would produce at the level of BB.

2. Dark matter hierarchy would correspond to evolutionary hierarchy and evolution would be unavoidable.

Metabolism and self-organization are essential aspects of biology.

1. Self-organization require energy feed. In biology this means metabolic energy feed and nutrient molecules serve as storages of metabolic energy making possible the extraction of energy.

2. An important consequence of ZE is that the aspect of ZEO corresponding to buildup of new structures can be seen as dissipation in non-standard arrow of time implied by a generalization of second. In standard direction of time one sees generation of structures and gradients - in particular temperature differences - instead of their decay. Enormous number of specific mechanisms becomes un-necessary. One can also say that apparently the system extracts energy from the environment rather than serving as a passive receiver.

   Motor activity serves as a basic example. It would correspond to BSFRs whereas sensory activity would correspond to SSFRs. In notor activity as BSFR brain only apparently generates signals inducing motor activity.

3. One problem of standard ontology is that it is very difficult to understand how living matter can react so rapidly. The nerve pulses between brain and muscles are slow and multiple feedback would be needed to the fine adjustment of motor activity. Someone has estimated that the process in which cat gets frightened so that its hair raises, would take time of order of the age of the Universe. Penrose discussed the reaction of tennis player to the approaching tennis ball as an example of this.

   ZEO solve this problem. The activities which should precede the reaction due to frightening has led to the final state and the processes that would precede it in standard ontology take place in non-standard time direction. One could also say that the reaction starts already in geometric past and is initiated by signals proceeding into geometric past. No separate mechanism are needed: it is enough to have stored metabolic energy and proteins take care of this.

ZEO and dark matter at MB allow also to understand why the biomolecules participating to bio-catalysis are able to find each other and why the bio-catalysis so extremely effective.

6.4 TGD based model for CF

Coulomb wall is the basic problem of CF. Also the fractions of the produced nuclear isotopes differ from those predicted by fusion and gamma rays seems to be missing. X rays have been however reported.

6.4.1 Nuclear string model

For more than two decades ago I proposed that in TGD Universe ordinary nuclei could correspond to nuclear strings [K103, L4].

1. Nuclear strings would be magnetic monopole flux tubes (not possible in Maxwellian world) at which nucleons and the stable units formed from the (deuterium, ^4He at least) condense. There would be hierarchy of flux tube within flux tubes. The radius R of flux tubes would be of the order of proton Compton length. Basic units would have a distance of order of the distance between nucleons. The basic units would be connected by meson-like flux tubes having quark and antiquark at their ends. The simplest assumption is that the flux tubes are color singlest and masses are much lower than those of ordinary mesons and even lower than about MeV energy scale for nuclear energies. keV energy scale was proposed on basis of the observed anomalies. They could correspond to a scaled down version of hadron physics such that pion has mass scale is of order of keV.
2. In standard picture the strong isospins of proton and neutron are opposite and p-n pairs have attractive interaction energy. In the harmonic oscillator model of nuclei, this kind of pairing is assumed. What could it correspond at the level of nuclear strings? Do proton and neutrons form pairs - deuterons - in such a way that the distances between surplus neutrons or protons are maximized. Or does one have helical pairing of proton and neutron flux tubes such that neighboring p and n are paired?: this would be analogous to base pairing by hydrogen bonds taking place in DNA double strand.
3. ^{4}He is also a stable nucleus for which neutron and proton numbers are same. Could one imagine fractal structure consisting of flux tubes within flux tubes. ^{4}He flux tube would consist of 2 D flux tubes, and one could build flux tubes containing closed ^{4}He flux tubes. Also heavier nuclei allow stable isotopes for which proton and neutron numbers are same and one cannot exclude the possibility that even these could form nuclear strings. Also DNA double strand has this kind of coils-within-coils structure and I have proposed similar mechanism at the level of associated magnetic flux tubes.

Quite recently considerable progress took place as I learned observation suggesting a new particle, whose quantum numbers are those of pion and also mass is not too far from pion mass. The new particle does not fit in standard model. One can find a popular article about the discovery in Scitechdaily (`http://tinyurl.com/wb98u6u`) and an article in Phys Rev Letters (`http://tinyurl.com/v2rwh3e`).

1. The observation was not actually new. For years ago Tatitcheff ja Gustafson reported that pion seems to have what they called "infrared" (IR) Regge trajectory, in fact several of them. There would be states at least with the masses 60, 80, 100, 140, 181, 198, 215, 227.5, ja 235 MeV. The value of string tension deduced from the mass difference of 40 MeV:n is in good approximation $T(\pi) = .01$ GeV^2 and corresponds to a mass about 100 MeV, which is mach smaller than the hadronic string about $T_H = 1$ GeV^2 assignable to color magnetic flux tubes. TGD predict a p-adic hierarchy of magnetic flux tubes characterized by string tension.

2. Could $T(\pi)$ be associated with the interactions of atomic nuclei? Surprisingly, the energy scale associated with the nuclear excitations would be about 5.1 MeV, which is smaller but of same order of magnitude thatn the electromagnetic energy scale determined by Coulomb energy for nucleus, which is is of the order 7.8 MeV ($\alpha\hbar/R$, R is the radius of nucleus of order .1 fm). This energy scale is same as that for the atomic binding energies for ^4H and heavier nuclei.
3. One can ask whether the string tensio is same for (possibly em) flux tubes for nucleons as for for pion. Nucleus corresponds to p-adic length scale $p \simeq 2^k$, $k = 113$ and scaled down hadronic string tension $T(\pi) = T_H/64$. The corresponding energy scale would be 7.8 MeV. If nucleons correspond to $n \geq 0$, it can happen that in atomic nucleus the value of n for nucleons is smaller than for free nucleons: this could allow an elegant explanation for nuclear binding energies by reducing them to the level of magnetic body of nucleon.
4. The harmonic oscillator model of nuclei would be replaced with a model in which the excitation energies of nuclei would be of the sam form as those of oscillator model in the approximation in which the mass scale determined by string tension is smaller than the mass of nucleon. Because there are three flux tubes associated with nucleon consisting of 3 quarks, nucleon behaves effectively like 3-D harmonic oscillator. The nucleons of the nuclear string are in good approximation free so that the model resembles strongly harmonic oscillator model. Nuclear physics would reduce in good approximation to single nucleon level - or more precisely, to the level of magnetic body of nucleon: Hartfree-Fock philosophy would be completely wrong! It would be possible to understand that behavior of nuclear binding energies in a rather detailed manner as a function of charge and mass number [L119] [K66].
5. What is the energy scale of the flux tube pairs? If the neighboring nucleons are connected by a flux tube the flux tube must correspond to an energy scale considerably lower than MeV scale of nuclear binding energies. X ray radiation having energy scale of order keV has anomalous effects on nuclei. For instance, the decay rates of nuclei have been reported to depend on how intense the X ray radiation arriving from Sun is: the intensity varies with Earth-Sun distance [C74].

   This has motivated the earlier proposal that the energy scale for the flux tubes is of order keV. If color magnetic flux tube is in question - perhaps p-adically scaled down pionic flux tube could be in question - the p-adic length scale would be of the order of electron Compton length. MeV scale would scale down by a factor $m_e/mp \simeq 2^{-11}$. Also em flux tube could be in question.

   On the other hand, the model of cold fusion and of also nuclear fusion based on the observations of Pollack ja Holmlid suggests that the energy scale e_B for the flux tubes connecting dar protons/D-nuclei is about eV and therefore the basic energy scale of biology. This would suggest that keV is the energy scale for the flux tubes connecting nucleons in ordinary nuclei, and e_B corresponds to energy scale for flux loops assignable to nucleons and is the energy scale for secondary IR Regge trajectories.

6.4.2 Pollack effect

Pollack effect [L24] [L24] was one of the first empirical inputs of the model of CF.

1. Pollack effect is observed when water bounded by gel is irradiated using for instance IR radiation. Also other wave lengths can be used and it has been argued that almost energy energy feed works. What happens is charge separation: a negatively charged region -exclusion zone (EZ) - is formed near the boundary of gel and water phase: part of protons goes somewhere. Stoichiometrically one has $H_{1.5}O$ molecules and they form a structure formed from hexagonal 2-D layers. EZ is thermodynamically anomalous. It excludes various impurities which is in conflict with second law predicting that concentration gradients disappear. Also charge separation can be seen as a thermodynamical anomaly.
2. The TGD based interpretation is that protons transform to dark protons and go to magnetic flux tubes, where they form sequences, dark nuclei. Energy feed is needed to increase h_{eff} since the energy of the system quite generally increases with h_{eff} with other parameters kept constant. This is essentially metabolic energy. One can argue that the Coulomb repulsion of

protons is compensated by dark interaction energy, which is of order keV, if binding energy scales down like $1/h_{eff}$. Here one must be however cautious since the energy assignable to flux tube is expected to scale like h_{eff} and the energy in question would correspond to the energy assignable to the bonds connecting protons rather than ordinary nuclear binding energy.

The quantum states of dark proton triplets can be classified to 4 types and the numbers of states in these classes correspond to the numbers of DNA, RNA, tRNA, and amino-acids. Genetic code is realized in a simple manner and the number of dark DNAs coding for given dark amino-acid is same as in vertebrate genetic code. This inspires the idea that dark DNA and ordinary DNA are paired and that the distance of dark protons at the flux tube is of order nanometer as is also the distance of DNA codons at DNA strand. Dark genetic code would be the fundamental code and ordinary genetic code would represent its chemical mimicry. Binding energy for dark nucleon bond would scale down to eV scale correspond to the energy scale for the photons fed into the system.

3. These dark nuclei could also appear in the initial state of CF as also bio-fusion suggests. The radius and length of the flux tube can of course correspond to a p-adic length scale: I have proposed long time ago that transitions reducing h_{eff} to h and preserving flux tube thickness are possible [K85, K86, K59].

4. Zero energy ontology (ZEO) would explain thermodynamical anomalies associated with EZs. The arrow of time would change in BSFR at MB and induce effective reversal of the arrow of time at the level of BB.

The fact that the energy scale of Pollack effect is of order eV and the length of flux tubes is of order nm suggests that the string tension for them is rather small - of order $T \sim 10^{-3}$ eV^2. This and bio-fusion serve as hints in the attempts to understand CF.

1. Twistor lift of TGD [L65] predicts that the string tension T for flux tube corresponds to length scale dependent cosmological constant Λ. The length scale defined by it corresponds to the radius of the flux tube. T produces attractive force. There are reasons to assume that the length of flux tube is proportional to h_{eff} so that also the energy has this proportionality.

2. One could think that Pollack effect makes bio-fusion possible. $T \sim 10^{-3}$ eV^2 is rather small. If h_{eff} is large, then Λ must be correspondingly smaller so that small T is obtained. This value of T is quite too small to help protons over Coulomb wall.

   In bio-fusion protons must fuse together to ordinary nuclei and therefore near each other. One must overcome the Coulomb wall and this requires energy. Could the process start with a quantum jump increasing the value of Λ and therefore also the value of T. Either nucleus or both would provide the needed energy of order MeV to the flux tube! This would be somewhat like metabolism as energy change between proton and the MB, and would conform with TGD based view about pre-biotic biology [L77].

   The increase T would produce a force, which would attract the protons at the ends of the flux tube to each other and lead to the birth of ordinary nucleus.

   If h_{eff} decreases in steps the flux tube length decreases and protons receive the kinetic energy helping them to overcome the Coulomb wall. Also Λ must eventually decrease, which means that nucleon shifts back to normal state at its Regge trajectory.

3. The mechanism brings in bio-chemical catalysis in TGD based quantum biology. The value of h_{eff} and also the energy of the flux tube are large in the initial state. The energy of flux tube would come from metabolism by a quantum jump increasing Λ. Also now h_{eff} would decrease gradually and lead to a shortening of the flux tube and liberation of energy used to overcome the potential wall making the reaction slow. After the reaction the energy would be return in the ideal case.

6.4.3 The observations of Holmlid

The observations of Holmlid represent second empirical input [L48] [L48]. Holmlid has proposed a model for this observations, which served as an inspiration in the development of TGD based model [L54, L27].

1. Holmlid assumes that Rydberg atoms, which are atoms having one or more valence electrons at orbitals with large value of the principal quantum number N so that the radius of the corresponding Bohr orbit proportional to N^2 is very large.

   These valence electrons could be also dark since $h_{eff} = nh_0$ together with $h = 6h_0$ implies that $n = 6m$ electron at orbital N corresponds to Rydberg electron at orbital at orbital mN. One must however notice that in this case one obtains smaller number of values of orbital angular momentum so that the two options can be distinguished from each other. Also apparently fractional orbitals are possible corresponding to values of n not divisible by 6.

   How this could be significant from the point of view of CF? The production of dark nuclei requires energy feed to increase h_{eff}. Could the dark analogs of Rydberg atoms transform to ordinary ones by $h_{eff} \rightarrow h$ transition and liberate energy serving as "metabolic energy" in the generation of dark nuclei? Or could the energy feed using laser beam increase also the value of h_{eff} of dark valence electrons and generate dark variants of Rydberg atoms as a side product?

2. Holmlid uses laser beam (visible light) directed to Pd target containing D. He believes that laser produces ultradense phase, in which the distance between nuclei is of the order of Compton wave length of electron. He believes that this is enough to start nuclear fusion. The objection is that the creation of this kind of phase is energetically very difficult due to the Coulomb repulsion of protons. In TGD picture the binding energy of dark nuclei could come in rescue.

   Holmlid assumes that the ultra-dense phase is 3-D. In TGD it is enough to have 1-D phase corresponding to D nuclei at flux tube whose radius is of the orer of electron Compton length. h_{eff} would be of $h_{eff} = 2^{11}h$.

   Why 1-dimensionality would be so important? The creation of 1-D compression is easier using laser pulses. Furthermore, Coulomb energy for 1-D structure is proportional to the distance between the ends of the structure and would increase linearly with distance r unlike in 3-D case, in which it behaves like $1/r$. Repulsive Coulomb energy thus contributes to string tension a term reducing it. Could this have meaning.

3. The fact that the energy of laser beam is of order eV as in Pollack effect suggests that Pollack effect or its generalization is the first step in the formation of dark nuclei. This would explain also bio-fusion.

4. Holmlid reports several surprising observations [L48], for instance production of muons and even kaons. The mass of muon is of order 100 MeV and much higher than the nuclear binding energy scale. Kaon mass of kaon is even higher, about 500 MeV. These mass scales are associated with hadron physics, which suggest that somehow hadron physics enters into the picture. The transition changing dark nucleus to ordinary nucleus can liberate so large energy only if the transition to ordinary nucleus occurs quantum coherently for the entire dark nucleus as a collective transition. One could imagine that a dark nucleus formed from deuteron pairs transforms to that formed from ^{4} He nuclei. If one has dark nucleus with mass number Z=32 (Ge) more than 7.8 MeV per nucleon would be liberated in the case of kaon production.

The fact that the energy of the laser beam is of order eV as in Pollack effect suggests that Pollack effect or its analog as a formation of dark nuclei is the first step of CF. This would explain also bio-fusion. Could the already speculated mechanism for bio-fusion work also now?

1. The initial situation would like in Pollack effect. h_{eff} would be large at quantum criticality for the flux tube pair with length scale nm connecting dark nuclei. D-nuclei would be p-n pairs at closed flux loops, length about L_p. In the case of Pollack effect they are flux loops associated with protons, and in the case of D-nuclei they must be accompany nucleons. They cannot be flux tubes connecting p and n to which it is natural to assign keV energy rather than eV energy. This energy can be of order eV also in normal nuclei so that it would correspond to a new nuclear energy scale besides keV. This would mean connection between biology and nuclear physics.

   The loops associated with the nucleons of subsequent D-nuclei reconnect to long flux tube pairs - length of order few nm. h_{eff} is large but Λ correspondingly small so that $T \propto \hbar_{eff}\Lambda$

is small constant and the energy is of order eV. This guarantees the energy degeneration associated with quantum criticality.

2. After than Λ and therefore also T:n increases and the energy for the flux tubes becomes of order MeV. The energy would come from the shift of the nucleon downwards at its Regge trajectory. An analogy of metabolism is in question.

3. At the next step h_{eff} decreases in stepwise manner: $\Delta h_eff/h_0 = \Delta n$. $\Delta n = 1$ is the minimum step, for which the liberated energy would be $\Delta E = e_B$ of order eV. In the general case the liberated energy is $\Delta n e_B$ and is of order keV if Δn is of order $6m_p/m_e \simeq 6 \times 2^{11}$. This is natural if one has $h_{eff}/h_0 = n = 2^{11} \times 6m$. At the step preceding the last one, the distance between D-nuclei would be of order L_e and n would be $n \simeq 6 \times 2^{11}$. After that one would obtain $n = 6$.

One must remember that this is just for-definitess-model and experimental data certainly allow a lot of flexibility.

6.4.4 What the dark nuclei associated with CF could be?

The idea about dark matter as phases of ordinary matter with $h_{eff} \neq h$ leads to the question whether it is possible to talk about dark nuclei. What could dark nucleus mean?

1. One could think that dark nucleus is generated when the value of h_{eff} at the highest level of hierarchy labelling the thickest flux tube increases and scales like h_{eff}/h. This requires energy. In CF based on electrolysis it would be provided by electric field and in the experiment of Holmlid by laser beam [L48].

2. In electrolysis experiments using ordinary water protons would form the dark nucleus. The corresponding nucleus is not stable and could decay by beta emission. If the value of h_{eff} for weak interactions increases in such a way that the electroweak scale is larger than the thickness of at dark flux tube and thus of the order of electron length, weak bosons are massless below this scale and weak interactions are as strong as em interaction. Weak decays could take place already at this level. Second option is that also negatively charged flux tubes connecting the protons are allow so that proton can effectively behave like neutron. One can even ask whether the neutrons inside nuclei are actually pairs of protons and negatively charged flux tube.

   Nuclei with different proton and neutron numbers are possible as final states.

3. In electrolysis using heavy water D-nuclei would form dark nuclei as their sequences. Both Pons and Fleichman and Holmlid used heavy water. If the dark nuclei transform directly to ordinary nuclei, the nuclei with identical proton and neutron numbers are favored. These nuclei exists as stable isotopes with largest abundance and they are bosons (D,He,C,N,O,Ne,Mg,Si,S,Ca), which could be of importance from the point of view of quantum biology. Tritium (T) and ^3He cannot be generated n this manner. Also neutrons are impossible. ^{4}He can be generated and was reported already 1920.

   If the photons emitted int he transformation to ordinary nuclei correspond to the energy scale of energy scale of dark nuclei (no change for the bonded nuclei), only X rays would be obtained rather than gama rays. X rays have been reported.

4. ^{11}B, which is stable as also ^{10}B, has one surplus neutron. HB11 is used in the reported CF (`http://tinyurl.com/tbloqfw`). Could protons fuse to dark proton sequence connected by dark flux tubes? Is this enough for cold fusion?

   Or could also ^{11}B nuclei combine to a sequence connected by dark flux tubes with electron radius? Could dark protons fuse in the transition to ordinary nuclei with the surplus neutron and one D of $^{-11}$B to form ^{4}He. This would give stable isotope ^{12}C consisting of ^4H nuclei. The fusion of two D:s to ^He would be a genuine nuclear reaction liberate much higher energy than liberated in the transformation involving only the emission of keV radiation. Already the fusion of two dark D:s to ^4He would produce energy in the same scale as ordinary nuclear fusion.

6.4.5 A possible model for CF

The energy of laser beam is measured in eVs. Somehow this energy scale must be central for the mechanism involved. This energy scale is same as in Pollack effect, which suggests a connection between these effects. The following scenario is an attempt to formulate what might happen in CF.

1. The generalization of Pollack effect generating flux tube pairs connecting nuclei at distances of order nanometer would initiate the cold fusion process. Flux tube pairs would be generated by reconnection from the flux tube loops associated with nucleons.

   The energy associated e_B associated with the flux tubes would be of order eV and define a new energy scale in nuclear physics. The situation would be quantum critical and involve flux tubes with different lengths $L \propto h_{eff}$ and cosmological constant $\Lambda \propto 1/h_{eff}$ so that the energies e_B would be the same.

2. Quantum criticality would be broken in such a way that the IR Regge trajectory of nucleon would provide and energy of order nuclear binding energy for the flux tube. Λ would increase by a factor of order 2^{22}. The string tension would produce a force attracting nucleons towards each other and induce a contraction of the dark nucleus, which would correspond to the formation of the ultra-dense phase postulated by Holmlid.

3. The length of dark flux tube connections with length about nanometer scale would shorten about electron Compton length about L_e in a series of phase transitions in which $h_{eff}/h_0 = n$ is reduced as Holmlid's observations suggest. This phase transition series would continue further and eventually lead to ordinary nuclei.

   The most general option is that $h_{eff}/h_0 = n$ decreases in stepwise manner. The energy liberated at single step would be $\Delta E = \Delta n e_B$. If one has $\Delta n = 2^{11}$ the liberated energy would be out $\Delta E = 2^{11} e_B$ and in keV range. $h_{eff} = 2^{11} n$ would correspond to this as a reduction of n. This would explain why gamma radiation is not detected and also the reported X rays. The energy scale would be about 1/1000 of the energy scale from that in ordinary nuclear fusion and could partially explain the conflicting views about energy production. The transition series bring nuclei from distance of few nanometers to the distance of nucleon size scale.

4. This suggests that MBs of nuclei play a key role not only in the understanding of nuclei but also of nuclear reactions. A fractal analogy with TGD based view about bio-catalysis emerges. In bio-catalysis the reconnections between the U-shaped long flux tubes associated with reactants allow the reactants to find each other. The energy liberated in the shortening of the flux tube induced by the reduction of h_{eff} would kick the reactants over the potential wall making bio-chemical reactions extremely slow.

   This could happen also in nuclear reactions and explain why the nuclear reactions are possible at temperatures by factor 1/100 lower than the Coulomb wall for point-like nucleons would allow. Coulomb energy at distance of $L(127)$ would be few keV and consistent with the temperature in Sun, which corresponds to thermal energy of about 1.5 keV.

Two kinds of flux tubes would be involved. The flux tubes connecting nucleons of ordinary nuclei with keV energy scale and flux loops assignable to nucleons with eV energy scale.

1. Do also keV flux tubes play some role in CF? Could this be the case in the situation in which nanometer length scale for dark nuclei is not possible (say in hot fusion). Could the IR Regge trajectories provide the energy needed to overcome Coulomb wall in this kind of situations.

2. What can one say about the radii R and lengths L of the flux tubes connecting nuclei of ordinary nucleons? R ei cannot be much larger than the nucleon size but L could be larger. I have considered the possibility that the flux tubes connecting nucleons are loopy just like the "internal" flux tubes associated with nucleons to which one can assign nuclear binding and excitation energies in terms of IR trajectories.

   L could be considerably longer than the M^4 distance between nucleons. This looks strange at first. This which looks strange. The notion of many-sheeted space-time suggests a solution of the problem. The long distance between nucleons along flux tube mediating electric flux would reduce the repulsive Coulomb interaction energy between nucleons.

3. From solar temperature the energy with the flux tube should be of few keV. This suggests that flux tube length corresponds to electron Compton length of order p-adic length scale $L(127)$ by a factor about 2^{11} longer than the distance between nucleons.

6.4.6 Does the model of CF force to modify the basic views about nuclear physics?

The attitude of the orthodoxy of nuclear physics towards CF has been very repulsive. Perhaps for full reason, CF could be parasite cuckoo evicting the eggs of the host bird from the nest.

1. The notion of Coulomb wall is central in the modelling of nuclear reactions. Its height determines classically what energy is needed to overcome the wall so that the reactions can begin. Nuclear reactions however begin at energies, which are typically about 1/100 of the required energy. Same applies to the needed temperature and thermal distribution of energies does not explain this. This temperature is around million Kelvins in Sun.
2. Quantum mechanical tunnelling is thought to explain this. Also nucleons and nuclei have wave nature and Schrödinger equation allows solutions for which tunnelling through the Coulomb wall is possible. The rate of tunnelling depends very sensitively on height and width of the Coulomb wall via an exponent factor. The height and width of the wall are determined by the details of the potential used to model the strong interaction. By choosing the potential suitably one can understand the collision energy at which the reactions become possible.

   This is however only a model: the parameters of the model are determined separately for each pair of colliding nuclei. A genuine theory would be needed.

What is the situation in TGD?

1. Already the nuclear string model implies a dramatic modification of the existing picture and the introduction of IR Regge trajectories provides the model with additional details and concrete connection with harmonic oscillator model. The nuclear physics is reduced to the level of MBs of nucleons.
2. In zero energy ontology (ZEO) quantum states are superpositions of deterministic classical time evolutions analogous to Bohr orbits connecting 3-surfaces at the boundaries of CD. By holography forced by general coordinate invariance one can speak either about these 3-surfaces or space-time surfaces. Instead of point like particles one has pairs of 3-surfaces having members at opposite boundaries of CD. One indeed has analogs of wave functions as superpositions of these pairs and the analog of tunnelling is possible.

   Tunnelling phenomenon however requires that the 3-surfaces associated with the reacting nuclei at the boundary of CD corresponding to the initial state behave like single particle. This is guaranteed by the flux tube connections between them. This is however not for having quantum-classical correspondence required by ZEO.
3. Quantum criticality is the key element of quantum biology in TGD framework - in fact, entire TGD Universe is quantum critical. The superposition of states involving U-shaped flux tubes of various lengths and values of h_{eff} but of same energy and scanning their environment like tentacles would represent quantum criticality.

   In nuclear reaction one would have quantum critical phase for the bonds connecting nucleons as a superposition of states with different length scale characterized by length scale dependent cosmological constant Λ predicted by the twistor lift of TGD [L65]. The value of the bond energy e_B would be essentially constant. If this applies also to flux tube bonds of nanometer scale appearing in Pollack effect the value of e_B would be of order eV.
4. An interesting question is whether the character of quantum criticality is determined by the environment. A natural upper bound for the variation of h_{eff} and therefore for the length of flux tube length L is determined by the density of nuclei. In solar core the density is about 150 times water density: the flux tubes with nm length scale are not possible and $L_{max} = L_e$ could serve as upper boundary for their scale as assumed in the model for solar core [L103]. In neutron stars L_{max} cannot be much larger than L_p. In Big-Bang nucleosynthesis quantum criticality would have prevailed in the length scale of nucleons.

Quantum classical-correspondence suggests a classical counterpart for the quantum tunnelling. Here one must just imagine different options taking the TGD view about bio-catalysis as a "role model". The following is the simplest toy model achieved hitherto.

1. On basis of quantum biological picture the U-shaped flux tube bonds connecting nucleons of the colliding nuclei having length of about electron Compton length reconnect. This can take place at distance R equal to roughly twice the electron Compton length L_e.

   In Pollack effect the distances L are order nm and because laser light initiates the process, it seems that nm scale is associated with the quantum critical initial situation. The energy e_B of order eV would be same for all flux tubes in the superposition at quantum criticality. Also Holmlid's observations correspond energy e_B in eV range and by criticality $R \sim L_e$ could define upper boundary for the distance L but L in nm scale is not excluded.

   Flux tubes have at quantum criticality also other possible scales and by $h_{eff} = nh_0$ the most general situation corresponds to integer multiples of basic scale such that $h = 6h_0$ corresponds to nucleon scale. $\hbar_{eff}\Lambda = constant$ guarantees energy degeneracy.

   In order get to this distance the nuclei must have minimal energy E in cm frame, which is Coulomb potential $V = Z_1Z_2e^2/R$ if the situation is 3-D. At this step the strong interaction potentials does not appear at all. For $R = L_e$ E is of the order of keV for $Z_1 = Z_2 = 1$. If the value of h_{eff} for the flux tubes connecting nucleons is about 2^{11} before this, one can understand its length. If the situation is effectively 1-D as it seems, the repulsive Coulomb potential energy of form $V = (Q_1Q_2e^2/S)R$, where S is the transversal area of the flux tube: now one would have $Q_1 = Q_2 = 1$.

2. Energy transfer to flux tube with nm scale from nucleon IR Regge trajectory would initiate the reaction: the transferred energy would be few MeV and would induce a dramatic increase of Λ, flux tube tension, and - energy by a factor of order 10^6. The emerging attractive force would compress the flux tube, Coulomb wall would be overcome and the nuclear reaction could happen via a reduction of h_{eff}.

3. $n = h_{eff}/h_0$ would be reduce in stepwise manner. At step Δn the liberated energy would be $\Delta E = \Delta n e_B$. If the liberate energy corresponds to keV scale, $\Delta n \simeq m_p/m_e \simeq 2^{11}$ is a natural guess. For $h_{eff}/h_0 = n = 2^{11}m$ this guess is natural. Holmlid's observations suggest that $R \sim L_e$ has preferred role. The last reduction $n \simeq 2^{11} \rightarrow n = 1$ would lead from the scale L_e to nucleon scale L_p.

   Pollack effect and Holmlid's observations allow to estimate e_B to be of order eV before the initiation of the reaction. e_B would be a new energy scale in nuclear physics and mean a connection with biology.

4. The primary nuclear reactions would occur already in dark phase via the reconnections of quantum critical flux tube bonds. If quantum criticality prevails only during the reaction, a spontaneous reduction of h_{eff} would take place after this and the dark nuclei would transform to ordinary nuclei. For instance, the fusion of two D:s to ^{4}He could occur in the final state.

5. In ZEO BSFR could lead to quantum critical state. After that second BSFR would lead to ordinary nucleons. The space-time surfaces associated with the final state having opposite arrow of time would provide the classical description just as in the case Minev's experiment [L90].

6.4.7 The anomaly in the nuclear physics of Sun

CF challenges the basic assumptions of nuclear physics but can be labelled as pseudoscience. There is however second anomaly discovered for 10 years ago, and it is not so easy to get rid of this anomaly.

The abundances for nuclei heavier than He in Sun - astrophysicists call these nuclei "metals", which is somewhat misleading term - can be deduced from solar model for the spectrum of solar radiation. The spectral lines at photosphere serve as finger prints. The abundances can be deduced from the intensities of the spectral lines. They can be deduced also from meteorites. These two methods give consistent results.

The third manner to deduce abundances is to use model for the physics of solar core. Here helioseismic waves, which correspond to collective oscillations of Sun, serve as a source of information. Using this information one can build a model for the nuclear abundances in solar interior. Also solar neutrino data can be used. The model can be extrapolated to photosphere. The group led by Martin Asplund observed that the photospheric abundances deduced in this manner are somewhat higher than the abundances deduced from the direct observations [E7] (http://tinyurl.com/y4bmbjzg) .

A possible explanation would be that part of the nuclei in the solar core are dark [L103]. Assume that the fraction of ordinary nuclei in the solar core is what standard model of nuclei predicts. One can of course criticize this assumption. If so, the dark fraction of abundances would bring in an additional contribution visible in the description of helioseismic waves in the model and would increase the effective abundances in the core. As one moves to the surface of the Sun, the dark abundances would be reduced and one obtain the abundances deduced from the spectroscopy of the photosphere.

6.4.8 Some consequences

The possible reshuffling of nuclear physics can have rather dramatic consequences.

1. Standard stellar models cannot explain the presence of nuclei heavier than iron. One proposal is that they are born is supernova explosions in so called r-process based on neutron capture (http://tinyurl.com/hs3x3se). Supernova SN1987A did not support this hypothesis.

   Also the abundances of light nuclei Li, Be, B are problematic. Their production in the stellar cores is predicted to be very meager. Their abundances are however high and Li is essential for life. Could CF be responsible for their production outside stellar core. Even ^4He on ongelmallinen ja on myös CNO ongelma [L120] (http://tinyurl.com/v7chztc and http://tinyurl.com/tk9vk6b).

2. Should one reformulate the ideas about pre-stellar evolution? Could it be that CF has served as "warm-up band", which has liberated nuclear energy, generate nuclei with various masses from hydrogen, and gradually raised the tempature so high, that ordinary nuclear reaction become possible.

3. CF outside stellar cores is possible. What could be the situation in the planetary cores? Usually one thinks that when planet is born, the heavy metals in of proto-planet fall do the core of the planet. Could one think that the metals in the core have born via CF. Could the Fe core of Earth be due to this kind of process? What about the matter in the crust? What about meteorites.

4. Could one think production of heavier elements based on CF? Could it have happened spontaneously and produced ore bodes. What comes in mind is Oklo fissio reactor (http://tinyurl.com/l3h6t9v), which is the only known spontaneously formed nuclear reactor at Earth. Could CF have served as "warm-up band" and make possible fission reactions in matter already containing heavy nuclei.

The mechanism of CF and nuclear fusion could be universal and have very general consequences for the understanding of physics in TGD Universe. The notions of magnetic flux tube, hierarchy of effective Planck constants, ZEO based view about state function reduction (SFR), and quantum criticality (QC) of TGD Universe are the essential elements.

1. QC in the initial state would make possible flux tube contacts of small energy between reactants with various lengths as analog of long range fluctuations. This would break the limitation due to the short range of nuclear forces and Coulomb wall and is an essentially new element missing from standard nuclear physics. The values product $h_{eff}\Lambda$ would be constant for the flux tubes in the superposition and $h_{eff} > h$ would be true.

2. At the next step the breaking of QC would be induced by the increase $\Lambda_i \rightarrow_f > \Lambda_i$ of the Λ for flux tubes predicted by twistor lift of TGD [L65] increasing their string tension. The resulting force would attract reactants together and classically would allow to overcome the Coulomb wall so that the reaction could proceed.

   The energy to increase Λ and string tension for the flux tube energy would come from reactants: essentially an analog of metabolic energy would be in question.

The reduction $h_{eff,i} \rightarrow h_{eff,f} < h_{eff,i}$ would liberate the energy and lead to a shortening of the flux tube allowing to overcome Coulomb wall. After this quantum criticality would prevail again: $(\Lambda_f, h_{eff,f}) \rightarrow (\Lambda_i, h_{eff,i})$.

The mechanism is basically the same as in bio-catalysis [L77], where the energy wall hindering the reactions corresponds to Coulomb wall. The key step is the increase of Λ for long flux tubes. By fractality of TGD Universe this same mechanism could apply also at the level of hadron physics with meson exchange replaced by this mechanism, and also at the level of M_{89} hadron physics defining a scaled up version of ordinary hadron physics emerging at the quantum criticality against what was expected to correspond to color de-confining phase transition. M_{89} hadron physics predicts scaled variants of ordinary mesons for which LHC produced considerable but forgotten evidence as bumps with predicted masses [K66, K67]. Even application to catastrophic astrophysical events such as creation of supernovae and blackholes and their time reversal meaning birth of stars could involve the same mechanism [L91].

6.4.9 How TGD could help in the development of CF nuclear technology?

What help could TGD provide in the development of CF-technology. TGD of course provides only a theoretical vision and a lot of theoretical work would be needed to develop it and experimentally test it. TGD could however already in its recent form provide a possible intuition to innovate technical ideas.

1. The production of dark nuclei by phase transition changing ordinary matter dark would be the basic step. Ordinary nuclei would be emerge spontaneously after the reduction of h_{eff}. Both steps would involve BSFR and here a lot of yet non-existing theoretical understanding would be needed. Quantum criticality is second basic idea and also here one must learn a lot. Ordinary criticality accompanies quantum criticality and its role should be understood.

2. CF involves a self-organization process so that energy feed is involved and here several options can be considered. One should find the most effective and most precisely targeted manner to feed energy. In electrolysis the energy is fed via electric field and is perhaps not the best manner to do it. Here also Pollack effect might be involved. Leclair has proposed cavitation as an effective manner to feed energy. The collapse of an acoustically oscillating vapour bubble could liberate energy to build dark nuclei and also lead to sono-fusion [K24].

3. How to harvest the liberated energy most efficiently? The transition to ordinary nuclei should take within reactor volume. If the flux tubes formed are too long, the dark nuclei could leak out of the system and transform to ordinary nuclei outside the system [K24]. The flux tubes assignable to dark nuclei seem to be relatively short but they could be located inside long flux tubes made possible by quantum criticality. LeClair talks about microjets (`http://tinyurl.com/oopu3p2`) and suggests that their birth in cavitation accompanies CF (`http://tinyurl.com/y786gy89`). Leclair has also claimed that fusion products were formed in their experiments at rather large distances from the reaction volume and that the distribution for the isotopes resemble the distribution for r-process in which neutron capture produces nuclei heavier than Fe.

   The dark nuclei in microjets have positive charge and could be attracted by and collide with a negatively charged metal surface. Here one cannot avoid the association with the experiments carried out by Tesla using a voltage critical against dielectric breakdown (quantum criticality). The charged particles were detected in scales considerably larger than the size of the laboratory. Could one test an arrangement, in which positively charged dark nuclei can propagate along flux tube and collide with negatively charged metal targets and transform to ordinary nuclei and liberate their energy?

   One should understand the (topological) dynamics of magnetic flux tubes. In Holmlid's experiments [L48] the length between nucleons along flux tube was of order electron Compton length. The recent view suggests that the radius of flux tubes connecting D nuclei was given by nucleon size scale rather than electron Compton length but what was the typical length of the flux tubes determining the mass number of dark nucleus?

6.5 The implications of .5 MeV and 3.5 keV monochromatic lines for TGD based nuclear model

Very interesting popular article (http://tinyurl.com/scuddeg) in Nature tells about very interesting new results found by Safti *et al* [E10] (http://tinyurl.com/um3jreb). The findings challenge the prevailing particle physics view about existence of galactic dark matter halo and consisting of some exotic new particles behaving like dark matter. These findings add to a long list of negative results related to the existence of dark matter halo and the attempts to find predicted dark matter particles.

There are two observed candidates for particles what would form the speculative galactic dark matter halo. They would have as decay products monochromatic gamma rays at energy of around .5 MeV and 3.5-keV X rays having no standard identification. The recent findings exclude the possibility that these particles reside in the conjectured galactic dark matter halo. They could however reside in galactic centers so that their existence is not challenged.

The detailed consideration of these findings led to an unexpected further progress in TGD based vision about nuclear physics summarized in [L117]. A correct prediction for the energy of 3.5 eV line in terms of cyclotron transition emerges, and also the .5 MeV line is predicted correctly in terms of TGD based nuclear physics [L4, K24, L103] [L117].

It also turns out that TGD inspired nuclear physics provides an explanation for 1 MeV electropion as a scaled down variant of electroweak pseudoscalar P for which evidence as 96 GeV bump exists. Muonic and tau leptopions would correspond to higher families of P. Also other weak bosons as also gluons would have higher families [K66, K67] as suggested also by the evidence for the breaking of universality of standard model interactions. The p-adically scaled down electroweak bosons would appear as flux tube bonds between nucleons in nuclear string model [L4, L117]. In particular, a pseudoscalar having interpretation as X boson with mass about 17 MeV is also predicted.

CVC and PCAC hypothesis, M^8-H duality, and p-adic length scale hypothesis support the view that hadron and nuclear physics could allow a description dual to QCD like picture in terms scaled down weak interaction physics. This picture finds concrete quantitative support. Several p-adic length scales would be involved and the active scale would depend on interaction energy.

6.5.1 .5 MeV gamma ray signal

There is an old gamma ray signal from Milky Way at gamma ray energy of slightly more than electron mass. It has been proposed that it results as dark particle and antiparticle almost at res with respect to each other annihilate. Now it seems that the interpretation as in the proposed sense seems to be excluded.

One can of course, why not a particle which has mass nearly twice the electron mass could not decay to two gamma rays. For some reason this option haven not been experienced as interesting.

1. Support from the existence of pseudo-scalar with this mass emerged already at seventies but because it did not fit witht he standard model picture it was forgotten. Later evidence for a particle with masses twice the mass of muon and tau lepton with similar interpretation emerged. For the same reason also these pieces of evidence were forgotten.
2. TGD led long time ago to what I call lepto-pion hypothesis [K115] (http://tinyurl.com/vr2ynhp). In TGD color is not spin-like but angular momentum-like quantum number. Color correspond to the analog of angular momentum for the analog of rigid body rotation in CP_2 degrees freedom. In particular, TGD allows colored excitations of leptons: for instance, electron could appear in color octet state. Color excited electron and positron might form a pion-like color confined pion with mass very nearly 2 times electron mass. Same for muon and tau.
3. These states could be dark in the sense that they have non-standard value of effective Planck constant $h_{eff} = n \times h_0$. This would explain why they are not produced in the decays of Z^0 boson and therefore do not affect its decay rate. Otherwise Z^0 and W decays widths exclude leptopions.

4. This darkness has however nothing to do with the darkness of galactic matter, which reside as energy and possibly dark matter at long very cosmic strings to which linear structures formed by galaxies can be assigned. These cosmic strings can locally thicken to flux tubes and liberate energy as particles forming galaxies. They generate radial gravitational force predicting the flat velocity spectrum of distant stars.

TGD picture would explain why these particles have not been observed outside galactic nucleus. It also turns out that TGD inspired nuclear physics provides an explanation for 1 MeV electropion as a scaled down variant of electroweak pseudoscalar P for which evidence as 96 GeV bump exists. Muonic and tau leptopions would correspond to higher families of P. Also other weak bosons as also gluons would have higher families [K66, K67] as suggested also by the evidence for the breaking of universality of standard model interactions. The p-adically scaled down electroweak bosons would appear as flux tube bonds between nucleons in nuclear string model [L4, L117].

6.5.2 3.5-keV X ray signal

Can one imagine any standard physics identification for the 3.5-keV line?. An interesting atomic physics based identification is as X ray emitted in the capture of electron by sulphur ion with principal quantum number $n \geq 9$, which is rather high (`http://tinyurl.com/w9jaqvv`this and `http://tinyurl.com/r6uvwlb`). This requires plasma at temperature of order 3 keV plus cold dense cloud moving at few hundred km/s .

3.5-keV X rays appearing as an un-identified mono-chromatic line in X ray spectrum have been proposed to result from the annihilation of dark particles having mass about 7 keV: annihilation of inert neutrinos is one proposal. The experimental findings exclude the possibility that these X rays are produced in the proposed galactic halo. TGD suggests two alternative explanations based on the notion of monopole flux tube.

1. In TGD framework also 3.5-keV X rays could result in a decay of pion-like state with mass of 7 keV. TGD indeed predicts new nuclear physics in keV scale.

   As a matter fact, TGD leads to a new vision about nuclear physics on basis of model of "cold fusion" [L4, L117, L103] (`http://tinyurl.com/s8gzrfe`) . Magnetic flux carrying monopole flux serve as basic building bricks also now: TGD Universe is indeed fractal.

2. Nuclear string model [L4, K24, L103] relies on the assumption that nuclei are sequences of nucleons connected by pionlike bonds - loopy flux tubes much longer than the M^4 distance between nucleons. These loopy flux tubes have length of order electron Compton length are essential for the TGD based model of nuclear reactions [L117] and also of "cold fusion" [L54].

3. This model allows to consider two options concerning the interpretation of 3.5-keV line.

   Option I: These flux tubes would be like pions with mass about 7 keV decaying to two X rays with energy 3.5-keV. They might be produced even in nuclear physics laboratory. Also now darkness in TGD sense ($h_{eff} = n \times h_0 > h$) is essential and one can talk about dark nuclei.

   In the annihilation of pion like bond to X ray pair, fission of the nucleus would take place. There is no dependence on environmental parameters like temperature.

   Option II:

   The 3.5-keV energy could correspond to a cyclotron transition of for a light quark with mass scale of E=5 MeV assignable to the flux tube having cyclotron energy of this order of magnitude. [Recall that cyclotron frequency is determined by the radius of the monopole flux tube and from the quantization of magnetic flux assumed to be minimal plus the from the fact that $B_{end} = .2$ Gauss for electron is .6 MHz].

   In this case however the pion-like long flux tube bonds between nucleons would have mass about 2 quark masses, which would be of the order of nuclear binding energy of order E rather than being in keV range. The energy differences for subsequent states at nuclear IR Regge trajectories assignable to nucleons are predicted also to have energy of order E. Both the intra-nucleon bonds and inter-nucleon bonds would have the same mass scale. The model for nucleus constructed recently [L117] (`http://tinyurl.com/s8gzrfe`) however assumed that the mass scale for the bond is keV. The masses of ibonds ncreasing mass could be compensated by downwards shifts at IR Regge trajectories of nucleons.

The cyclotron transitions emitting 3.5-keV X ray would naturally correspond to the return to the ground state after thermal excitation. Temperature would correspond to thermal energy of order 3 keV. The line intensity depends on the temperature of environment.

Remark: For Option I the cyclotron energies for quarks with masses in keV range would be of order eV, which is also predicted to be a nuclear energy scale in the proposal for TGD based nuclear physics discussed in [L117].

4. The intensity of 3.5-keV lines depends on environment. This excludes Option I but saves Option II. For instance, it is known that 3.5 keV line is associated with galactic clusters and galactic nuclei but not with spheroidal dwarf galaxies with little or no star dust, no recent star formation, and low luminosity (`http://tinyurl.com/wh8lcx4`) . The presence of plasma at temperature of order 3 keV distinguishing between these options seems necessary. This temperature is possible for several astrophysical X-ray sources (`http://tinyurl.com/te9e7rq`. Also celestial sources such as the surfaces of stars with surface temperature of this order of magnitude are possible (for Sun the surface temperature is 3 orders of magnitude lower).

   The temperature of order 3.5 keV makes possible for hot fusion to start- in solar core the temperature is 1.5 keV) so that 3.5 keV line could serve as a signature for regions, where star formation is beginning. In TGD framework, where dark fusion explaining "cold fusion" serves as a "warm-up band" for hot fusion, this correlation is especially natural.

5. One should be able to predict correct value of the cyclotron energy with natural assumptions. The loopy flux tube would correspond to $k = 127$ for electron. The endogenous magnetic field carrying monopole flux corresponds to $B_{end} = .2$ Gauss assignable to $k = 167$ flux tube. The cyclotron of $f_e = B_{end}/m_e$ of is electron $f_J = 6 \times 10^5$ Hz for $h_{eff} = h$. f_e is scaled up by a factor $2^{20} \simeq 10^{12}$ in the replacement $k = 167 \to 127$.

   Proton cyclotron frequency is scaled $f_p = (m_e/m_p)f_e$. For proton cyclotron energy one obtains $(h_{eff}/h) \times (m_e/m_p) \times (g_p/2) \times f_J$. Proton has magnetic oment $\mu_p = 2.79e/2m_p$. For $h_{eff}/h = 2^{11}$ this gives $E_{c,p)} \simeq 3.78$ keV, which is sligthly higher than 3.5 keV. If one has $h_{eff}/h \simeq m_p/m_e \simeq 1876$ one obtains 3.46 keV quite near to 3.5 keV! For $h_{eff} = h$ one have in this case 1.8 eV so that eV scale emerges and would correspond to the cyclotron energy of single sheet of covering. Therefore proton's cyclotron energy for $h_{eff}/h \simeq m_p/m_e$ or electron's cyclotron frequency for $h_{eff} = h$ could be in question in B_{end} scaled up from $k = 167$ to $k = 127$.

   For neutron the dipole momenta is $\mu_n = -1.91 \times e/2m_p$ and cyclotron energy would be $E_{c,n} = 2.46$ keV, which might be a testable prediction. Cyclotron energy per single sheet would be $E_{c,n} = 1.31$ eV.

6.5.3 Questions raised by the interpretation of 3.5-keV signal

These interpretation of 3.5-keV signal raises several questions.

1. The earlier proposal has been that nuclear neutrons could correspond to pairs of proton and pion-like flux tube carrying negative charge. The observation above forces to ask whether the intra-nucleon flux tubes carry electrons and have $h_{eff} = h$. Could nuclear proton transform effectively to neutron by the presence of flux tube carrying electron so that the idea about neutrons as pairs of proton and electron-neutrino pair could make sense inside nuclei.

2. Could also interpret the bonds as scaled down analogs of weak bosons? I have actually considered the possibility of scaled down variants of electroweak gauge bosons earlier in the model [L50] for the so called X boson anomaly [L50, C68]. The inspiration for this came from CVC *resp.* PCAC hypothesis relates the conserved vectorial *resp.* partially conserved axial electroweak currents to strong interactions. This hypothesis is encouraged also by $M^8 - H$ duality strongly suggesting that QCD type description provides the quark-gluon description at high energies at the level of $H = M^4 \times CP_2$ and $M^8 = M^4 \times E^4$ description provides the description of hadron physics in terms of $O(4) = SU(2) \times SO(3)$ symmetry group acting as isometries of E^4 of old-fashioned hadron physics appearing in CVC and PCAC.

   What is important is that weak bosons would be effectively massless below the scaled up weak scale $L(127)$, and depending on the situation also to some other scales as p-adic length scale hypothesis suggests, and being as strong as electromagnetic interactions below this scale. Could one interpret strong interactions in hadronic and nuclear scales as scaled-down weak interactions?

This hypothesis combined with p-adic length scale hypothesis is very powerful and can be tested.

1. Higgs boson with mass 125 GeV would correspond to $k = 89$. Higgs mass would be minimal possible if p-adic mass squared is of order $O(p)$ so that real mass squared is $m_R^2 = 1/p$. Contrary to the long-held expectations W and Z bosons with standard values of Weinberg angle naturally correspond to $k = 90$ if pure U(1) boson would have Higgs mass.

   TGD predicts also pseudo-scalar variant of Higgs. For $k = 90$ the minimal mass would be 88 GeV. LHC has observed a bump at about 96 GeV (`http://tinyurl.com/yyqwlh44`), and this could correspond to pseudo-scalar Higgs, call it P, and assume its mass is indeed 96 GeV. The masses of weak bosons would be therefore $(m(H), m(P), m(W), m(Z)) = (125, 96, 80.4, 91.2)$ GeV and masses for other p-adic length scales follow by simple scaling.

2. The masses of Higgs and W and Z bosons with same Weinberg angle for $k = 127$ would be obtained by scaling with a factor $2^{(-127+k)/2}$, $k = 89$ for Higgs and $k = 90$ for P, W and Z. This would give $(m(H), m(P), m(W), m(Z)) = (.238, .129, .11, .12)$ MeV. What is nice is that these scales are considerably below the nuclear binding energy scale about 7-8 MeV per nucleon for heavier and 1.1 MeV for D so that one could indeed assign nuclear binding and excitation energies to the nucleon flux tubes as proposed in [L117].

This raises questions.

1. Could also the intra-nuclear flux tube bonds have scaled-down weak boson masses but with different p-adic length scale? Can one regard the electrons in these bonds effectively as free electrons as far as cyclotron energies are considered? Could the old-fashioned hadron physics at least partially reduce to weak interaction physics below electron Compton length and possible other p-adic length scales assignable to the flux tubes involved?

2. Intra-nucleon flux tubes have been assumed to have intra-nucleon binding energy scale about 7-8 MeV (1.1 MeV for neutron-proton pair)? The proposal is that binding energy scale corresponds to the energy scale of IR Regge trajectories for nucleons and is thus single nucleon property (or that of the MB of nucleon). Nuclear strings would be strings formed from ^{4}He strings a units, possible D type string, and lonely nucleons (protons or neutrons depending on the sign of $Z - N$.

   Nuclear binding energy scale 7-8 MeV would be assignable to the MB of nucleons of ^{4}He and of heavier nuclei and 1 MeV energy scale to the MBs of p and n in D. The binding energy scale and energy scale of excitations would be determined by the p-adic length scale assignable to the intra-nucleon flux tubes and depending on environment via the value of k defining the p-adic lengths scale.

3. What would this mean p-adically? The scaling of weak boson masses with mass scale .1 MeV to larger mass scale should correspond to that for the binding energy scale and give binding energy scale 1 MeV for D and 8 MeV for ^{4}He.

   (a) Consider first 1 MeV scale assignable to intra-nucleon flux tubes in D. $k = 127 - 6 = 121$ would give $(m_H, m_P, m_W, m_Z) = (1.90, 1.06, .877, .8)$ MeV. The mass of P is quite near the D binding energy 1.11 MeV.

   A connection with lepto-hadron hypothesis [K115] (`http://tinyurl.com/vr2ynhp`) suggests itself. For $k = 121 = 11^2$ the mass of P would be 1.06 MeV and very nearly twice the electron mass 1.022 MeV. The mass of the electr-pion proposed to explain the pseudo-scalar resonance observed in heavy ion collisions is very very near to $2m_e$. Could electro-pion identified as a pair of color octet leptons correspond scaled down P? Also evidence for muon-pion and tau-pion exists. Could these correspond to higher generations of weak bosons predicted by TGD?

   Recall that there were to alternative interpretations for 3.5-keV line as cyclotron energy of proton with $h_{eff}/h \simeq m_p/m_e$ or of electron with $h_{eff}/h = 1$. The interpretation of the flux tube as electro-pion/P selects the latter interpretation. This modifies the model of "cold fusion" [L117] based on quantum criticality and the model of bio-catalysis, and also explains why the flux tubes with radius about electron Compton length are of special importance as the work of Holmlid shows [L48] [L48]. One would have $h_{eff}/h \simeq 2^{11}$ for the quantum critical flux tubes with nanometer length scale central also for TGD inspired quantum biology and giving rise to dark variant of DNA as dark nuclei consisting of dark proton sequences [L122]. This would also explain biofusion [C33, C150] as a special case of "cold fusion". Note that the magnetic field strength would be smaller by factor 2^{-11} by the reduction of the length scale dependent cosmological constant Λ and cyclotron energy would be same. A deep connection between biology and nuclear physics would emerge.

(b) What about 7-8 MeV scale? $k = 113$ is basic candidate for nuclear scale and the corresponding masses would be scaled by factor $2^7 = 128$ giving $(m_H, m_P, m_W, m_Z) = (30.5, 16.5, 14.1, 15.4)$ MeV. These scales are too large by a factor of order 2 that $k = 111$ looks more appropriate.

4. There exists evidence for so called X boson with mass of 17 MeV [L50, C68]. One interpretation would be in terms of pion like state which could corresponds to the electroweak pseudo-scalar predicted by TGD. The mass of $k = 113$ P-boson would be 16.5 MeV and quite near to X boson mass. This would suggest that several p-adic length scales are indeed possible. This interpretation can be tested by checking whether other exotic bosons in this range exist.

To sum up, the TGD inspired model for nucleus predicts correctly the 3.5-eV X ray energy as cyclotron energy with using the earlier assumptions of the model. Also other predictions and tests follow. For instance, the model could be tested by irradiating nuclei in laboratory using 3.5 eV X rays and looking whether this has effects. For instance, nuclear decay rates could be affected.

What $M^8 - H$ duality together with CVC and PCAC suggests and the above observations quantitatively support is that p-adic length scale hierarchy could allow a description of hadronic and nuclear physics in terms of p-adically scaled down variants of weak interactions such that the value of k for weak bosons would depend on the energy scale of the strong interactions.

Chapter 7

Comparing Electric Universe hypothesis and TGD

7.1 Introduction

I have encountered the notion of Electric Universe (EU) several times during the years. Rational Wiki (see `http://tinyurl.com/y847jn6w`) describes EU as pseudoscience claiming that the formation and evolution can be better explaining by electricity and magnetism than by gravity alone as the standard belief goes. Aether is also reported to be part of the theory and have elements from mythology.

One must be however very cautious with these kind of highly negatively emotional articles pretending to represent balanced and objective scientific statements. The words crank and crackpot appeared quite too often in them, and when the entire article is collection of emotionally negative associations about people behind EU than the contents of EU itself, one knows that this is not science.

I have become during last 42 years very familiar with people calling themselves "skeptics" and therefore I decided to to take a more analytic approach and concentrate on "than in terms of gravitation alone". This tells the reductionistic motivations of the author. Author has decided cosmology and astrophysics can be described in terms of gravitation only: the proposal that electromagnetism could be involved, is pseudoscience. The article is only part of battle between different world vires. It is already now clear that one day "gravitation alone" hypothesis will be regarded comparable to the aether hypothesis.

7.1.1 Could we learn something from EU and the work of SAFIRE team

What EU (see `http://tinyurl.com/y847jn6w`) really claims. There is of course no unique EU but collection of models. Rather, it claims that electromagnetism, in particular plasmas, are central for the understanding of galaxies and astrophysical objects, in particular nuclear fusion. The Electric Sun model (see `http://tinyurl.com/y2mm8cjg`) assumes that astrophysical objects derive their main sources of their power electrically. That gravitation would not be needed at all is only an extremist claim. To me the claim that nuclear physics is not needed, looks unrealistic.

The lucky instance, is that the experimental work of SAFIRE team (see `http://tinyurl.com/y2ae9tar` and `http://tinyurl.com/y2ae9tar`) to be discussed in the sequel concentrates only on question whether nuclear fusion can be achieve in plasma system and the conclusion is that nuclear transmutations occur. This does not mean that nuclear physics is not needed. What it however implies that the recent view about nuclear physics is wrong also also the phenomenon dubbed as "cold fusion" or "low energy nuclear reactions" (LENR) has demonstrated [L54, L48, L27]. Nuclear physics of solar core has been also plagued by a very serious anomaly for 10 years now [L103].

Could we take a less emotional approach and look whether we could learn something - open-mindedness if not anything else - from the people labelled with "EU"? I had luck: I received two extremely interesting links from Wes Johnson to videos describing purely empirical and experimental physics. Nothing about mythology, aether, or anything like that but two highly inspiring videos allowing to see what science as a process of discovery is. This is something totally different from what I have seen SUSY and superstring theoreticians doing last four decades. It is about what is there in the real world, concrete numbers and correlations, discovery of physical anomalies. Something different from infertile games with braney worlds, multiverses, blackholes, etc. and endless production of hype.

It was clear from beginning that these videos provide further applications for the TGD view about cosmology and formation of galaxies and smaller stellar objects.

7.1.2 TGD view about classical fields

TGD does not assume aether but neither does it assume that gravitation alone is enough for understanding cosmology and astrophysics. In TGD both gravitation and long range electromagnetic fields are in crucial role. Nuclear physics is part of TGD but TGD view from it differs in some crucial aspects.

TGD leads to a new view about classical fields differing from the views of standard model and General Relativity (GRT).

1. The notion of field is generalized by induction procedure. All classical fields are expressible in terms of 8 coordinates of 8-D embedding space $H = M^4 \times CP_2$ and their gradients. General coordinate invariance reduces their number to 4 effectively. This means enormous reduction in local field like degrees of freedom. The extreme complexity of many-sheeted space-time compensates for this reduction and space-time is topologically complex in all scales.

   This does not reduce gravitation to electromagnetism as EU claims: rather both gravitation, electromagnetism and actually electroweak and color interactions are reduced to the geometry of space-time surface via the notion of the induced gauge field and metric. The induction of spinor structure does the same for spinor fields.

2. Standard model and GRT emerge at QFT limit when space-time sheets are replaced with single region of M^4 made slightly curved. The replacement of many-sheeted space-time with Einsteinian space-time however means enormous loss of information. In particular, the information about magnetic flux tubes is completely lost. This loss of information makes description of systems like living matter extremely difficult.

3. In primordial cosmology Einsteinian picture does not work even as approximation. At this limit space-time surfaces can be idealized by what I call cosmic strings having 2-D M^4 projection and behaving like strings for most practical purposes. Ironically, string like objects are present in all scales in TGD, not only something in Planck length scale. The tragedy of superstring models is easy to see: people had so enormous hurry to guarantee the call from Stocholm that they did not have time to realize that strings must be generalized to 3-D objects having interpretation as both particles and 3-space - depending on the scale.

7.1.3 Cosmic strings thickening to flux tubes as basic element of TGD based cosmology and astrophysics

Cosmic strings carrying monopole fluxes bring a lot of new elements to cosmology and astrophysics and solve the numerous problems of "gravitation only" approach.

1. These cosmic strings, in particular those carrying monopole flux possible due to the non-trivial topology of CP_2 thicken gradually to flux tubes, which are central element of TGD view about formation of various structures, in particular galaxies, stars, planets, and even smaller objects.

   They are present in all scales: also in quantum biology, biochemistry, chemistry, molecular physics, atomic physics, nuclear physics, hadron physics. In all scales new phenomena are predicted and it has been fascinating to realize that the experimental physics is producing anomalies in all these branches of physics and really stunning to realize that theoretical physicists could not be less interested.

   Also in cosmology and astrophysics they are crucial and without them one cannot understand cosmological constant, the notion of dark matter and energy, the formations mechanisms of galaxies, stellar object, stars, and even smaller objects. "Gravitation alone" is not enough.

2. The twistor lift of TGD predicts that cosmological constant depends on p-adic length scale and become extremely small in cosmological scales but very large in short scales. This solves the basic problem of cosmology due to the gigantic value of cosmological constant also due its wrong sign which eventually killed string models.

   During cosmological evolution phase transitions reducing the value of cosmological constant occur leading to an accelerated expansion since volume energy is reduced. This sequences of jerks replaces smooth cosmological expansion of standard cosmology and solves the mystery due to the fact that astrophysical objects co-expand but do not seem to expand themselves. Smooth cosmic expansion is replaced with a sequence of jerks involving accelerating and slowing down periods.

   The reason is that magnetic contribution to string tension is reduced in thickening but volume energy increases so that one has acceleration followed by slowing down leading to a stationary situation. This expansion transforms the energy of flux tube identifiable as dark energy/dark matter to ordinary matter and is counterpart for inflation but occurring in all scales.

3. The model for galaxies as tangles along long cosmic strings predicts that the thickening of flux tube in the tangle generates ordinary matter. This explains the flat velocity spectrum of stars around galaxies as being due to the gravitational field of long string, and also the galaxies apparently without dark matter as galaxies formed around short circular cosmic strings. The model allows to solve the accumulating anomalies of halo model based on dark matter identified as some exotic particles.

4. The local jerks have counterpart even at the level of Earth and the TGD inspired Expanding Earth model predicting that in Cambrian Explosion the radius of Earth increased very rapidly by a factor of 2 can be regarded as this kind of jerk [L76]. This leads also to an explanation of Cambrian Explosion and a model for the evolution of prebiotic life as occurring in underground oceans shielded from cosmic rays and meteoric bombardment and preventing the oxygen from leaking to outer space. The splitting of core of Earth to inner core and rotating outer core generated ordinary magnetic field making possible atmosphere.

5. TGD suggests also that dark matter identifiable as $h_{eff} = n \times h_0$ phases and dark energy identifiable as magnetic and volume energy of flux tubes are by quantum classical correspondence (QCC) one and same thing basically. More formally, QCC implies that the eigenvalues for fermionic representations of Cartan algebra generators as Noether charges - observables - are same as the values for classical Noether charges. In particular, energy, momentum and angular momentum.

From this picture it is clear that in TGD Universe both gravitation and electromagnetism - or more generally the physics of induced electroweak and color fields is crucial for understand the formation of astrophysical objects.

7.1.4 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L41].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = 8\pi^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as$\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L41] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L83].

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see `http://tinyurl.com/k4bwlzu`). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.
2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \sim 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L48, L54]: this requires $h_{eff} \sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

   The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L103] (see `http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.
3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see `http://tinyurl.com/y5ukv2wt`) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?
4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see `http://tinyurl.com/y3n78tjs`)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

7.1.5 TGD view about craters of Moon and findings of SAFIRE team

This article is a commentary of the mentioned two videos from TGD point of view.

1. The first video told about craters of Moon and I learned that existing theories, about which I found representations in Wikipedia too, are full of anomalies. I could not find anything obviously pseudoscientific in the representations apart. Since I have a habit to concentrate on content than social clues, I realized only later that the killer label EU assigned with these both videos.

   It was immediately clear that TGD based model for "cold fusion", another branch of evolving science labelled as pseudoscience but already now led to a developing technology, can be scaled up to describe the formation of craters.
2. Second video was about experiments done by SAFIRE team. They forget theoretical prejudices and just try to look whether Sun can be created in laboratory. Sun would be spherical

electrode with positive charge surrounded by similar electrode with opposite charge and there would be strong electric field between them. The video told about the discoveries made also by "cold fusion" people: transmutations producing elements with higher isotope number are found to occur. Do transmutations occur everywhere and is nuclear fusion in solar core only one part of the story? This is the question that also TGD raises.

It must be emphasized, that these videos represent only two examples of the continual stream of anomalies having immediate explanation in TGD framework. Some time ago I had learned that even the cherished nuclear physics has had a very serious anomaly for a decade [L103]: the model of cold fusion [L54] [K24] based on TGD view about dark matter and the notion of monopole magnetic flux tube generalizes to a model of nuclear reactions and of Sun itself explaining this anomaly too. Only few weeks ago I had learned that the magnetic field of Mars behaves very weirdly: popular article used the word "magnetic madness" [L93]. Some days ago I learned about evidence that Earth's surface 600 million years was without details such as rivers and lakes: this fits with the Expanding Earth hypothesis [L76]. I learned also fascinating and strange facts about earthquakes and volcanic eruptions providing an applications for zero energy ontology based view about state function reduction in macroscopic length scales [L96].

7.2 What created the craters of Moon and other celestial bodies?

I received from Wes Johnson a link to to a Youtube video of Space News: Electric Universe titled "*Our Lightning-Scarred Moon-The Evidence Grows*" (see `http://tinyurl.com/y3bsgevu`). Very briefly: the basic message is that in case of Moon the basic theories for the formation of craters assuming impacts and volcanism as mechanisms are challenged by a large number of anomalies. It is also claimed that the theory assuming electric discharges - lightnings- as a cause is consistent with the data.

The video was highly interesting and I listened it through several times and the following is my attempt to summarize what I learned and how the model based on electric lightnings can be formulated in TGD framework. Actually a generalization of a model formulated for what happens in "cold fusion" as dark nuclei transform to ordinary ones, is in question. The formation of craters could involve "cold fusion" and a kind of nuclear explosion.

7.2.1 Standard view about the formation of craters

Consider first what mainstream science says about the formation of craters. Impacts and volcanism would be the basic mechanisms. Most of craters would be however due to impacts.

1. According to Wikipedia article (see `http://tinyurl.com/7vnrysd`), the cratering records of very old surfaces, such as Mercury, the Moon, and the southern highlands of Mars, record a period of intense early bombardment in the inner Solar System around 3.9 billion years ago. This is actually hypothesis known as late bombardment hypothesis.
2. The Wikipedia article about craters in Moon (see `http://tinyurl.com/y2ja9qjg`) states that most craters in Moon are impact craters. The number of craters in Moon and Mars is many orders of magnitude larger than that of impact craters in Earth. A natural explanation is that geological processes have destroyed the craters and very few from time before 500 million years are known (happens to be the time of Cambrian explosion [L76] (see `http://tinyurl.com/yc4rgkco`) about which I have talked a lot).

7.2.2 Anomalies of the standard model

The video argues that the properties of craters of Moon are not consistent with either hypothesis.

1. The sizes of craters can be enormous. Moon has a gigantic crater which has radius of 25000 km and is 390 km deep. It is one of the largest craters in solar system. Impact theory predicts that there should be material bursted from the mantle to the surface. The material is shocked and melded and there is no material from mantle as volcanic hypothesis would require (data are from Apollo mission).

2. Why Moon should be so heavily cratered? The hypothesis that so called late heavy bombardment (see `http://tinyurl.com/y6hx2q3b`) period 4.5-3.8 Gy ago lasting for 20 -200 million years gave rise to the impacts producing the craters. Asteroids have been assumed to have caused the impacts. The video mentions an article claiming that asteroids are not probable cause. The modified hypothesis is that remnants from the formation of planetary system caused the impacts.

3. The craters are highly circular and can form sequences. There are also smaller craters at the rims of the craters bringing in mind fractal structure: vortices containing vortices containing....

4. Also very long rilles very different from lava tubes at Earth are found and often start from the circular craters. Rilles have sequences of craters within them. The rilles can be very long, much longer than at Earth: the longest rille is 185 km long. Just the opposite should be the case, since the heat loss in very thin atmosphere should be faster than at Earth with insulating atmosphere so that the rilles should be shorter. There is no rubble at the bottom of rilles as at Earth. The rilles can be directed uphill rather than downhill as in hydrodynamic and lava flows. Rilles also disappear instantaneously. The rilles dwindle suddenly, which does not support the idea that lava flow caused their formation by "eating" the surface material. Rather this, suggest a sheet like structure entering the surface as giving rise to the rille. In the case of the highly circular craters a tube like structure meeting the surface orthogonally suggests itself.

5. Also glass spheres and chondrules and minerals formed at very high temperatures are found in craters. Amusingly, crop circles [K38, K39] (see `http://tinyurl.com/y32n3qwc` and `http://tinyurl.com/y4mawmqh`) involve also glass spheres and the model that propose for their formation decades ago would be the same as the model to be discussed for the formation of craters.

6. The near side of Moon less cratered than far side. There are even hexagonal craters. At Mars there is hemisphere dichotomy with southern hemisphere containing more craters.

7.2.3 Electric discharge model

Consider the model based on electric discharges argued to be consistent with all data.

1. Immanuel Velikovsky proposed that cosmic lightnings between planets and Moons created the craters of Moon Mainstream has labelled Velikovski as pseudoscientist. Carl Sagan has written a rather civilized critic (see `http://tinyurl.com/yxfzae93`) of Velikovski's ideas concentrating on content rather than direct personal insults. On basis of his vision Velikovski predicted remanent magnetism in lunar rocks. Nowadays the magnetic field is very weak. This remanent magnetism has been observed.

2. The crucial discovery by Brian J. Ford was that the electric discharges in lab applied also in industrial processes produce structures very similar to those observed in Moon. The ratio of sizes of largest to smallest craters is the same in Moon and in Mars. In particular, the craters produced in electric discharges are extremely circular. The document claims the electric discharge hypothesis is consistent with all findings about craters in Moon.

3. R. Juergens studied the rilles appearing in many scales and starting typically from the craters. They were originally called cracks and proposed to be formed by a flow of water or lava across surfaces or beneath the ground. Juergens found however that high energy electric discharge is favoured as a model. Lava and water cannot explain the features of rilles already listed like craters along rilles whereas electric discharges reproduce these features.

7.2.4 TGD based model

If the arguments of the document are true, the proposal must be taken very seriously. It seems incredible that mainstream could neglect so serious anomalies but I have seen this to happen in particle physics for decades. So: suppose that one take the claims seriously. What could be TGD explanation?

1. Monopole magnetic flux tubes carrying dark matter - perhaps dark nuclei as dark proton sequences is of course what comes first in mind. The flux tubes carrying the dark nuclei as dark cosmic rays could be associated with solar wind and are proposed to form a part of a bigger network allowing cosmic rays to propagate between galaxies, stars and smaller astrophysical objects. This would be a cosmic analog of blood circulation [L103, L96] (see `http://tinyurl.com/yyjy5e2r` and `http://tinyurl.com/y23qczau`).

   Flux tubes have flux tubes within flux tubes that mathematical connection between incompressible liquid flow and magnetic field would allow to understanding the various structures as analogs of hydrodynamic tubules having vortices within vortices fractal structure.

2. In the collision with ground the dark nucleus formed by dark nucleon sequence nucleons would transform to ordinary nucleons and liberate practically all nuclear binding energy [K24] [L54] (see `http://tinyurl.com/y7u5v7j4` and `http://tinyurl.com/y2v3qn6a`) . The event would be like a nuclear explosion and this could explain why the effect is so large. This would be "cold fusion" event in macro scale. "Cold fusion" is known to involve formation of craters in micro scale and it would interesting to see whether the situation are scaled versions of each other.

   Also flux sheets are possible and the long rilles could correspond to these. Flux tubes inside flux tubes and inside flux sheets are possible and could give rise to fractal craters. This explanation would mean that also electric discharges in laboratory give rise to nuclear transmutations producing heavier elements as happens also in "cold fusion". This predictions could be tested in lab.

3. From Wikipedia article (see `http://tinyurl.com/7vnrysd`) one learns that ores often accompany craters and an interesting question is whether the craters formed in this manner give rise to ores.

4. What one can say about these monopole flux tubes carrying the dark nuclei to Moon. Most naturally they would be dark flux tubes associated with solar wind bringing cosmic rays. Earth does not have this kind of craters and the number of impact craters is small. The simplest explanation is that geological and atmospheric processes have caused the erosion of these structures. This is proposed as an explanation for the very small number of impact craters in Earth (190), whereas their number in Moon, some planets and their moons is much larger due to the absence of atmosphere.

   It is also possible that reconnections of solar flux tubes with the flux tubes of dark magnetic field associated with the Moon (planet or its moon) is involved and leads to the event! Also the flux tubes of dark magnetic fields of planets and Moon (moons of planets) could take place.

One can test the hypothesis is consistent with the TGD inspired version of Expanding Earth model [L76] (see `http://tinyurl.com/yc4rgkco`).

1. The model assumes that Earth had radius, which is half of the recent value before Cambrian explosion and same as the recent radius of Mars. Then came geologically fast expansion (jerk in sequence of fast expansions reducing the value of length scale dependent cosmological constant replacing smooth cosmic expansion in TGD Universe) and the life that had evolved in underground oceans below Earth's surface bursted to the surface and oceans were formed.

2. The assumption that the situation at Earth was the same as in Mars before the expansion [L93] (see `http://tinyurl.com/yxzye6xu`), would explain the finding that the surface of Earth seems to have lost various details like rivers and lakes about 600 million years ago preceding Cambrian explosion about 512 million years ago.

   If the surface of Earth was like the surface of Mars now it would have been full of craters formed by electrical discharges due to the solar wind. This does not kill the model. The presence of erosion due to the emergence of atmosphere and biosphere would explain the absence of these craters at the surface of recent Earth. At the bottom of oceans formed in the expansions they would be automatically absent. Inside tectonic plates signatures of their presence might be found.

3. The recent Earth is shielded by van Allen belts. If the van Allen belts consisted of dark flux tubes, they should have been present also before expansion and shielded Earth from cosmic

rays and solar wind by guiding it to the Earth's interior. This would have brought ions and dark photons into the underground oceans and made possible the evolution of multicellular life capable of photosynthesis.

7.2.5 Strange glass spheres in the Moon

According to the Eurekalert article (https://cutt.ly/3CWde6M), translucent glass globules have been found on the Moon in a study led by Dr. Zhiyong Xiao (Planetary Environmental and Astrobiological Research Laboratory, School of Atmospheric Sciences, Sun Yat-sen University), who is a core scientific team member of the first in-situ lunar mission to the Moon, Chang'E-4.

1. The team examined images taken by the panorama camera onboard the Yutu-2 rover, and discovered several translucent spherical and dumbbell-shaped glassy globules (see the images in https://cutt.ly/3CWde6M). Perching on the surface regolith, the globules are transparent to translucent, and they exhibit a light brownish color. Such centimeter-sized translucent glass globules are not found on the Moon before and their presence was unexpected.
2. This kind of glassy globules were found also by Apollo astronauts and their size was also below 1 cm but they were mostly opaque and clast rich, which means that the glass crystals are accompanied by some other material . The sizes of tektites found at the surface of Earth, believed to be produced in terrestrial impact events, are opaque and have sizes ranging from micrometers (microtektites) to a few centimeters. They are believed to be produced in impact events creating craters.

There is an alternative theory explaining the formation of craters in planets and Moons related to the notion of the Electric Universe (see http://tinyurl.com/y3bsgevu). Electric Universe in its extreme nothing-but-version claims that electromagnetism determines everything even in astrophysical scales and that one can forget gravitation, whereas the standard view is that gravitation determines everything.

In the TGD framework, both gravitation and the analog of electromagnetism are key players in astrophysics. In particular, the Kähler magnetic flux tubes carrying monopole flux are predicted to be key players in all scales from biology to the formation of galaxies and stars. This explains anomalies such as the existence of magnetic fields in cosmic scales and also the stability of the Earth's magnetic field.

1. The craters, and also glass spheres, could be due to strong electric currents flowing between planets rather than due to the collisions of meteors and meteorites. Lightning strikes could cause these strong currents. Volcanic lightning is indeed known to cause the formation of glass spheres (see https://cutt.ly/wCWsKSM). I have discussed both the standard view and the lightning theory for the formation of craters from the TGD point of view [L89].
2. If the electric currents arrive orthogonally to the surface of the planet, this theory explains various anomalies such as the fact that craters are disk-like. For collisions of meteors one would expect all elliptic shapes depending on the arrival angle. This theory could also explain the glass balls.
3. In the TGD framework, these currents could consist of very high energy dark matter particles (dark in the TGD sense, and thus having $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0 \geq\geq \hbar$, $\beta_0 = v_0/c \leq 1$, arriving along monopole flux tubes of Kähler magnetic field to the surface and liberating energy as they transform to ordinary particles. This would generate a high temperature, which would melt the quartz and produce the glass spheres and dumb-bell like objects. The large value of h_{eff} at flux tubes implies a very low rate of dissipation, which would explain the association of relativistic electrons and gamma rays with lightnings. In the atmosphere, they would rapidly lose their energy.
4. The gravitational Compton length associated with particles of mass m is given by $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0 = r_s/2\beta_0$ and does not depend on the mass of dark particle (Equivalence Principle). If M is the Earth's mass M_E, one has $\Lambda_{gr} > .45$ cm. Intriguingly, this is the size scale of the glass spheres found on the Moon and of tektonites found on the Earth.

   Moon mass is 1.2 percent of M_E so that the size scale would be above 45 μm, the size scale of a cell, for the gravitational flux tubes assignable to the Moon. The size scale of one centimeter would suggest that the monopole flux tubes of the Earth's magnetic field extends at least to the Moon, whose distance from Earth is about 30 Earth radii.

Interestingly, the size scale of snowflakes is also this and the explanation could be based one gravitational quantum coherence predicted to be possible in arbitrarily long scales [L163, L161].

The same mechanism could explain the reported and published finding of glass spheres around crop circles [H17, H15, H12, H2, H16, H24, H5] available at `https://cutt.ly/CCWvMFR`.

1. I have discussed crop circles from the TGD point of view [K38, K39]. The high temperature explains boiling, which has occurred for the crops (like for a tomato in a microwave oven) would make possible the formation of crop circle. Meteoric iron has been found in the glass balls and could have arrived along magnetic flux tubes and originate from a meteorite arriving in the atmosphere.

2. In TGD, the magnetic bodies (MBs) consisting of momopole flux tubes and sheets with a very large value of h_{eff} equal to h_{gr} would be intelligent entities controlling various biosystems. Quite generally, h_{eff} would serve as a measure of algebraic complexity and the level of intelligence in TGD based view of consciousness and cognition based on number theory [L64, L63].

   Even crop fields would have MB. The charged meteoric iron could have ended up in the monopole flux tubes of the MB of the crop field, accelerated in the electric field parallel to flux tubes, and ended up to the surface of Earth and made the MB visible as a crop circle. An alternative idea is that the crop circles are purposefully manufactured by a higher intelligence using this mechanism. Crop circles could be analogous to neural representations but in crop fields instead of brains. The large value of h_{gr} for flux tubes is the same as for living matter in general and could explain why crop fields can have aspects, which bring to mind the brain. The conscious intelligence would however reside at the level of MBs.

   These flux tubes would connect astrophysical objects, even galactic blackhole-like objects to distant stars and make the Universe a kind of neural network.

7.2.6 Why do meteors always land in craters?

Why do meteors always land in craters? I encountered this innocent layman question on Face Book and from the TGD perspective it looked brilliant. I did a web search and found this question at some pages accompanied by strong emotional responses in style "craters are of course made by meteorites, you idiot!".

This is of course true and one must formulate the question more precisely. One must characterize meteor crater by size. Suppose that smaller craters assigned to meteors indeed have a tendency to appear inside larger craters. One would have a fractal like structure.

What is known about the size destribition of meteor craters and its correlation with the distribution of their locations? Is the fractal structure only an illusion: is it easier to spot the crateres if they are inside craters? Or is this tendency real? I do not know for certain but I can make what-if... questions.

I have proposed a model for the craters created in meteor collisions based on the TGD view of the magnetic body of a planet, say Earth [L89].

1. The model was inspired by an anomaly: the meteor craters seem to favor meteor orbits orthogonal to the surface of the planet so that the craters tend to look like circular disks rather than ellipsoids.

2. The craters assigned with meteor collisions could be created by matter, which arrives along magnetic flux tubes roughly perpendicular to the surface of the planet. Part of the material of the meteor could end up as dark, possibly charged, matter at the magnetic flux tubes or bundle of tubes. Since the friction and electric resistance of the dark matter inside the flux tube are much smaller than for ordinary matter, dark particles could achieve very high energies before collision with Earth. This would also explain the gamma rays and ultrahigh energy electrons associated with lightning.

3. If the magnetic flux tube bundles form rather stable structures with fractal flux tubes inside flux tubes inside ... inside flux tubes, which emanate from larger craters, the meteors or the material created in their decay could tend to land in craters. This hypothesis should be testable. For instance, could lightnings have tendency to be associated with craters?

One exotic application of the idea relates to the observation that the craters in the Moon are accompanied by glass spheres [L89]. Also the crop circles, which any real academic physicist of course regards as pseudoscience, involve glass spheres suggesting very high temperatures created somehow [K38, K39].

7.3 The findings of SAFIRE team as support for dark nucleosynthesis

I got from West Johnson a highly interesting link to a video providing a representation about the experimental work done in SAFIRE project (see `http://tinyurl.com/y548t9qk` . The motivation is so called Electric Universe model, which I see as unrealistic but the work itself was purely experimental. The mainstream claim, which can be found in Wikipedia is that these scientists are crackpots. To my best understanding this claim is simply an intentional lie. This conclusion is not difficult to make on basis of what I have been experienced during these four decades of TGD. The world view is changing: the old memes defending themselves against new memes desperately and the end justifies the means.

One must of course be extremely cautious. Nuclear transmutations are in air, so to say. This is because mainstream nuclear physics has had for a decade profound anomaly associated with solar nuclear synthesis: the abundances deduced in solar interior differ from those deduce from spectroscopy and meteorites [L103] (see `http://tinyurl.com/yyjy5e2r`). It is difficult to believe that TGD would be totally unknown in physics community although there is politically motivated total silence about TGD leading to even comic manifestations. When it begins to look plausible that certain theory might provide a breakthrough at the level of entire world view, it might lead to over-reactions. However, Electric Universe seems to be the theoretical background of SAFIRE project and it is very different vision as compared to TGD.

7.3.1 What SAFIRE team is studying?

What SAFIRE group is doing?

1. SAFIRE team is studying plasma (see `http://tinyurl.com/yxkw334n`). They are not doing it in garage, a big laboratory is in question, and the researchers have academic credentials.
2. One has two electrodes - positively charge inner spherical electrode and outer negatively charged spherical anode. This gives rise to a strong electric field. Various gases are in the atmosphere, in particular hydrogen: (see `http://tinyurl.com/y4cxohp3` for the Youtube video). Electric discharge is created and electric currents run in the voltage. The situation is like in electrolysis. The temperatures is rather low: around 100 degrees Celsius.

   Note that in cold fusion experiments one has a situation in which hydrogen atoms are absorbed in the cathode. Plasma is created in this kind of situation and one looks what happens by measuring all kinds of observables. One can study what happens at the surface of the anode, one can study the plasma atmosphere say by measuring the voltage and doing optic spectroscopy.

7.3.2 What SAFIRE team observed?

SAFIRE team observed several phenomena challenging the existing views about plasmas.

Occurrence of nuclear transmutations

For me the most interesting topic of the talk (see `http://tinyurl.com/y4cxohp3` for the Youtube video) were nuclear transmutations. "Cold fusion" model based on magnetic flux tubes containing dark matter as $h_{eff} = n/timesh_0$ phases predicts just what has been observed. It was really amazing to see direct experimental verification of the most radical predictions of TGD: things are going really fast now.

1. One of the basic predictions of TGD are nuclear transmutations. They observe nuclear transmutations at low temperatures than believed and production of energy. Essentially this is observed also by "cold fusion" experimentalists [?]see http://tinyurl.com/y7u5v7j4) and http://tinyurl.com/y2v3qn6a).

2. Energy production was claimed. The ratio of the output power to input power seemed to me incredible. Dark nuclear fusion predicts in optimal situation very large COP but in the "cold fusion" experiments the COP is of order 2-3 typically. If I understood correctly, it was now something like 10 or even more. Maybe I misunderstood.

3. The experimentalists do not know the mechanism involved and there is no such mechanism in standard model Universe. In TGD Universe it would be the formation of dark proton sequences - dark nuclei - transforming to ordinary nuclei and liberating essentially nuclear binding energy. In fact, also ordinary nuclear reactions would also proceed by the formation of dark nuclei as intermediate states: this replaces tunnelling phenomenon as mechanism in TGD Universe [?]see http://tinyurl.com/yyjy5e2r). A long list of elements produced in transmutations was claimed: C, O in the second row; Na, Mg, (Al,Si), P, S, Cl in the third row; K, Ca, Ti, Zn in the fourth row; Sn in the fifth row; Ba in sixth row; and La in the eigth row of the periodic table. Al and Si are not certain since they could have contamined.

4. It was also claimed that SAFIRE produces by transmutations just those non-organic atoms that are observed in interstellar space. If true, this would support the TGD based proposal that part of elements is formed in interstellar space besides solar cores. If both are involved, the abundances from both should be very similar. If nuclear transmutations involve only the production of dark proton sequences transforming to ordinary nuclei whereas ordinary nucleosynthesis in Sun would involve also the fusions of ordinary nuclei by generating dark nuclei as intermediate states, it is is not clear whether this is the case.

5. The flux tubes carry also electric fields parallel to them in average sense and charges along them can accelerate to high energies. Second point is that dissipation is very slow due to the large value of h_{eff}: this brings a completely new element into the picture. The dark protons and ions at flux tubes can accelerate to very high energies. This would explain for instance the production of very high energy electrons in lightnings: would they accelerate to unexpectedly high energies in the electric field of Earth prevailing also inside flux tubes. By the way, I am still not sure whether gravitational flux tubes can be regarded as monopole flux tubes.

The phenomena at the surface

Consider first the phenomena observed at the surface of anode. Highly interesting were the pictures about the microscopic structures involved. They brought in mind the craters on the surface of Moon (see http://tinyurl.com/y6yqtdj7). The mechanism would be the same - TGD Universe is fractal.

The balls of size in micron scale formed by elements were one very interesting detail that should be understood. Some kind of micro-crystallization happening in cooling of liquid or vapour phase of elements fromed by dark fusion mechanism could be in question. In the talk this is suggested to be very much analogous to gravitational phenomenon. The propolals relies on the EU hypothesis that gravitation reduces to electromagnetism and the belief that plasma phenomena are purely electromagnetic. Note that micron scale corresponds to biological length scale.

Was the transformation to ordinary nuclei quantum coherent process as I have proposed on basis of large h_{eff} and occurred for a bundle of flux tubes simultaneously? - these bundles are actually part of the h_{eff} hypothesis. The motivation was the observation of Holmlid [L48] that even kaons with masses in 500 MeV range were produced! The production of so large energy quanta is not possible without large scale quantum coherence since nuclear binding energies are in MeV range. h_{eff} is proportional the number of flux tubes in bundle [L79] (see http://tinyurl.com/yy88v35d) .

The formation of double plasma layers

The formation of self-organized double plasma layers in the atmosphere around anode formed from double layers was also reported. The layers have opposite charges at their boundaries. Double layers represent a standard phenomenon in plasma physics (see `http://tinyurl.com/y52s3a32`.

1. The thickness of the double layer is of order 10 Debye lengths $\lambda_D = 1/k_D$,

$$k_D^2 = (4\pi)^2\alpha q^2 n\lambda_{th} \qquad \lambda_{th} = \frac{n\hbar}{T} \ . \tag{7.3.1}$$

   n is the density of screening ions, q their charge using e a unit, and $\alpha = 4\pi e^2/\hbar \simeq 1/137$ is fine structure constant (I have used units with $((c = 1, k_B = 1))$. λ_{th} is thermal Compton length telling the distance below which macroscopic quantum phenomena are possible.

2. Debye length is the distance over which charge is screened in plasma in the units used. λ_D is few centimeters in the ionosphere, few tens of meters in the interplanetary medium, and tens of kilometers in the intergalactic medium. Note that the formula is purely classical in the sense that $\hbar$ disappears from it.
3. In the layer the electric field is strong that outside it because of the polarization. The temperature T inside double layer is higher than outside it because of acceleration and dissipation of charges in the electric field. These double layers bring in mind cell membranes and polarization over cell membrane. Also a negatively charged layer very near to the positively charged anode has been observed.
4. So called dark mode was mentioned and the behaviour of electric voltage as function of distance for dark mode and glow mode with visible atmosphere were compared. If I understood correctly, the plasma becomes invisible in dark mode. What could this mean in TGD Universe? Could a phase transition transforming ordinary photons to dark photons be in question? Or is the rate for the transformation of dark photons to ordinary photons for some reason much slower in the dark mode? Could this rate be proportional to h_{eff} and could dark mode have larger h_{eff}.

7.3.3 TGD based model for the findings

In the following the basic building bricks of TGD based model are described and then a model for the formation of the spherical crystals is considered.

Some applications of the TGD view about dark matter as starting point

It is good to start with the basic building bricks provided by existing applications of the vision about dark matter as phases of ordinary matter labelled by the hierarchy of Planck constants

1. Nottale [E9] [K96, K78, K10] was the first to propose the expression $h_{eff} = nh_0 = \hbar_{gr} = GM_Dm/v_0$ for the gravitational Planck constant assignable to gravitational flux tubes. Here M_D is some large dark mass. v_0 is a parameter with dimensions of velocity: for the 4 inner planets of Sun $\beta_0 = v_0/c \simeq 2^{-11}$ gives a satisfactory estimate for their radii as radii of Bohr orbits.

   $\hbar_{gr}$ must be used when its value is larger than $\hbar$: one motivation is that Nature itself guarantees the convergence of the perturbation series by making a phase transition increasing the effective value of Planck constant. This transition can be interpreted as a change of the space-time topology: one can say that it becomes n-sheeted structure. A more detailed view is that one has $n = n_1n_2$, where n_1 is the number of sheets over CP_2 and n_2 over M^4. Sheets over CP_2 would correspond to parallel flux tubes.

   For gravitation the parameter $GMm/\hbar_{gr} = \beta_0$ appearing in perturbation series is smaller than 1. The integer n has concreate topological interpretation in terms of space-time topology [L79] (see `http://tinyurl.com/yy88v35d`) . This formula has rather obvious generalization to the electromagnetic case.

   How to identify the large dark mass M_D? $M_D = M_E$ is the naïve first guess. On the other hand, the application to the fountain phenomenon in super-fluid in turn suggests $M_D \sim 10^{-4}M_E$.

2. In accordance with Equivalence Principle the gravitational Compton length $\lambda_{gr} = GM_D/v_0 = 2r_s/\beta_0$ does not depend on m at all and also cyclotron energy $E_c = \hbar_{gr}ZeB/m$ is independent of m. In TGD inspired quantum biology this would guarantee that the cyclotron energies of all charged particle generate same molecular transitions in UV and visible range.

   $\lambda_{gr} = 2r_S(M)/v_0$ looks like a natural parameter for the size scale (radius) of the layers and corresponds to the same scales as the system itself (say anode). For $M_D = M_E$ one would have $r_s(M_E) \sim 1$ mm. $v_0 = 2^{-11}$ (true for Sun and inner planet flux tubes) would give $\lambda_{gr} \sim 4$ m. For $M_D \sim 10^{-4}M_E$ suggested by the model of fountain effect of super-fluidity one would have $\lambda_{gr} \sim r_S$. Could the value of M_D be determined by the condition $\lambda_{gr} = r_S(M)$? This is however not the case for Sun.

   If this picture makes sense, quantum gravitation could be central element of plasma phenomena regarded usually purely electromagnetic in contrast to EU hypothesis stating just the opposite. Later it will be found that quantum gravitation could be essentials also for phenomena like crystallization.

3. The model for the quantal effects of ELF radiation on vertebrate brain involves the assumption about the presence of "endogenous" magnetic field $B_{end} \sim 2B_E/5$, $B_E = .5 \times 10^{-4}$ Gauss is the nominal value of the Earth's magnetic field strength. Is B_{end} is associated with the gravitational flux tubes or with monopole flux tubes and can gravitational flux tubes be monopole flux tubes. I cannot answer this question definitively. In any case, since the magnetic field should consist of monopole flux tubes and those assignable to the ordinary magnetic field, B_{end} can correspond to the monopole fluxes.

   Dark ions are not only an essential element of the effects of ELF em fields on vertebrate brain but of entire TGD inspired quantum biology [K85, K86]. What makes ion dark and how do they relate to the dark variants of atoms/ions explaining Pollack effect and "cold fusion"? The vision has been that dark atoms/ions differ from ordinary atoms/ions in that their magnetic body has dark part with non-standard value of h_{eff}. The value of Planck constant should be large: perhaps the gravitational part of the magnetic body is dark having Planck constant $h_{eff} = h_{gr}$.

4. Also the thermal Compton length $\lambda_{th} = \hbar_{gr}/T$ is expected to be relevant and is very large for large values of h_{gr}. For instance, at room temperature one has $T \sim 10^{-2}$ eV and $\lambda_{th} \simeq 10^{-4}$ m. Bio-applications suggest that EEG frequencies - say $f = 10$ Hz - correspond to energies $E = h_{gr}f$ above thermal energy of 10^{-2} eV and having $\lambda \sim 10^{12}$ Hz giving $\hbar_{gr}/h \geq 10^{11}$. This would correspond to $\lambda_{th} \sim 10^7$ m which is of the order of the Earth's radius. This length scales could correspond to the size scale of gravitonic Bose-Einstein condensate. Note that the effective value of fine structure constant is scaled down to keep so that the Debye length is unaffected.

"Cold fusion" and Pollack effect represent situations in which the value of h_{eff} is not so large and might be assignable to flux tubes mediating electromagnetic interactions.

1. The dark protons in "cold fusion" have essentially the same Compton length as electrons from the findings of Holmlid [L48, L54], which would suggest that analogs of hydrogen atoms are formed as neutral bound states of dark protons and ordinary electrons. This generalizes: further scaling of h_{eff} for protons can be accompanied by similar scaling for electrons to guarantee local charge neutrality. Similar local neutralization mechanisn applies to dark DNA identified as dark protons sequences and ordinary DNA [L70].

   For "cold fusion" h_{eff} would be about $m_p/m_e \sim 2^{11}$ and much smaller than h_{gr}. Therefore the flux tubes assignable to the dark atom cannot be gravitational flux tubes although dark atom flux tube can reside inside gravitational flux tube. One would have two kinds of flux tubes: do they correspond to the monopole flux tubes and non-monopole flux tubes predicted by TGD and which is which?

   The binding energy of dark nuclei is scaled down by $1/h_{eff}$. The proposal is that this is due to the lengthening of the flux tubes of the magnetic body of nucleons mediating nuclear interactions. Nuclei would look like plants: the nucleus would be like the seed or root and magnetic body would correspond to the visible part of the plant. Parts of magnetic body could become dark by the change of h_{eff} from the standard value.

2. Dark nuclei formed in Pollack effect [L24] [L24] would be dark proton sequences but with a value of h_{eff} differing from that in cold fusion. If also weak interactions become dark, their rate is comparable to that for em interactions below the scaled up weak length scale h_{eff}/M_W and one can say that electroweak symmetry breaking is absent. Could the dark proton sequences transform to dark nuclei by dark weak decays $p \rightarrow n + e^+ + \nu_e$. Could the resulting stable dark nuclei correspond to stable ordinary nuclei?

Thermodynamical anomalies as apparent breaking of second law and causal anomalies due to the change of the arrow of thermodynamical time are predicted by ZEO based view about macroscopic quantum jumps requiring also large value of h_{eff}, and might be observable in the system studied.

A model for the formation of spherical micro-crystals

TGD encourages to consider the possibility that all self-organization process are basically quantal [L102] and even more, involve the increase of the effective Planck constant $h_{eff} = n \times h_0$ requiring energy feed. If the interpretation of transmutations in terms dark nuclear fusion is correct, the energy needed would come from this. Self-organization would be associated with the long range quantum coherence at dark magnetic flux tubes in turn forcing non-quantal long range coherence of the ordinary matter realized now as a double layer.

Concerning the values of h_{eff} the situation is far from understood. The values of h_{eff} label the flux tubes mediating various interactions and one can talk about gravitational Planck constant h_{gr} and electromagnetic Planck constant h_{em}. The TGD based model for "cold fusion" leads to a concrete identification of Planck constant involved, and one might call it nuclear Planck constant or assign it with dark color interactions. Flux tubes can be also classified according to whether they carry monopole flux or not. Therefore the applications involve guesswork.

1. The formulas for the Debye length and thermal Compton length give some idea about the self-organization process involved. Debye length is purely classical notion having no dependence on Planck constant and characterizes ordinary matter: this scale defines naturally the thickness of the layers. If dark matter and ordinary matter are in thermal equilibrium, the value of thermal Compton length is scaled up by $\hbar_{eff}/\hbar$ for which the estimate is $\hbar_{eff}/\hbar = n/6$ [L42]. Dark thermal Compton length $\lambda_T = \hbar_{eff}/T$ would define one quantum scale.

2. EU theory assumes that electromagnetism is enough to understand the situation. In TGD however quantum gravitation plays key role in living matter and perhaps also in self-organization in long length scales. This motivates the notion of gravitational Planck constant $h_{eff} = h_{gr}$ assignable to the flux tubes mediating gravitational interactions (it is not clear whether they are monopole flux tubes carrying net magnetic flux or not) - to be distinguished from the flux tubes mediating em interaction and having much smaller value of h_{eff}. One can also talk about h_{em}, h_{weak} and h_{strong}.

3. TGD predicts also scaled up Compton lengths of dark variants of particles proportional to h_{eff}. In particular, dark gravitational Compton length associated with gravitational Planck constant $h_{gr} = h_{eff}$ having no dependence on particle mass is predicted.

The talk claims that the formation of balls with radius about few microns - biological scale - looks like a gravitational phenomenon: the idea would be that gravitation reduces to plasma physics. In TGD framework the claim is that gravitation is involved with plasma physics thought to be a purely electromagnetic phenomenon.

Spherical micro-crystals are quite general phenomenon and the natural guess is that the balls are micro-crystals. This would suggests that crystallization in general could involve quantum gravitation in an essential manner.

1. The thermal Compton length λ_{th} for the ordinary value of Planck constant is of order 10^{-5} m at room temperature: not far from the size scale of the balls. This is a possible clue but will not be followed in the sequel. The thickness of the flux tubes for B_{end} is few microns. This inspires some guesses concerning the formation of the balls having also radius of this order of magnitude.

2. Suppose that the balls are formed from dark atoms as they transform to ordinary atoms. What dark atoms could be? Pollack effect suggests that dark protons rather than dark hydrogen atoms reside at flux tubes. Dark proton sequence could be accompanied by a neutralizing sequence of ordinary electrons. If this is the case, one can talk about dark atoms.

   Could the dark atoms in this sense with $h_{eff} \leq\leq h_{gr}$ reside at the gravitational flux tubes with $B = B_{end}$ having $h_{eff} = h_{gr}$ and make a phase transition to ordinary atoms condensing to form spherical micro-crystals with size scale of the thickness of the gravitational flux tube? h_{gr} is proportional to the mass of the atom so that given ball characterized by h_{gr} would consist of single type of atom and one would indeed obtain mono-crystals.

3. Quasicrystals cannot be formed by crystal growth as realized by Penrose, who suggested that the formation takes place by macroscopic quantum transition. This kind of transitions are a general TGD based prediction and one of the latest applications is to earthquakes and volcanic eruptions [L96] involving in an essential manner zero energy ontology predicting the observed causal anomaly.

   Could the formation of all crystals quite generally involve quantum gravitation and identifiable as a macroscopic quantum jump and involve the proposed selection mechanism putting atoms with different mass numbers to different flux tubes like books with different topics in library as I have suggested earlier? Note this would make living matter a well-organized library instead of random soup of biomolecules.

7.3.4 How stars and planets could have formed?

In the second part of a talk a proposal for how stars and planets are formed was discussed.

1. It was essentially TGD view except that they did not talk about monopole flux tubes and tangles along them: the natural possibility is that tangles have structure analogous to that of flux lines of dipole magnetic field.

2. One of the basic conjectures of TGD is that stellar interiors are not the only places, where elements are produced. They could be produced by "cold fusion" everywhere and the craters would provide direct evidence for this. The dark currents going along flux tubes to the interior of planets and smaller objects coming from Sun along flux tube network could be in crucial role and give rise to dark nuclear fusion.

3. Electromagnetic fields in long length scales are essential for the formation of the planets and their chemistry. But I do not see purely electric universe as a realistic option. Gravitational fields are also central and the role of gravitational Planck constant assignable to gravitational flux tubes having huge values is in key role in TGD. But also "gravitation alone" approach has failed. What makes electromagnetic fields equally important is the existence of monopole magnetic flux tubes and the hierarchy of Planck constants.

Chapter 8

Solar Metallicity Problem from TGD Perspective

8.1 Introduction

For ten years ago it was though that Sun isa well-understood system but more precise computations demonstrated a problem. The metallicities deduced from spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data as described in the Annual Review of Astronomy and Astrophysics by Martin Asplund *et al* [E7] (see `http://tinyurl.com/y4bmbjzg`), who were pioneers modelling solar surface as 3-D structure rather than idealizing it with 2-D structure.

Calculations of metallicities and their comparison with the helio-seismological results are discussed in [E43] (`http://tinyurl.com/yyxw9bpn`). The abundances used are determined from meteorites and these estimates are more accurate and are consistent with the values determined by Asplund *et al* and used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund *et al* would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic?
2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismological data. The earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

8.1.1 Is there something wrong with the standard solar model?

I received interesting links to a couple of popular articles (see `http://tinyurl.com/y4zxmdqz` and `http://tinyurl.com/y52clelq`) suggesting that the physics of solar core, where nuclear fusion is assumed to take place, might not be quite what it is believed to be. Here is the abstract of the first popular article:

Analysis of sound and light transmission from solar surface using a new 3-D model instead of the standard 2-D standard model suggests that the chemical composition of the Sun is far different from what has been assumed. There appears to be significantly less elements heavier than hydrogen than had been estimated using obsolete models that use calculations assuming completely flat surface for the Sun. Sun's missing metals means that there is a large mass, several billion megatons, of material that is unaccounted for. One possibility that has been suggested is that the Sun's core may be comprised dark matter - a source of mass that exerts gravitational force and does not interact in the same way that ordinary matter does.

The popular article talks about 1500 Earth masses of missing matter particles heavier than hydrogen and helium so that the amount of missing mass would be about $M_D \sim 8 \times times 10^{27}$ kg, perhaps dark matter. Solar mass is about $M(Sun) = 2 \times 10^{30}$ kg. The fraction M_D/M would be $M_D/M \sim 4 \times 10^{-3}$. This missing mass is obtained if the metallicities deduced from the spectroscopy are indeed correct.

Just to check that there are no mis-understandings, one can estimate the missing mass in core by using the fact that in the core (see `http://tinyurl.com/nrcojr2`) has about 34 per cent of solar mass and the reduction of metallicity 1.3 per cent deduced from the earlier value 1.8 per cent is .5 per cent. This gives the estimate $M_D/M \simeq 1.7 \times 10^{-3}$, which is roughly 1/2 of the estimate.

The metallicity deduced from spectroscopy is 1.3 per cent, and helio-seismology gives metallicity of 1.8 per cent. Who is right: spectroscopists or helio-seismologists? Or could both be right: could the very notion of metallicity used by them be actually different?

1. The first option is that spectroscopists are right and that there is some form of matter in the core not behaving like ordinary matter and has different opacity and acoustic resonances. The higher the metallicity, the higher the opacity since metals absorb light. The exotic state of of matter should have higher opacity and absorb light more effectively so that it would give too high metallicity in standard model for the core.

   If so, the amount of elements heavier than Helium could be what 3-D spectroscopy predicts. There is some empirical support for this expectation from the opacity measurements for Fe at temperatures and pressures expected to prevail in solar core by Jim Bailey working at Sandia National Laboratories in New Mexico (see `http://tinyurl.com/y5fp4fhk` and `http://tinyurl.com/yxqtpe34`).

   The model introduced by Vincent *et al* [E47] discussed in popular article (see `http://tinyurl.com/y68p4lqb`) assumes the missing matter to be dark matter with rather exotic and implausible-to-me properties. If I have understood correctly, the model of Vincent *et al* claims that if the abundances in the interior are indeed lower if there is a dark mass about $M_D \sim 10^{27}$ kg in the core of the Sun giving $M_D/M \sim 2^{-11}$.

2. Second option would be that helio-seismology gives a correct estimate for the metallicity and that that the extrapolation of the spectroscopic data obtained from the surface layer of Sun to interior is somehow wrong. Also this brings also in mind some new physics: what comes in mind in TGD framework is many-sheeted space-time and magnetic flux tube structures with non-standard value of effective Planck constant $h_{eff} = nh_0$.

3. The third option is that both spectroscopists and helio-seismologists are right and that metallicity means different thing for them. TGD based model for cold fusion on the vision about dark matter as hierarchy of $h_{eff} = nh_0$ phases predicts the possibility of dark nuclei. Spectroscopists measure only the abundance of ordinary dark matter but helio-seismologists measure also the contribution of dark nuclei present in core and perhaps also in convective zone to metallicity.

8.1.2 More precise statement of the problem

Consider now a more precise statement of the metallicity/abundance problem. This problem can be seen a problem of the entire astrophysics since the model of Sun is extrapolated to deduce the structure other stars from the spectroscopic data. Estimates for the metallicity and abundances of elements heavier than He in Sun can can be deduced in several way.

1. One can deduce metallicity by spectroscopy based on emission and absorption lines at solar surface and here the work of Martin Asplund and his group developing 3-D models for the atmosphere of Sun (photosphere,chromosphere, and solar corona) has been of utmost importance and deduce that the metallicity should be 1.3 per cent. This model also gives for the thickness of the convection zone a value smaller than older approach approximating the surface with 2-D structure.

2. Metallicity can be deduced also from helio-seismology by studying the oscillations of Sun allowing to deduce information about the inner structure of Sun. This gives metallicity of about 1.8 per cent consistent with the earlier 2-D model. For instance, it was found that the

light from the Sun suggests that it had about 20 to 25 per cent less C, N, and O than thought previously. These findings contradict the data from helio-seismology which can deduce precise information about the abundances of elements heavier than helium since they affect the sound wave propagation within the star.

Earlier 2-D model however agrees with helio-seismological data. Ironically, a more precise model for the solar atmosphere leads to a conflict with other data. Could the approximation of solar surface as 2-D structure be better than 3-D description for some reason: in TGD framework one can ask whether the notion of many-sheeted space-time - in particular p-adic length scale hypothesis) suggesting layered structure - could somehow relate to this. This does not look plausible.

3. Metallicities can be also deduced very accurately from meteorites and these abundances are in good accordance with the the 3-D model and are used in the comparison. This gives support for the model of Asplund but means that meteoritic abundances would be lower than those expected in the solar interior on basis of standard solar model.

4. A further approach is based on solar neutrinos (see `http://tinyurl.com/yy5ewynp`). This approach gives a result consistent with 1.8 per cent. The model of solar neutrinos is very sensitive to metallicity.

It seems that without new physics one has a paradox.

8.1.3 Possible approaches to the problem

One should explain the conflict between the two determinations of metallicities. The first option would be that the spectroscopic determinations give correct result. The optical and acoustic properties of the matter in the core could however differ from those assumed in standard model. Due to unexpectedly high opacity of the core the metallicity determined from standard helio-seismology would be too high. Also acoustic characteristic should be different. The many-sheeted space-time of TGD and the notion of magnetic body could provide concrete ideas in this respect.

Second possibility is that there is a new physics mechanism increasing the rate of production of nuclei as one goes deeper. Even more, the produced nuclei could exist in some exotic states not possible outside solar interior. If a production mechanism involving some new physics exists, one can wonder whether it could allow to understand the nuclear abundances outside stars in the framework of standard model.

1. Standard model has already a problem with elements heavier than Fe. The generation of elements heavier than Fe in stellar interiors is not possible, and one proposal has been that they are generated in supernovas but this model has not received empirical support (see `http://tinyurl.com/y74rh5rw`).

2. If the abundances of elements heavier than He are small in solar core, then also the elements lighter than Fe could pose a problem. Super-nova explosions should scatter elements lighter than Fe to interstellar space and their amount in interstellar space could be smaller than predicted by the standard model. Could the fusion of these elements take place also outside core or even in interstellar space?

TGD based model of "cold fusion" relies on the notion of dark nucleus [L54]. Could also dark nuclei be possible inside Sun and contribute also to metallicity? The paradox would dis-solve due to the different notion of metallicity used outside Sun and in the interior of Sun. TGD based view about quantum tunnelling essential for the modelling of solar fusion indeed predicts that both ordinary and dark nuclei are in kinetic equilibrium inside solar core at least.

The model proposed by Aaron Vincent

Could the dark matter model proposed by Aaron Vincent *et al* [E47] (see `http://tinyurl.com/y68p4lqb` and `http://tinyurl.com/yy5ewynp` relate to ZEO based model? The weird looking assumption of the model is that the dark particles in question would have higher probability of having collisions with larger energy and momentum transfer than those with small energy transfer. In the hot solar core these dark particles would get heated and then propagate to cooler parts of Sun and in interactions with would provide very effectively their energy to ordinary.

I must admit that I do not really understand the argument leading to the increase of the metallicity as one goes deeper into the sun. One might however think that this energy feed raises the temperature faster towards core than standard model predicts so that also the metallicities should increase faster.

How TGD could cure the problem?

TGD based new nuclear physics suggests both spectroscopists and helio-seismologists are right.

1. Solar core and also convective zone could contain dark nuclear matter explaining the missing mass. The amount of dark nuclei would be fraction of order 4×10^{-2} of the ordinary matter. TGD based model for the formation of galaxies, stars and planets involves magnetic flux tubes carrying dark energy and possibly also dark matter as key elements, and the dark matter might be assigned to a dark nuclear flux tubes going through the solar core.

   The dark nuclei at the magnetic body would affect the model for the propagation of light and sound in the solar core and also outside it. For instance, photons could be transformed to dark photons at flux tubes an this would increase opacity. Also sound waves would interact with dark nuclei since the acoustic oscillations could be transformed to oscillations of magnetic fields tubes (dark Alfwen waves) and oscillations of dark nuclei.

2. TGD based models of "cold fusion" [L54] and of Pollack effect [L24] [L24] led to a proposal of what I call dark nuclear physics. Dark nuclear physics explaining "cold fusion" in TGD framework could play a central role even in the pre-stellar evolution and in nuclear fusion in stars. As will be found, this suggests a new way to see tunnelling crucial for nuclear fusion inside stars and even in laboratory.

   Tunnelling is not allowed in TGD since classical physics is exact part of quantum TGD, and would be replaced by a generation of dark nuclei with $h_{eff} = nh_0$ by state function reduction and having lower nuclear binding energy scale making possible to overcome Coulomb wall so that nuclear fusion would be possible without tunnelling.

   The most conservative expectation is that this model for tunnelling reproduces the nuclear physics of ordinary nuclear matter in good approximation. What is however new is that the dark nuclei are present as new exotic states of nuclei, and must be taken in the modelling of sound waves and photons. Therefore helio-seismology and solar neutrinos would allow to deduce the total metallicity as sum over ordinary and dark metallicity whereas spectroscopy and meteorite determinations would provide only the ordinary metallicity since the attention is paid only to ordinary nuclei as outcomes of reactions.

The vision about galaxies and stars

The view about the role of new nuclear physics predicted by TGD in the model of solar interior [L103] gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also “too” fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

8.2 Could solar metallicity problem reflect the presence of dark matter in solar core?

Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand “cold fusion” [L54]. In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase would lead to the final state of the reaction. In ZEO “big” (ordinary) state function reduction (BSFR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than “small” state function reductions (SFSRs) as TGD counterparts of “weak” measurements, ZEO would make possible nuclear fusion. The recent findings of Minev *et al* [L90] provide support for ZEO [L90].

The missing nuclear matter inside the core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those deduced from helio-seismic data on the other hand. The reason would be that sound waves and photons in the core would couple to both ordinary and dark matter so that helio-seismology would give metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of “cold fusion”, one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume, which is rather near to the maximal allow value and implies that dark nuclear strings must be taken into account.

One can relate the model also to the model for the formation of galaxies, stars, and planets [L65, L67, L53, L83] as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

8.2.1 Could “cold fusion” come in rescue?

TGD based on the model of “cold fusion” [L54] predicting that all elements can be produced by what I call dark fusion outside stellar cores could come in rescue.

1. Standard model has what I tend to see as a potential problem related to the temperature in the solar core. naïvely the nuclear fusion in stellar temperatures around 1.5×10^3 eV is not possible since nuclear binding energy scale is above MeV. Quantum tunneling is however believed to make it possible to overcome the Coulomb wall. The main argument against “cold fusion” is that the colliding nuclei cannot overcome the Coulomb wall at room temperatures. TGD provides a mechanism allowing to overcome the problem [L54]. Could this mechanism be at work also in ordinary nuclear fusion in stars and make it possible outside stellar core?

2. The model relies on the notion of dark nuclei as dark nuclear strings [L4], flux tubes containing sequences of dark protons and neutrons and having non-standard value of effective Planck constant $h_{eff} = nh_0$. Also ordinary nuclei would be nuclear strings but for their dark variants the binding energies would scale like inverse of size scale and thus like $1/h_{eff}$. The binding

energy scale would therefore be lower for dark nuclei and they could be formed at lower temperatures.

3. This suggests a model for pre-stellar evolution in which dark nuclei would be formed first. Their transformation to dark nuclei with smaller h_{eff}, even ordinary nuclei with $h_{eff} = h$, would liberate energy and cause heating making possible the fusion of dark nuclei with various values of h_{eff}. Eventually the temperature would reach the value making formation of ordinary nuclei possible. Heavier elements could be generated also outside stellar cores. Also now the mechanism would be formation of dark nuclei, possibly fusing to form heavier nuclei, and decaying to ordinary nuclei.

4. Dark nuclear physics would be present also at low temperatures. For instance, in Pollack effect [L24] [L24] dark nuclei could be formed at room temperature by irradiation of water in presence of gel. The transformation of dark nuclei to ordinary nuclei could explains the reported bio-fusion [C33, C150]. The dark nuclei would give rise to a realization of genetic codons in terms of linear dark proton triplets [L36]. Chemical codons would be kind of secondary representation.

In "cold fusion" [L54] dark nuclei would be formed in the similar manner and they could transform to ordinary nuclei liberating essentially entire nuclear binding energy. Could the ridiculed "cold fusion" provide a possible mechanism generating not only only the elements heavier Fe but all elements heavier than He outside stellar cores in the case that core consists of dark matter - and perhaps also in interstellar space? One can however counter argue.

1. Ordinary nuclear physics provides a well-tested description of fusion reactions in laboratory and the model based on "cold fusion" in TGD sense should be consistent with the standard model for cold fusion. In stellar core the temperature is however not much higher than $T \sim 1.5 \times 10^3$ eV. Tunnelling effect should be involved in an essential manner. These models are phenomenological potential models. What the TGD description of tunnelling could be?

   In TGD framework all quantum processes should have exact classical space-time correlates as space-time surfaces analogous to Bohr orbits, preferred extremals. Quantum state would be superposition of these. The first new elements would be the description of nuclear dynamics in terms of space-time surfaces obeying classical dynamics.

   By definition, tunnelling represents a process impossible classically. Could the TG counterpart of tunnelling involve a state function reduction creating a superposition of space-time surfaces for which tunnelling is replaced by a process possible classically? Could the tunnelling involve the formation of dark intermediate state with much smaller nuclear binding energy scale and its decay to the final state containing the fused nuclei?

2. What could the creation and decay of this dark intermediate state mean? If it corresponds to ordinary state function reduction, it means in zero energy ontology (ZEO) reverse the arrow of time. The recent strange findings of Minev *et al* [L90] about state function reduction in atomic systems provide rather strong support for ZEO based quantum measurement theory [L90], whose main justification is that it solves the basic paradox of quantum measurement theory.

   The time reversed zero energy state would be a superposition of preferred extremals starting from final dark nucleon state and going to geometric past and decay to state consisting of ordinary nucleons in accordance with the generalized second law.

   During subsequent time evolution by SSFRs as analogs of "weak" measurements nuclear fusion would occur easily due to the small binding energy.

   After that second BSFR replacing the arrow of time with original one would occur and induce the decay of dark nuclei to ordinary nuclei including the fusion products. This process could take place also in "cold fusion". This description might make sense since also ordinary nuclei are in TGD framework string like entities [L4].

3. One must be however cautious here. One cannot exclude the possibility that also SSFRs increasing the value of h_{eff} could give rise to tunnelling but to me the proposed model looks more attractive.

   (a) ZEO based quantum measurement theory [L66] combined with $M^8 - H$ duality ($H = M^4 \times CP_2$) [L56] and number theoretic vision [L99, L98] leads to the view that preferred extremals in M^8 consists of a sequence of 4-D pieces glued together at preferred values of M^4 time $t = r_n$, which correspond to the roots of a polynomial with rational coefficients determining the extension of rationals characterizing the adele in adelic physics which can be seen as a fusion of real physics of sensory experience and various p-adic physics of cognition [L63, L64].

This polynomial would determine octonionic polynomial as its analytic continuation in turn defining 4-D space-time surface in M^8 as an algebraic surface identified as a root of its "real" or "imaginary" part in quaternionic sense. The roots $t = r_n$ would correspond to special 6-D brane like solutions of the polynomial having topology and metric of 6-sphere S^6 and intersecting M^4 along the 3-ball $t = r_n, r < r_n$ defining a "special moment in the life of self" in TGD inspired theory of consciousness [L98].

This surface would be mapped by $M^8 - H$ duality to a preferred extremal in H, which is minimal surface having string world sheets and partonic 2-surfaces as singularities. At the 2-D singularities 4-D quaternionic tangent or normal space in M^8 would degenerate to 2-D space.

(b) One can say that incoming and outgoing space-time surfaces representing particles are glued together along their ends at these hyperplanes of M^4. These time values would naturally correspond to the time values at which SFRSs take place. SSFRs correspond to quantum measurements that commute with the observables, whose eigenstates the states the passive boundary of CD are. Time would be one of the observables measured in SSFR and involve temporal localization for the position of the active boundary of CD determining the size of CD.

4. The most conservative picture is that the existing nuclear physics deduced from laboratory experiments provides a faithful phenomenological description of nuclear physics of ordinary nuclei. However, if this picture is correct, nuclear fusion might occur also in the convective zone with dark fusion as intermediate step. One expects that the rate is very sensitive to the temperature and becomes very small near the surface of Sun. Dark fusion could increase the temperature and this could reduce the thickness of the convective zone deduced from the model of Asplund *et al* [E7, E43].

Could this model solve the metallicity problem?

1. In spectroscopic determinations only ordinary matter becomes visible. Also spectroscopic determinations detect only the ordinary matter. On the other hand, the intermediate states with non-standard value of Planck constant would be however real rather than virtual states. Therefore dark nuclear matter should be taken into account in the models the propagation of sound waves and photons in solar interior.

2. For sound wave propagation the time scale of propagation is much longer than the time scale assignable to the dark nuclei. This is the case also for photons with energies below the scale of dark nuclear energies if they have same value of h_{eff} and are thus dark. This would suggest that the density of dark nuclei contributes to the total density of nuclei deducible from the opacity, sound velocity, and density as parameters. The solar abundance problem would be thus provide direct evidence for dark matter in TGD sense.

3. Dark nuclei would correspond to magnetic flux tubes carrying dark nucleon sequences and the mass fraction of dark nuclei would correspond to the fraction of missing matter estimated to be 1500 Earth masses giving $M_D/M/ \sim 4 \times 10^{-3}$. The ratio of the dark metallicity to ordinary metallicity would be about 5/13 from the metallicities 1.3 per cent *resp.* 1.8 per cent deduced from spectroscopy *resp.* helio-seismology.

8.2.2 Evidence for the tunnelling of electrons in nanoscales

The proposed model would mean that dynamical tunnelling could have in TGD framework different description. Is there any empirical evidence for this prediction? There is a popular article in Phys.org describing a highly interesting finding (`https://tinyurl.com/ybkewpga`) made by condensed matter physicist Doug Natelson and his colleagues at Rice and the University of Colorado Boulder. Light emission associated with the tunnelling of electrons through a nano-scaled potential barrier between Gold electrodes has been observed. The intensity of emission is larger by factor 10,000 than predicted and this suggests new physics.

By definition tunnelling means that electrons get through the potential barrier without getting energy - classical picture would require this. Now it however seems that electron receives energy and the higher the barrier the larger energy is needed. Should one challenge the notion of tunnelling? Could it have a classical counterpart?

In TGD framework all quantum phenomena should have classical counterparts, also tunnelling. Therefore the tunnelling electron would somehow get energy to get over the potential barrier classically. I the case of nuclear reactions this energy would come from the

1. In zero energy ontology (ZEO) [L105] (`https://tinyurl.com/wd7sszo`) solving the basic problem of quantum measurement theory quantum states are superpositions of deterministic classical time evolutions, preferred extremals. Classical physics is exact part of quantum theory. The key prediction is that in ordinary, "big", state function reductions (BSFRs) the arrow of time is changed. In small SFRs (SSFRs) - analogs of weak measurements - this does not happen. ZEO leads to a theory of self-organization in which energy feed to self-organizing system corresponds to dissipation for time reversed state associated with dissipating system.

2. In ZEO tunnelling [L103] (`https://tinyurl.com/yyjy5e2r`) could mean that electrons make a BSFR reversing the arrow of time. In time reversed state they dissipate in reverse time direction: in standard time direction of observer they receive energy in standard time direction allowing them to get over the potential barrier. In the second BSFR establishing the original arrow of time they would liberate the energy and the higher the barrier, the larger the liberated energy and the brighter the light emission.

   The tunnelling in this sense would be already self-organization phenomenon involving BSFR. This dynamical tunnelling does not exclude the analog of wave-mechanical tunnelling as a non-dynamical process. The dynamical tunnelling could actually lead to asymptotic states in which particle is at both sides of the forbidden region or even in forbidden region but with extraction of classical energy from environment so high that this is not forbidden anymore.

8.2.3 Could Sun contain dark magnetic flux tubes carrying dark matter?

The proposal of metallicity problem proposed above relies on dark matter in TGD sense - that is as $h_{eff} = nh_0$ phases. TGD predicts however also galactic dark matter assignable to long cosmic strings which thicken to magnetic flux tubes during cosmic evolution. These objects carry dark energy as magnetic and volume energy and it might be that one should dark about galactic dark energy. They can carry also dark matter in TGD sense. In any case, they would produce ordinary matter and its dark variants as $h_{eff} = n \times h_0$ phases in the thickening process reducing string tension somewhat like the decay of inflaton field produces ordinary matter.

Galactic dark matter in TGD

Consider first the model for galactic dark matter in TGD

1. TGD explains galactic dark matter as being associated with long cosmic strings, which form tangles at which the cosmic string thickens to flux tube and part of its Kähler magnetic energy transforms to ordinary particles and creates the ordinary matter associated with galaxy (this might included also $h_{eff} = nh_0$ phases which also behave like dark matter whereas galactic dark matter could correspond to dark energy alone). The thickening however generates volume energy and the process must stop.

   A phase transition reducing the value of thel ength scale dependent cosmological constant proportional to the inverse square of p-adic length scale $L_p \propto \sqrt{p}$, $p \simeq 2^k$ [K70], and thus reducing the contribution of volume energy however initiates the expansion again. Accelerating cosmological expansion and inflationary cosmology would represent examples of these accelerating periods. This gives a sequence of expansion period first accelerating and then decelerating. The values of cosmological constant and string tension come in some powers of 2. $T_{tube} = 2^{-k}T_{max}$, $k > 0$ some integer. In this picture cosmological expansion would mean generation of space-time sheets with larger size scales and smaller cosmological constant but also the space-time sheets with smaller cosmological constant would be present unlike in standard cosmology.

2. This model assigns galactic dark matter with long cosmic strings and automatically predicts flat velocity spectrum with velocity proportional to $\sqrt{T_{tube}G}$, T_{tube} string tension. It also explains the old observation that galaxies form long linear structures.

   Here one must stop and ask what string tension does mean. T_{tube} has been taken to mean classical string tension determined by the Kähler magnetic energy and volume energy. What about the contribution of dark matter inside flux tube and consisting at fundamental level of quarks? Should one count it separately? Or does quantum classical correspondence (QCC) imply that the classical contribution is equal to the quantum contribution? QCC as basic principle of TGD indeed suggests that the latter option is correct. But does this mean that dark matter and dark energy in TGD sense should be regarded as equivalent?

3. The fractality of TGD Universe suggests that stars and even planets are sub-tangles of the tangles associated with galaxies. Even the TGD counterparts of galactic magnetic fields as flux tube structures could be understood as tangles resembling field line structures of dipole magnetic field. This could apply to stars and even planets. Stars and planets emerge at later stages of cosmic evolution so that one would have $T_{tube} << T_{max}$. One would have fractal structure: tangles along tangles along ...

Could solar core contain dark matter as dark nuclear strings at magnetic flux tubes?

The proposed explanation assumes that dark nuclear strings assignable to magnetic flux tubes define the intermediate states providing the TGD counterpart of quantum tunnelling impossible in TGD The flux tubes would be generated by the thickening of cosmic strings during cosmic evolution and it is interesting to look whether this picture conforms with this model.

1. The expression for string tension T_{max} for cosmic string as an object of form $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$, where X^2 is minimal surface and S^2 is homologically non-trivial geodesic sphere, is deduced in [K96] and is given by

$$T_{max} = \frac{1}{8\alpha_K R^2_{CP_2}} \quad .$$

   Here one assumes that only Kähler action contributes. The volume contribution is expected to be of same order of magnitude and of the same sign since in twistor lift volume contribution is also essentially magnetic energy. For $\alpha_K = 1/137$ and $R^2_{CP_2} \sim 10^7 G$ one would obtain $T_{max} \sim 10^{-6}/G$.

   p-Adic length scale hypothesis suggests that the thickening reduces T_{tube} by powers of 2 in equilibria in which magnetic energy does not transform to particles anymore. Note that the decay of magnetic energy to particles is analog for the decay of inflaton field in inflationary cosmology.

2. To get an idea about the value of reduced string tension T_{tube}, one can estimate the mass of a straight string portion with length of solar diameter $D(Sun) = 2R(Sun) = 1.4 \times 10^6$ km going through the Sun and having string tension $T_{tube} = T_{max}$. Solar mass $M(Sun)$ corresponds to a blackhole with Schwartschild radius $R_S \sim 3$ km. Solar diameter corresponds $D(Sun) = 2R(Sun) \sim .46 \times 10^6 \times R_S$.

   For $T_{max} \sim 10^{-6}/G$ and for $D(Sun) = 2R(Sun)$ the mass of straight string portion the mass would be about $2.3M(Sun)$. This option would suggest that a portion of long string with length of solar diameter of Sun and having solar mass has thickened to a flux tube forming a tangle filling the entire Sun and perhaps also the Kähler magnetic flux tubes assignable to the solar magnetic field.

3. If only the solar mass has been produced by the transformation of the dark energy of cosmic string to particles and dark flux tubes, the string tension should be corrected to $T_{max}/2.3$ to give just the solar mass. The mass for the portion contained in the core would be $M(Core) \sim 8 \times 10^{-3} M(Sun)$, which is roughly twice the estimated missing mass if it is 1500 Earth's masses mentioned in the popular article would correspond to a fraction of 4.5×10^{-3} of solar

mass. My own estimate gave roughly twice this value, which happens to co-incide with the above value. Is this a mere co-incidence?

4. The discrepancy could be resolved by assuming that the flux tube has formed a tangle extending outside Sun. Roughly half of the flux tube mass should go to the tangle outside Sun. The general proposal indeed is that the tangle represents also the Kähler magnetic field of Sun. It could even give rise to the planetary tangles.

One can imagine two extreme options.

1. The thickness of the flux tube would be very small in the core for $T_{tube} = T_{max}/4$. For T_{tube} not much smaller than $T_{max}/4$ it would take negligibly small volume and could not have strong effects on opacity, acoustic properties, and nuclear fusion by the proposed counterpart of tunnelling. This option seems to be excluded.
2. If the flux tube is strongly thickened and has thus small T_{tube} it must be much be considerably longer than core diameter and thus form a spaghetti like structure filling a considerable portion of the volume of core. Filling fraction must be however smaller than 1. This could increase opacity and modify acoustic properties, and most importantly make possible nuclear fusion. The thickened flux tube would serve as seat of dark nuclei and give rise to dark nuclear strings. This option is favored by the proposed solution of the abundance problem.

Consider now a more detailed estimate.

1. The model for "cold fusion" [L54] suggests that at least in this case the flux tube thickness corresponds to electronic Compton to which one can assign Mersenne prime $M_{127} = 2^{127} - 1$. A good guess is that this is the case also in nuclear core.

   One would have $L_e \simeq \sqrt{5}L(127) = 2.4 \times 10^{-12}$ meters assignable to electrons essentially equal to the electron Compton length about 10^{-12} meters. The p-adic length scale assignable to proton and neutron corresponds to $L(107)$ and if this scale characterizes also the nuclear strings, the scaling of the nuclear flux tube thickness would be roughly by a factor $\sqrt{5} \times 2^k$, $k = (127 - 107)/2 = 2^{10}$, giving roughly the scaling factor 2^{11}.

   The ratio of the flux tube thickness to the thickness of cosmic string given by $R_(CP_2) \simeq 10^{3.5}L_{Pl}$, where L_{Pl} is Planck length, would be roughly the ratio $L_e/R_{CP_2} \sim 4.7 \times 10^{19}$. The string tension of cosmic strings would be reduced by a factor of order $L_e^2/R_{CP_2}^2 \sim .45 \times 10^{-39}$. The reduction of string tension from the estimate for T_{max} to L_e^2 would give 10 times larger estimate $L_e^2 T_{max} \sim 4.5 \times 10^{-39}$.
2. If nuclear binding energy scales like inverse of p-adic length scale $L(k)$, the nuclear binding energy scale would be reduced roughly by the ratio L_p/L_e of Compton length scales of proton and electron scaling roughly by a factor $m_e/m_p \sim 2^{-11}$ from the maximal value about 7 MeV to 3.5 keV. The temperature of the solar core corresponds to thermal energy larger than 1.5 keV. Thus the "cold fusion" inspired estimate for the flux tube thickness seems to make sense.
3. The condition that string tension is $T_{tube} \sim 1/L_e^2$ and the dark mass is about $M_D \sim 4 \times 10^{-3}M(Sun)$ gives and estimate for the length L_{tube} of the flux tube inside solar core from the equation

$$T_{tube}L_{tube} \sim \frac{L_{tube}}{L_e^2} \sim M_D \sim 4 \times 10^{-3}M(Sun) \sim T_{max}R(core) \ . \tag{8.2.1}$$

   This gives for L_{tube} the estimate

$$L_{tube} = L_e^2 T_{max} R(core) \tag{8.2.2}$$

   giving

$$\frac{L_{tube}}{R(core)} = L_e^2 T_{max} \sim 2.2 \times 10^{39} \tag{8.2.3}$$

   using the earlier estimate.

4. Does this make sense? In other words, is the volume fraction filled by the flux tube smaller than one? The fractional volume taken by the flux tube of transversal area $S \sim \pi L_e^2$ would be

$$\frac{V_{tube}}{V_{core}} \sim \frac{3}{4}\frac{L_{tube}L_e^2}{R(core)^3} = \frac{3}{4}L_e^2 T_{max}\frac{L_e^2}{R(core)^2} \sim .3 \quad (8.2.4)$$

for $R(core) = 1.4 \times 10^5$ km. 30 per cent of volume would be filled by flux tube so that dark nuclear physics would be important and could explain the missing mass. This estimate is rough but suggests that the model might work.

One can look the situation from the viewpoint of twistor lift predicting a hierarchy of cosmological constants depending on the p-adic length scale [L65, L85, L82, L111, L112].

1. The value of the cosmological constant in cosmic scales would correspond to an effective volume energy density proportional to $1/GL_{p_H}^2$ with $L_{p_H} \sim 10^9$ ly H refers to "horizon". The effective volume energy density could be expressed at GRT limit as proportional to $1/L_{p(small)}^4$. One has $L_{p(small)} \sim L_{neuron} \sim 10^{-4}$ m, the size scale of large neuron, which suggests a connection between cosmology and quantum biology. $1/L_{neuron}^2$ defines order of magnitude for string tension of the flux tubes involved and having thickness of order $1/L_{neuron}^2$.
2. In the case of nuclear flux tubes in solar core the dark energy density in scale of large neuron would be larger by fact L_{neuron}^4/L_e^4 by a factor of order 10^{-32}. The scale L_{p_H} defining scale of horizon would be reduced by factor of order 10^{-16} from its cosmological value $L_{p_H} \sim 10^9$ ly to $L_{p_H} \sim 2.5 \times 10^8$ m to be compared with the radius $R(core) \sim 1.4 \times 10^8$ meters of the solar core. In many-sheeted cosmology nuclear core could be seen as scaled down cosmology.

To sum up, these estimates are rough and involve numerical factors but it seems to me that the model survives the simplest quantitative tests.

Is there a relation to the model of solar dark matter inspired by Nottale's proposal?

One can look the situation also in the TGD based model of solar dark matter [K96, K10] [L72, L71] inspired Nottale's proposal [E9] that planetary orbits could be interpreted as Bohr orbits. In TGD framework the Bohr orbits could be assigned with dark matter accompanying ordinary planetary matter perhaps assignable as distributions with the flux tubes along orbits.

First a couple of general comments about the TGD variant of the generalization of the model of Nottale to TGD framework.

1. What is new that the perturbative expansion for scattering amplitudes would be in powers of the gravitational analog of fine structure constant equal to $GMm/\hbar_{gr}(M,m) = v_0/c < 1$ and is expected to converge. This would make possible quantal perturbation theory for $GMm >> 1$.
2. Since the orbital radii do not depend at all on M (by Equivalence Principle dictating the form of h_{gr}) one can imagine decomposing m as $m = \sum m_i$. One indeed expects that gravitational flux tubes with a spectrum of $h_{eff} = h_{gr}$ is involved.
3. Can one assume that flux tube connects masses M and m forming its ends or does m correspond to space-time sheet having wormhole contacts with the gravitational flux tubes rather than serving as the end of flux tube? For the first option one would have decomposition to $M = \sum M_i$ to dark parts M_i and $m = \sum m_i$ with $\hbar_{gr} = GM_i m/v_0(M_i, m_i)$ at corresponding flux tubes connecting them to masses m at orbit with given radius. One would have partitioning of M and m to interacting pairs. There would be no gravitational interaction between M_i and m_j for $i \neq j$, and this does not conform with the universality of gravitational interaction.

   Note that would differentiate between gauge interactions and gravitational interactions. For the gauge of gauge interactions one could say that the flux tube as wormhole throats as its ends and there would be screening. Note however that flux tubes carrying monopole must be closed, and could be 2-sheeted with return flux going to a parallel sheet through wormhole contact and returning along it.

Consider now the possible relationship with the proposal that solar core carries dark matter.

1. $v_0 = 2^{-11}c$ appears as a velocity type parameter in the Bohr orbit model for planetary system proposed first by Nottale and later developed in TGD further [K96, K78, K10] [L72, L71]. The value of the gravitational Planck constant $h_{eff} = nh_0$ for the dark flux tubes mediating gravitational interaction between large mass M and small mass m would be $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. M would be solar mass. By Equivalence Principle m can the mass of the planet or of any particle composing it. $v_0/c \simeq 2^{-11}$ is the value required for the 4 inner planets.
2. The article mentions also the value of $M_D/M \sim 2^{-11}$ for the fraction of dark matter in the solar core. One would have $M_D/M = v_0/c$: is this mere accident? Notice however the value $M_D/M \sim 4\times2^{-11}$ is from $M_D = 1500$ Earth masses and my own estimate $M_D/M \sim 2\times2^{-11}$. I

   If one takes these estimates seriously, it would seem that the value of v_0/c in the core is larger than outside Sun. In this case flux tubes are longer and since flux tube length as quantal length is expected to increase with h_{gr}, one expects that h_{gr} is larger. Indeed, for the outer planets the Nottale model requires $v_0 \to v_0/5$.

What about galaxies?

I have proposed that this general vision applies also to the formation of spiral galaxies. This can be tested in the case of Milky Way at order of magnitude level.

1. The mass $M(gal)$ of the Milky way is estimated to be in the range $[.8, 4.5] \times 10^{12} M(Sun)$. For a string with maximal string tension this would correspond to a direct string portion with length $L(gal) = M(gal)/R(Sun) = M(gal)/M(Sun)$. In fact, this stringy mass formula is known to hold for quite a many astrophysical objects as I learned decades ago in a particle physics conference - in good old times times particle physics conferences allowed non-main-stream talks during the last conference day. This gives the estimate $L(gal) \in [.6, 3.3] \times 10^5$ ly. The radius R_{gal} of galaxy is estimated to be in the range $[.75, 1.0] \times 10^5$ ly. The length of string within galactic radius would satisfy $L_{gal} = [.8, 3.3]R_{gal}$. The estimate excludes the lower bound. For the upper bound the one has $L_{gal} \sim 3.3 \times R_{gal}$.

   The thickness of the Milky Way is about 2×10^3 ly which suggests that the portion of long string making galaxy is soaked up to the galactic plane [L83].

   The supermassive blackhole in the galactic center is estimated to have mass $M(BH) = 4 \times 10^6 \times M(Sun)$. By scaling this would correspond to a straight cosmic string portion with length $L_{BH} \sim .1$ ly. The size of the galactic blackhole (see `http://tinyurl.com/od3spdu`) is $R_{S,BH} \sim 4.4 \times 10^{-5}$ ly giving $R_{S,BH}/L_{gal} \sim 4.4 \times 10^{-4}$. One has $T_{max} \sim 10^{-6}/G$ and blackhole corresponds effectively to a string with tension $T_G \sim 1/2G$ and length $R_{S,BH}$ so that the ratio would be $R_{S,BH}/L_{gal} \sim 2G/T_{max} \sim 2 \times 10^{-6}$. The straight string with length L_{BH} would have been compressed to a volume of Schwartchild radius $R_{B,S} \sim 2^{-11} L_{BH}$.
2. Could the spiral structure of spiral galaxies involving several spiral correspond to a rotating cosmic string thickened to a flux tube? The original model for the spiral structure as a cosmic string at rest in in Robertson-Walker coordinates and seemingly rotating in linear Minkowski coordinates failed [K31] since it predicted too weak spiralling. The observed spiral structure could however corresponds to a thickened dark flux tube with lower string tension and longer length.

   If so the length of the original spiral should be about $L_{gal} = 3.3\times R_{gal}$. Perhaps the primordial configuration of the dark flux tube could be modelled as a cosmic string solution at rest in Robertson-Walker coordinates, which then thickened and gained length becoming more spiral.
3. For elliptic galaxies (see `http://tinyurl.com/ayyvg9n`) the sizes vary in the range $3 \times 10^3 - 7 \times 10^5$ ly (roughly 2 orders of magnitude) and masses in the range $[10^5, 10^{13}]$ ly (8 orders of magnitude!) so that linear relationship between size and mass is excluded. The length $L(gal)$ of the original straight string would be in the range $[10^{-8}, 7.4 \times 10^5]$ ly giving $L_{gal} \in [.3 \times 10^{-6}, 1.0] \times R_{gal}$. Thus elliptical cannot correspond to cosmic strings. At the upper limit elliptic galaxy could correspond to straight cosmic string and the visible matter would not come from the decay of the cosmic string. This estimate conforms with the earlier proposal that only spiral galaxies correspond to cosmic strings.

8.3 Some anomalies of astrophysics from TGD point of view

In the following some anomalous findings of astrophysics are discussed from TGD point of view.

8.3.1 Youthful Oldies

I received very interesting link (see `http://tinyurl.com/ryg2g3l`) to findings challenging the standard beliefs about the formation of stars and at the same time nuclear physics and providing support for the proposed picture about nuclear fusion [E14].

The standard story about formation of stars goes as follows. Nuclear fusion at the cores of stars produced the elements. In the first stars only light elements were formed and spewed out in supernova explosion to get gathered to the stars of next generation able to produce heavier elements. The elements heavier than Fe were not produced in stellar interiors since this was not energetically possible. One would expect that in very early Universe in which only few generations of stars had been present, the interstellar clouds would contain only light elements.

This story can be compared to empirical facts by observing quasars emitting light with huge intensity coming from cosmic gas clouds. The light from quasars reveals their chemical composition via absorption lines. The researches (Eduardo Banados, Michael Rauch and Tom Cooper) were able to identify 13 billion year old cosmic clouds formed 850 million years after Big Bang and study their spectroscopy. The work is published in The Astrophysical Journal (see `http://tinyurl.com/qkk26dv`).

The surprising finding was that the abundances of elements look very modern, they are very much like those in the cosmic clouds formed several billion years later. The conclusion is that the first generation of stars formed more quickly than believed and were already expired before the formation of the cosmic clouds so that the clouds would consist of chemical products of much later star generations even before the galaxies were in place.

To me this interpretation does not look convincing. For me these findings represent a further challenge for nuclear physics as we believe it to be. Let us list some shortcoming of the standard nuclear physics first.

1. The formation of elements heavier than Fe is still poorly understood. No evidence for the R-process in supernovae was found in the case of SN1987A. There is no generally accepted model for the production of elements heavier than Fe.

2. Even worse, nuclear fusion inside solar stars thought to be thoroughly understood, has a 10 year old anomaly [E7, E43]. The abundances of elements are higher in the interior than they should be (see `http://tinyurl.com/yyjy5e2r`). This is really serious anomaly and challenges the foundations of nuclear physics - in particular the idealization of nucleons with point like particles and use of potential models and the notion of tunnelling which is central for understanding nuclear fusion [L103].

3. There is also "cold fusion" or LENR, which is a fact but still not admitted by the mainstream [L54, L27, L89] (see `http://tinyurl.com/y7u5v7j4`) and `http://tinyurl.com/tqgwmz7`). The essential aspects are production of heat energy and transmutations.

4. The observed abundances of Li, Be, and B cannot be explained in terms of production in Big Bang, stellar interiors or in supernovas. It is not that the abundances were too low: they are quite too high. The amount of ^{6}Li and ^{7}Li produced in big bang nucleosynthesis (BBNC, see `http://tinyurl.com/qczc8ty`) have been found empirically to be near the correct values in the early Universe and the amount of Li approaches to constant for low-metallicity stars (first star generations) although the amount of ^{7}Li is too small by a factor of 1/3 at least (see `http://tinyurl.com/vwcfujb`).

   Li is however unstable in the stellar cores and is destroyed there since Li cannot survive in the high temperature of solar core and there is no manner to create it since the intermediate isotopes giving rise to them by decay are very short lived. Same applies to Be and B. The problem is that the amounts of Li, Be, and B in the recent Universe are too high. This is of course highly desirable from the point of view of living systems.

   The official explanation discussed is based on the notion of spallation (see `http://tinyurl.com/smgmvgf`). The collisions of very energetic cosmic rays with heavy nuclei would induce their decay to smaller ones and produce Li, Be, and B. There are many uncertainties involved so that taking this mechanism seriously remains a matter of belief. TGD proposal is "cold fusion" outside stellar interiors as a produced of Li, Be, and B. This mechanism might also relate to the ^{7}Li puzzle.

TGD based model of "cold fusion" leads also to a modification of standard view about what happens ordinary nuclear fusion.

1. The tunnelling is central element in ordinary nuclear fusion and is replaced by a new mechanism involving in an essential manner the geometrodynamics of space-time as a surface in $M^4 \times CP_2$ and new view about quantum theory and dark matter residing at monopole magnetic flux tubes. The mechanism of "cold fusion" relies on the formation of dark protons sequences at magnetic flux tubes giving rise to dark nuclei with much smaller nuclear binding energy. These decay spontaneously to ordinary nuclei and liberate almost all nuclear binding energy leading to the heating and transmutations.
2. Besides ordinary nuclei also their dark variants as phases having effective Planck constant $h_{eff} = n \times h_0$ are present in solar interior and contribute to the abundances deduced from helioseismic data.
3. The view about pre-stellar evolution changes. "Cold fusion" in near to the surface region of star precedes ordinary fusion and serves as "warmup band" heating the matter to temperatures of ordinary nuclear fusion.

   "Cold fusion" as induced by dark fusion becomes an important contributor to the production of also heavier elements formed already before the hot fusion in the solar core has started. This mechanism works also outside stars and the elemental abundances could be almost universal having very little to do with the nuclear physics in the stellar interior.

The basic prediction is that the spectroscopic signatures for the star would not depend much on the generation of the star. Therefore also the spectroscopy of cosmic clouds would be almost independent of their age.

8.3.2 Helium problem and CNO problem: two anomalies explained by dark fusion

Helium problem [E41] (http://tinyurl.com/r3xqebt) means that there are stars with very low Helium content in the very early Universe. The predicted content is 3 times higher. This suggests that the view about Big Bang Nucleosynthesis (BBN) is not quite correct. If the BBN abundance is one third from the accepted, there must be an additional mechanism producing He and it cannot be stellar fusion.

The popular article "*Astronomers detect very unusual chemical composition in ancient star's atmosphere*" (http://tinyurl.com/rhsqk8g tells about unexpectedly high C, N, and O contents in the atmosphere of one of the oldest and most elementally depleted stars known - a "primitive star" scientists call J0815+4729 representing. For a more technical representation see the original article [E12] (http://tinyurl.com/u3rrnn9). This finding obviously challenges the views about stellar nuclear fusion since the star in question is very young star and the element abundances should be near to those produced in BBN. Note however that the elemental abundances are associated with atmosphere of the star. Could there be a variant of fusion process taking place outside the stellar cores?

TGD predicts new nuclear physics, which could explain these anomalies. I have already earlier considered explanation of various anomalies [L97] (http://tinyurl.com/slyo8p3). These two anomalies are only additional items in a long list.

> "Cold fusion" researchers, originally labelled as swindlers and crackpots, are nowadays regarded respectable scientists. Genuine cold fusion not allowed by standard nuclear physics is not in question and "low energy nuclear reactions" (LENR) is a politically more correct expression. "Nuclear transmutation" is also a term used.
>
> In TGD framework "cold fusion" is replaced by dark fusion involving generation of dark proton strings (some protons can transform to neutrons) having interpretation as dark nuclei [L54, L27] (http://tinyurl.com/y7u5v7j4 and http://tinyurl.com/y2v3qn6a). They would

have non-standard value $h_{eff} = n \times h_0$ of effective Planck constant and would be formed of protons directly because of thei large Compton length. Dark nuclei can transform to ordinary nuclei. This would give rise to “cold fusion”.

2. Dark fusion would precede ordinary nuclear fusion occurring in the cores of stars and contribute to the nuclear abundances and modify the predictions of bigbang fusion and stellar fusion and explain a long list of astrophysics anomalies. Also the theory of ordinary hot fusion would be changed and solve the 10 year old anomaly related to metallic abundances identified by Asplund *et al* [E7, E43] [L103]. The fusion reactions could occur via a creation of dark nuclei - rather than via tunnelling - and the dark nuclei would read and reaction products would tranform back to ordinary nuclei.

3. The model change the view about the prestellar period of stars. “Cold fusion” in TGD sense would serve as a “warm-up band” and the energy liberated as dark nuclei generated from protons transform to ordinary nuclei would transform to ordinary nuclei and gradually heat the matter so that ordinary nuclear physics enters in the game and stellar core is born. The dark fusion generates nuclei with all nuclear weights.

How could understand the two anomalies in terms of dark fusion? Consider first the Helium content of the early Universe.

1. Light elements D, T, He, Be would have been produced during by Big Bang Nucleosynthesis (BBN) during first few minutes (`http://tinyurl.com/qczc8ty` and `http://tinyurl.com/vr7ctaq`). The production ceased as the temperature became too low for nuclear reactions to occur. Nuclear reactions started again in the stellar cores and according to the prevailing wisdom produced the heavier elements.

   The relative abundance of Helium (which cannot be produced in stellar interiors), estimated to be about 25 per cent, would be determined by BBN. He abundance depends on the density protons and the exact value of Hubble constant determining the expansion rate. It is possible to vary these parameters so that the observed value of He abundance (difficult to observe, for instance for Sun it is not known) is taken as the input.

2. Giving up entire Big Bang theory (BB) is not a plausible idea. One can modify the parameters of BB to obtain a lower amount of Helium. This however requires an additional fusion mechanism, which must have been at work outside stellar cores and produced higher He content outside stars after BB.

   The contribution of dark fusion tends to increase the abundances determined by BBN. The amount of Helium produced in BBN should be considerably lower than believed and Helium poor stars would provide a better upper bound for He produced in BB. The amount of He would increase at least by a factor 3 by the production during pre-stellar periods by dark fusion. This implies that the density fraction of baryonic matter - few per cent in standard picture - would have been even lower. This does not seem to be a problem.

Dark fusion outside stellar interiors could also explain the anomalously high CNO content in the atmospheres of stars as being due to the prestellar period and have nothing to do with the physics in the stellar cores. Exceptionally high C, N, and O abundances would be produced by dark fusion outside stellar interiors - such as stellar atmospheres - and relate to the warm-up period.

What is intriguing C, N, and O playing a central role in biology are involved. There is evidence for bio-fusion [C33, C150] - not taken seriously by the mainstream - and since Pollack effect [L24] generating dark nuclei at room temperature in presence of say solar radiation, is central in TGD based quantum biology, dark fusion producing ordinary nuclei in living matter is predicted [L54].

8.3.3 Basic organic molecules emerge much earlier than they should

Nikolina Benedikovic gave a link to an interesting popular article (`https://tinyurl.com/y7eqzjqz`) about the appearance of pre-biotic molecules in stellar nurseries at time when star formation had not yet begun. The article told about the work work of astrophysicists Yancy Shirley and Samantha Scibelli [E42] (`https://arxiv.org/abs/2002.02469`) published in Astrophysical Journal with the title "*Prevalence of Complex Organic Molecules in Starless and Prestellar Cores within the Taurus Molecular Cloud*" .

The stellar nursery studied consisted of 31 starless cores scattered throughout a star-forming region in Taurus molecular cloud located about 440 ly from Earth. The molecules studied were methanol (CH_3O-H) and acetaldehyde (CH_3CH=O). These molecules serving as building bricks for chemical life were found to be much more ubiquitous than expected and present hundreds of thousands of years before star formation actually began.

The molecular evolution producing complex organic molecules requires the analog of metabolic energy feed: the temperature should be quite high - measured using molecular binding energies as scale - about few eV typically. The existing theories assume that proto-stars - stars in the process of formation produced the heating necessary for the formation of these molecules. But in regions without proto-stars the temperature of gas has been quite to provide the heating. Where did the energy needed for local heating come from?

TGD based view about "cold fusion" - which during last years has been getting rid of the label of pseudoscience - is that it is induced by what I call dark nuclear fusion possible at low temperatures [K24] (`https://tinyurl.com/yd336epx`). Dark matter corresponds in TGD Universe to ordinary particles but with non-standard value of Planck constant (or cautiously effective Planck constant) $h_{eff} = nh_0$ larger than $h = 6h_0$ [L42, L73, L122].

Dark nuclei formed as dark proton sequences at magnetic flux tubes with protons having distance about electron Compton length and scaled down nuclear binding energy in eV scale would have formed at temperatures of order eV or even lower. They would have spontaneously decayed to ordinary nuclei liberating energy of order nuclear binding energy, which is in MeV scale. The dark nuclei can actually occur in several scales but could transform sequentially to ordinary nuclei. The liberated nuclear binding energy would have heated the gas locally. This kind of regions would have served as pre-stellar objects leading to protostars and eventually stellar cores as ordinary nuclear reactions would have started.

TGD predicts that alsoordinary nuclear reactions are initiated by phase transitions generating dark nuclei as intermediate states: this would be the counterpart for quantum tunneling assumed to take place in ordinary nuclear reactions and allow them to already occur at collision energies about 1/100 lower than classical considerations would allow (see for instance [L103, L117] (`https://tinyurl.com/yyjy5e2r`, `https://tinyurl.com/s8gzrf`).

8.3.4 Hyperon problem of neutron star physics

Hyperon problem (`https://cutt.ly/NQWZKvZ`) is a mystery related to the physics of neutron stars. In neutron star neutrons temperature is zero in good approximation and Fermi statistics implies that the all states characterized by momentum and spin are filled up to maximum energy, known as Fermi energy E_F identifiable as a chemical potential determined by the number density of fermions.

The increase of density inside a neutron star increases the total Fermi energy. Above a critical Fermi temperature possible in the core of the neutron star, the transformation of neutrons to hyperons which are baryons with some strange quarks becomes possible. λ hyperon with mass about 10 percent higher than neutron mass becomes possible. In a thermo-dynamical equilibrium the chemical potentials of hyperons and neutrons are identical. Note that chemical potentials are in a good approximation Fermi energies at zero temperature.

If part of neutrons transform to hyperons, the total energy decreases since the Fermi energy scales like 1/mass. One therefore expects the presence of hyperons in the cores of neutron stars, where the density and therefore also Fermi energy is high enough. The problem is that the maximal mass for known stars is above the maximal mass expected if hyperon fraction is present. Hyperon cores seem to be absent.

If further neutrons are added part of them transforms to hyperons and eventually all particles transform to neutrons and one can even think of the doomsday option that all matter transforms to hyperon stars.

Can one imagine any manner to prevent the formation of the hyperon core? Could the Fermi energy in the core remain below the needed critical Fermi energy by some new physics mechanism.

1. Apart from numerical constants, the Fermi energy for effectively n-D system is given by

$E_F = \hbar;^2 k_F^2/2$, where k_F is some power $(N/V_n)^{2/n}$ of number density, where V_n refers to volume, area, or length for $n = 3, 2, 1$. Since zero temperature approximation is good, Fermi energy depends only on the density.

2. Could one think that part of neutrons transforms to dark neutrons in the transformation $h_{eff} \rightarrow kh_{eff}$ such that neither mass, energy, and Fermi energy are not affected but that wavelength is scaled up as also the volume. For an effectively 3-D system, dark neutrons would occupy a volume which is scaled up by factor k^3.

3. The Fermi energies as chemical potentials for both ordinary neutrons and their dark variants could remain the same in thermal equilibrium and remain below the critical value so that the transformation to hyperons would not take place? The condition that Fermi energies are the same implies that the numbers of ordinary and dark neutrons are the same. This would reduce individual Fermi energies by a factor $1/2^{2/3}$ but is only a temporary solution.

   One can however introduce phases with M different values of h_{eff} and in this case the reduction of Fermi energies is $1/M^{2/3}$.

4. Fermi statistics might however pose a problem. The second quantization of the induced spinor fields at the space-time surface is induced by the second quantization of free spinor fields in the embedding space $M^4 \times CP_2$. Could the CP_2 degrees of freedom give additional degrees of freedom realized as many-sheeted structures allowing to avoid the problems with Fermi statistics?

8.4 Conclusions

First a general comment about nuclear physics, which applies with appropriate modifications also to the evolution of theoretical particle physics (or lack of it) after the emergence of standard model followed by GUTS and superstring models.

1. One can see the standard nuclear physics as a tragic Odysseia due to the stubborn sticking to the naïve length scale reductionism. All began with the modelling of nucleons as point like particles inspired by the successes of atomic physics. It turned out that the model for nucleons as point like particles failed and we still do not understand low energy nuclear physics. The wave-mechanical potential models and QFT models assuming the notion of point-like nucleon led to an inflation of nuclear models each of them explaining some aspects of nuclei but a real theory is still missing.

2. Dark nuclear physics was originally suggested in TGD framework to explain "cold fusion" and later conjectured to allow the understanding of pre-stellar evolution as a step-wise process leading to the gradual heating of matter leading to nuclear fusion. The model relies on nuclear strings and their dark variants as dark nuclear matter. In this article it is argued that this picture leads to a realistic model of nuclear fusion and of stellar core and perhaps entire stellar interior as a dark spaghetti like structure. Ironically, "cold fusion" researchers regarded for decades as the pariahs of physics community, would show the path to follow.

The proposed model involves several new deep ideas inspired by the fusion of general TGD based visions about nuclear physics on one hand and about the formation of galaxies, stars, and planets on the other hand. Behind both visions is the notion about fractal hierarchy of flux tubes formed from cosmic strings by gradual thickening during the cosmic evolution. A further important piece is ZEO based view about quantum state and quantum measurement forcing to modify ordinary quantum mechanical description.

1. The idea is that Sun and its Kähler magnetic field form a sub-tangle of the galactic tangle associated with a long cosmic string and extending outside Sun, and perhaps including also planets as sub-tangles. This can be made more precise by assuming that total mass of the straight cosmic string portion involved equals to the total mass of the system considered. The estimate from the diameter of Sun suggests that the total mass is few times the solar mass. This model connects closely with the problem of cosmological constant solved by the twistor lift of TGD and solar physics can be associated with one particular value of length scale dependent cosmological constant: also this idea forced by TGD is revolutionary.

2. Quantum classical correspondence stating that quantum states are superpositions of Bohr orbit like preferred extremals challenges the idea about tunnelling as an essential element of nuclear physics. The first option is that BSFR - identified as ordinary $\rightarrow$ dark phase transition increasing the value of h_{eff} and involving time reversal followed by its reversal - allows wave-mechanical tunnelling as an approximate description. An alternative realization encouraged by M^8-H duality would be as SSFR involving no time reversal but discontinuity at the level of space-time development involving TGD counterparts of branes. This option resonates with the idea about sequence of SRFFs as TGD counterpart of a unitary time evolution suggested by the wave mechanical model. In any case, both TGD view about dark matter and ZEO would become part of nuclear physics, and mean giving up standard ontology and standard wave mechanics as a description of nuclei.

   It would not be surprising if similar view about tunnelling could apply also to particle reactions and I have proposed that dark variants of nuclei of M_{89} hadron physics as scaled variant of ordinary M_{107} hadron physics have made themselves visible via the observed (but neglected) bumps with masses obtained by scaling up the masses of ordinary mesons by factor 512 [K66]. Tunnelling would be now from ordinary hadron physics to dark M_{89} hadron physics.

3. When one has paradox, one knows that something is wrong with the basic conceptualization. The presence of dark variants of nuclei makes itself directly visible via the conflict between metallicities deduced from spectroscopy and meteorite abundances and those derived from helio-seismology and solar neutrino physics. Besides ordinary nuclei also their dark variants would present and contribute to metallicity in the solar interior.

Chapter 9

Some unexpected findings in hadron and nuclear physics from TGD point of view

9.1 Introduction

This chapter discusses some recent unexpected findings related to hadron- and nuclear physics.

9.1.1 The asymmetry of antimatter in proton from TGD point of view

The recent experiments of Dove *et al* [C44, C104] confirm that the antiquark sea is asymmmetric in the sense that the ratio anti-d/anti-u is larger than unity. A model assuming that proton is part of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture.

The TGD based model discussed also in [L150] relies on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD. What TGD can give is the replacement of virtual mesons with real on mass shell mesons but with p-adically scaled down mass and a concrete topological description of strong interactions at the hadronic and nuclear level in terms of reconnections of flux tubes.

9.1.2 The strange fissions of heavy nuclei

That final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood.

The recent surprising finding by Wilson *et al* [L151] was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays. This represents a challenge for TGD inspired model of nuclei as nuclear strings, and one ends up to a rather detailed model for what happens in the fissions.

The TGD proposal discussed also in [L151] is that the generation of angular momentum is a kind of self-organization process. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics.

The observation that the final state nuclei have angular momenta $6-7\ \hbar$ suggests that self-organization increase the values of h_{eff} to nh, $n \in \{6,7\}$. Quantization of angular momentum with new unit of spin forces the generation of large spins. Also zero energy ontology (ZEO) is involved: ZEO provides a new element to the description of self-organization and a model for quantum tunnelling phenomenon.

9.1.3 The strange findins of Eric Reiner

Eric Reiner [L148] has studied the behavior of gamma-rays emitted by heavy nuclei going through a beam splitter splitting the photon beam to two beams. Quantum theory predicts that only one detector fires. This implies that the pulses in the two detectors tend to occur at different times. This has been verified for photons of visible light. The experiment studied the same situation for gamma-rays and the surprise was that one observes mostly half pulses in both detectors and in some cases also full pulses. Reiner has made analogous experiments also with alpha particles with the same conclusion.

These findings pose a challenge for TGD, and in this chapter a TGD based model for the findings discussed also in [L148] is developed.

9.1.4 Pomeron and Odderon in TGD framework

Quite recently, empirical support for a particle christened Odderon [C63] emerged. As the name tells, Odderon is not well-understood in QCD framework.

Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it.

These four findings pose a challenge for TGD, and in this chapter a TGD based model for the findings discussed also in [L148] is developed.

9.2 The decays of heavy nuclei as support for nuclear string model

Nuclear string model is more than 20 years ago old applicationof TGD [L4]. The model identifies nuclei as string-like objects i.e. flux tubes carrying nucleons represented as space-time sheets topologically condensed at the larger flux tube. Nucleon space-time sheets are also connected by short flux fube bonds carrying quark and antiquark and having total quantum numbers of a pion or ρ meson. The model has several variants but is surprisingly successful and also the connection with the shell model can be understood. The basic prediction is that nuclear reactions and decays should have a topological description based on reconnection as basic reaction vertex.

9.2.1 Angular momentum generation in nuclear fission is not understood

I encountered a highly interesting link to a popular article (`https://cutt.ly/XlLnNB5`) to a work of a large international research group studying the fission of heavy nuclei. The article "*Angular momentum generation in nuclear fission*" [L151] (`https://cutt.ly/hlLn86c`) reporting the research findings is published in Nature (February 24). Unfortunately, the article is behind the paywall.

The work involved studying the fragments that resulted from fission of several types of unstable elements, such as uranium-238 and thorium-232. That the final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood.

The recent surprising finding was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays. This represents a challenge for TGD inspired model of nuclei as nuclear strings, and one ends up to a rather detailed model for what happens in the fissions.

Recent findings

The fragments resulting in the scission of heavy nuclei possess relatively high rotational angular momenta, which are typically 6-7 using $\hbar$ as a unit. Why the nuclei should have so large angular momenta looks like a mystery. There are many theories for how this angular momentum is generated. The natural guess is that the angular momentum is possessed by the fragments already before the scission. This predicts that the fragments have opposite angular momenta.

The recent experiments [L151] studying the gamma ray spectrum emitted by the nuclei convincingly demonstrate that the angular momenta for the fragments are independent and therefore must be generated after the scission. This looks very strange from the point of view of angular momentum conservation.

What comes first in mind is that the gamma ray emission takes care of angular momentum conservation. The generation of angular momenta is however analogous to a self-organization process and in standard physics framework it looks strange that this would take place for nuclei.

The classical model proposed by the experimenters relies on an analogy with a rubber band. The nuclei resulting in the splitting of heavy nuclei to two parts are proposed to be highly elongated before the scission.

In the splitting of a rubber band the resulting ends of the rubber band generate opposite torques giving them angular momenta. The energy liberated as the fragment returns from an excited state to an approximately spherical shape would be transferred to rotational energy. Here the proposed analogy is soap bubble with surface tension and pressure difference determining its dynamics: minimal energy corresponds to a spherical shape. The emission of gamma rays would take care of the conservation of the angular momentum.

Elongation makes possible the scission (on could also compare the decay to a decay of water droplet). What could be the mechanism of the elongation?

The TGD based model for scission relies on the model of nuclei as nuclear strings [L4]. Also other other elements of the new physics predicted by TGD are involved. The first element is the identification of dark matter as phases of ordinary matter labelled by effective Planck constant [?] $h_{eff}/h_0 = n$, ($h = 6h_0$ [L42]), with n identified as the dimension of extension of rationals determined by the degree of a polynomial characterizing a given region of the space-time surface by M^8-H duality [L114, L115]. Also zero energy ontology (ZEO) [L105] is involved: ZEO provides a new element to the description of self-organization [L102] and a model for quantum tunnelling phenomenon as a pair of BSFRs with the time-reversed period between them identified as tunneling period.

The first guess was that flux tubes, which have much longer length than nuclear size, could explain the mysterious finding that in nuclear decay the fragments manage to generate their angular momenta after the reaction: the flux tubes would make possible the exchange of angular momentum required by angular momentum conservation. The prediction would be that the flux fragments have opposite angular moment but the discovery was that they angular momenta are independent.

A more realistic guess is that the nuclear flux tubes themselves correspond to MB and that the generation of angular momentum is a kind of self-organization process - something usually not expected to be possible at the level of nuclear physics.

1. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales [L102] and time reversal plays a key role in this process: dissipation with a reversed arrow of time looks like self-organization for an observer with the standard arrow of time.
2. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics [L64, L63]. The energy feed would be from the vibrational excitations of the flux tube to the rotational degrees of freedom.
3. The observation that the final state nuclei have angular momenta $6-7\ \hbar$ suggests that self-organization increases the value of h_{eff} to nh, $n \in \{6,7\}$. The quantization of angular momentum with unit $\hbar_{eff}$ forces the rotation.

The basic ideas of the TGD based model for the scission

In TGD nuclei are modelled as closed nuclear strings [L4]. The counterpart for an elongated nucleus would be a loop looking like a highly flattened square, possibly having helical linking making it a helical knot. This suggests a description of the scission as a reconnection of the flux tube - in the approximation of the flux tube as a closed string this would be basic string vertex.

Also the analogy with DNA is useful. In TGD Universe DNA [L88, L194, L192, L193, L137] and also other basic information molecules are accompanied by flux tubes carrying dark protons (ordinary protons with $h_{eff} = nh_0 > h$) controlling them: dark means that the protons at the flux tubes. The elongation of the nucleus could be analogous to the process of DNA unfolding.

The opening of the helical DNA double strand in transcription forces the rotation of DNA: same would happen for the nuclei. If the value of h_{eff} as a unit of angular momentum increases to say $h_{eff} = 6h$, the torque generating the rotation is necessary to realize minimal non-vanishing value of angular momentum.

9.2.2 Nuclear string model briefly

TGD based description of nuclei is as nuclear strings containing nucleons along string [L4]. Nucleons from sequences at the magnetic flux tube so that a string like object is in question. Rubber band is indeed analogous to a string.

1. Nucleons correspond to space-time sheets topologically condensed at magnetic flux tube and connected by flux tube bonds representing scaled down pion or ρ meson quantum numbersexcept that the mass is p-adically scaled down to MeV range.
2. There are three options for what nuclear string could mean:
   (a) Neutrons and protons from separate nuclear strings and the flux tube bonds correspond to neutral pionor ρ. Thiswould conform with the treatmentof protons and neutrons in the nuclear shell model.
   (b) Protons and neutrons reside at the same flux tube.
   (c) Neutronlike space-time sheets are not actually ordinary neutrons but correspond to a proton + negatively charged pion-like flux tube bond connecting protons together.

   One can also consider the possibility that there are several closed linked and knotted loops present in the nucleus. Reconnections between the loops could generate knotting and linking. For instance, alpha particle could correspond to such a loop.
3. The analogy with strings suggests as the first guess a correlation between masses and angular momenta of the fragments idealized by the mass formula $J = kM^2$. Here k would be determined by the nuclear string tension.
4. Nuclear reactions would proceed by reconnection of flux tubes which for ideal closed strings define the basic vertex. Same applies to nuclear decays. A closed loop representing say alpha particle would be emitted via a reconnection process.

9.2.3 Scission as reconnection

Consider now the scission of heavy nuclei in this framework.

1. Suppose that in standard configuration nuclear strings are flux tube tangles - kind of flux tube spaghettis. This would correspond to the analogy with a bee nest used in the popular article. The Universe of the TGD is fractal and flux tubes appear in all scales. Galaxies, stars, planets, etc would involve flux tube tangles. Even DNA and other linear bio-molecules would involve flux tubes.

   A flux tube as a volume filling spaghetti is an object analogous to blackhole-like. Since the thickness of the flux tube can vary having values determined by p-adic length scale hypothesis, a hierarchy of blackhole-like entities are predicted [L91]. Ordinary blackholes would have flux tube thickness equal to proton Compton length and consist of nuclear strings. Also stars could be analogous to blackholes. In the csae of Sun the thickness of the flux tube would be of order electron Compton length [**?**, L103].

   Also nuclei would be analogous to mini blackholes. If they are volume filling, the reconnections could occur all the time and the topology would be highly dynamical involving changes of knottedness and decay to disjoint and linked knots.

Consider first the decay of the nucleus in the general case.

1. In the general case, the flux tube spaghetti is knotted. How can the decay to two separate tangles proceed? An arbitrary reconnection does not lead to two separate sub-tangles but changes only the knotting and linking. Even if this happens, the subtangles remain knotted and linked and the decay is not possible without further reconnections.

If the nucleus manages to evolve by reconnections to two mutually unknotted and unlinked sub-knots, the situation changes. The nucleus would decompose to 2 sub-knots connected by a pair of parallel closely spaced flux tubes for which the reconnection can take place and yield two final state nuclei. A decomposition into a connected sum of two knots would precede the decay in the general case.

2. The hypothesized elongated nucleus could correspond to a more specific situation. A maximally elongated nucleus would correspond to an opened flux loop with a shape of say flattened square. The flux loop could also be helical and stability might favor this. Rubber band analogy would be therefore justified. The scission would correspond to the splitting of this flux loop by reconnection. It is however enough to assume the formation of two separate knots connected by pair of parallel flux tubes close to each other.

The generation of the rotational angular momentum after the decay would correspond to a generation of a rotation of the flux tube as a string-like entity. A helical configuration analogous to DNA double strand is highly suggestive. The elongated nucleus would correspond to this kind of configuration.

The splitting would kick the stringy flux tube to an excited state. The liberated energy would generate the rotational motion. Why the motion would be collective rotation is not at all obvious.

The emission of gamma rays having spin would take care of angular momentum conservation. This however requires that gamma rays tend to have parallel spins. It is not obvious why this should be the case.

9.2.4 DNA opening as analogue for the scission process

Why the fragments generate angular momenta? Flux tubes appear in all scales in TGD Universe. In particular, the TGD based model for DNA invovles besides ordinary DNA strand also dark DNA strand parallel to it and identifed as a magnetic flux tube carrying dark proton sequence [L88, L194]. Genetic code is realized for dark DNA as dark proton triplets: this realization involves only protons and codons are entangled 3 proton states which do not allow reduction to letters. These dark proton sequences can be regarded as dark nuclei. The nuclear realization of the genetic code would be the fundamental one and the chemical realization would be kind of mimicry.

The model predicts also the dark counterparts of RNA, amino-acids and tRNA as dark proton triplets. One cannot completely exclude the possibility that the genetic code is realized already at the level of ordinary nuclei. This motivates the question whether the opening of the ordinary DNA double strand controlled by dark DNA strand might provide a useful analogy for understanding what happens in the scission.

1. The opening of DNA double strand in the replication or transcription must eliminated the helical linking of strands to give pair of parallel straight strands so that the replication can take place. The opening requires the rotation of strands and generates angular momentum.

2. Could the parallel flux tube portions form an analog of DNA double strand? Amusingly, the spin and isospin states of nucleon give rise to 4 states so that 3 nucleons would form analogs of genetic codons. The "dark" realization as entangled 3-nucleon states is however more plausible.

   DNA/protein unfolding as a self-organiation process is a biological analog for the step leading to an elongated state. The return to the highly tangled state after reaction would be analougs to DNA/protein folding.

9.2.5 Does non-standard value of h_{eff} explain the values of final state angular momenta?

One should also understand the large angular momenta of the final state nuclei and why these values are around $6\hbar$.

1. The intermediate state in the first BSFR would correspond to a dark nucleus having $h_{eff} = nh_0 > h = 6h_0$. This could be true also after BSFR and the angular momentum could be

reduced to its standard value in the final state. This suggests that the angular momentum is quantized with $\hbar_{eff}$ as unit.

2. The observation that the angular momenta are around $6h$ suggests that in the final state one has $\hbar_{eff} = Nh$: $N \in \{6, 7\}$. This would explain why the rotational angular momentum must be generated.

   In standard quantum theory it is very difficult to understand why the emitted ordinary gamma rays could have correlated spins so that the total spin would be N units. If the emitted dark gamma rays are dark they would have angular momentum unit $\hbar_{eff} = N\hbar$ and would decay to ordinary gamma rays.

3. A connection with the notion of dark 3N-protons and 3N-photons of TGD inspired quantum biology [L88, L121, L137] is highly suggestivbe. Dark 3N-protons would be cyclotron condensates analogous to nucleons as color triplets behaving like a single particle. 3N-photons would be analogous to Bose-Einstein condensates of 3N photons [L192, L193]. The mechanism leading to these states would be Galois confinement possible in TGD framework [L51, L125, L139].

4. Since the energies of quantum states quite generally increase with h_{eff}, the increase of h_{eff} would require a "metabolic energy" feed. The excitation of the stringy degrees of freedom could provide this energy and transform to rotational energy. One could think that in the scission the flux tube as string is heated to high temperature and this energy is liberated to collective rotational motion. The minimal value of the angular momentum would be $\hbar_{eff} = N\hbar$ and would force coherent rotation.

9.2.6 ZEO based view about scission

It is also interesting to consider the description of the scission process could be in zero energy ontology (ZEO) [L105].

1. Quite generally, tunnelling phenomenon in nuclear reactions could correspond to a pair of "big state function reductions" (BSFRs) [L103]. BSFR is the counterpart of the ordinary SFR and changes the arrow of time [L105, L139]. The intermediate period with an opposite arrow of time would correspond to the tunnelling in nuclear reactions.

   This model emerged from a model "cold fusion" as nuclear reactions for dark nuclei with protons and neutrons having nonstandard value of h_{eff} increasing their Compton lengths [L27, L54, L117, ?].

2. When the state of the system is near the threshold for scission, the system is quantum critical and experiences long scale quantum fluctuations with varying balue of h_{eff}. Given fluctuation increases the Compton radius of nucleons by factor $h_{eff}/h = n/6$. Nuclear string would be scaled up in size. This might be true even for ordinary nuclear reactions. Nuclear binding energies would be scaled down like $1/h_{eff}$. After the second BSFR, h_{eff} would return to the original value, perhaps in a stepwise manner.

3. The decay process leading to an elongated nucleus as an intermediate state could emerge in the first BSFR leading instantaneously to the elongated state. In ZEO quantum states are superpositions of classical time evolutions and at the classical level this looks to an observer with a standard arrow of time classically like a deterministic time evolution leading from a roughly spherical initial to a highly elongated state. This interpretation explains the strange looking findings of Minev *et al* for state function reductions in an atomic system [L90] [L90].

   The state to which the classical time evolutions of the superposition apparently lead would correspond to the elongated nucleus. Actually it would be the initial state of the time reversed time evolution. The classical model of the authors would describe this period.

4. Second BSFR would re-establish the original time direction and correspond to the splitting of the elongated state to fragments in the manner already described.

9.3 The asymmetry of antimatter in proton from TGD point of view

I encountered a highly interesting popular article *"Decades-Long Experiment Finds Strange Mix of Antimatter in The Heart of Every Proton"* (`https://cutt.ly/BlZtNne`).

The popular article tells about the article "*The asymmetry of antimatter in the proton*" of Dove *et al* [C44] published in Nature (`https://cutt.ly/BlZt8sV`). This article is behind the paywall but the same issue of Nature has an additional article "*Antimatter in the proton is more down than up*" [C104] (`https://cutt.ly/blZyT4u`) explaining the finding.

What is found is an asymmetry for u and antiquarks in the sense that there are slightly more d-type antiquarks (anti-d) than u type antiquarks (anti-u) in quark sea. This asymmetry does not seem to depend on the longitudinal momentum fraction of the antiquark: the ratio of anti-down and anti-up distribution functions is smaller than one and constant.

A model assuming that proton is part of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture. Unfortunately, the old-fashioned strong interaction theory based on nuclei and pions does not converge by the quite too large value of proton pion coupling constant.

I looked at the situation in more detail and developed a simple TGD based model based on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD [L50]. What TGD can give is the replacement of virtual mesons with real on mass shell mesons but with p-adically scaled down mass and a concrete topological description of strong interactions at the hadronic and nuclear level in terms of reconnections of flux tubes.

9.3.1 TGD inspired model for the asymmetry

Basic data about quark and nucleon masses

To get a quantitative grasp about the situation, one can first see what is known about masses of u and d quarks.

1. One estimate for u and d quark masses (one must taken the proposals very cautiously) can be found (`https://cutt.ly/dlZukKC`).

   The mass ranges are for u 1.7-3.3 MeV and and for d 4.1-5.8 MeV.

2. In the first approximation n-p mass difference 1.3 MeV would be just d-u mass difference varying in the range 1.2 MeV-4.1 MeV and has a correct sign and a correct order of magnitude. 4.1 MeV for d and 3.3 MeV for u would produce the n-p mass difference correctly.

3. Coulomb interactions give a contribution E_c, which is vanishing por proton and and negative for neutron

   $$E_c(p) = 0 \quad , \quad E_c(n) = -\alpha \times \hbar/3R_e \quad .$$

   R_e is proton's electromagnetic scale.

   This contribution reduces neutron mass. If R_e is taken to be proton Compton radius this gives about $E_c \simeq -3.2$ MeV. This would predict mass n-p difference in the range -1.1-0.9 MeV. This favors maximal n-p mass difference 4.1 MeV and m(u)= 1.7 MeV and md =5.8 MeV: d-u mass difference would be 4.1 MeV roughly 4 times electron mass.

TGD based picture about hadronic an nuclear interactions

Consider first the TGD inspired topological model for hadronic an nuclear interactions implicitly contained in the model of nuclei as nuclear strings [L4] further developed in applications to "cold fusion" [L27, L54, L117] and by using input from the anomaly assignable to the nuclear physics of solar core [L103, L91].

1. The notion of magnetic body (MB) assignable to color and em and electroweak interactions is essential. The interactions are described by virtual particle exchanges in quantum field

theory (QFT). In TGD they are described by reconnections of U-shaped flux tubes which are like tentacles.

In interaction these tentacles reconnect and give rise to a pair of flux tubes connecting the particles. The flux tubes would carry monopole flux so that single flux tube cannot be split. These flux tube pairs serve also as correlates of entanglement replacing wormholes as their correlates in ER-EPR picture.

This picture looks rather biological and was developed first as a model of bio-catalysis [L194] [K84]: reconnections of U-shaped tentacles would make possible for reactants to find each other and their shortening in phase transitions reducing h_{eff} would bring them near to each other. The picture should apply quite generally to short range interactions at least.

2. The U-shaped flux tubes of color MB replace virtual pion and and ρ meson exchanges in the old fashioned picture about strong interactions. They represent in TGD framework real particles but with p-adically scaled down mass. For instance, pions are predicted to have scaled down variants with masses different by a negative power of 2 from pion mass. Same is true for rho. Now the masses would be below MeV range, which is the energy scale of nuclear strong interactions. Also nuclear strong interactions would occur in this manner [L4] [L103].

A model for the anti-quark asymmetry

Consider now a model anti-quark asymmetry for sea quarks.

1. Quarks and antiquarks would appear at these flux tubes. The natural first guess is that meson like states are in question.

   The generation of u-anti-d type pion or ρ would transform proton to neutron if the valence u transforms to valence d and W boson with scaled down mass.

   Note that the scaling down would make weak interaction stronger since weak boson exchange amplitude is proportional to $1/m_W^2$ and scaled by up by a factor of order 10^{10} if m_W has mass in MeV range.

   This would give the analog of neuron plus charge virtual pion. Taking two sea quarks would lead to trouble with the too large Coulomb interaction energy about -10 MeV of negatively charged sea with positively charged valence part of proton if the sea is of the same size as proton.

2. Does the scaled down W^+ decay to u-anti-d forming a scaled down meson π^+ or ρ^+? Or should one regard u-anti-d as a scaled down W^+ having also the spin zero state analogous to pion since it is massive?

3. Here comes a connection with old-fashioned and long ago forgotten hadron physics. Thepartially conserved axial current hypothesis (PCAC) gives a connection between strong and weak interactions forgotten when QCD emerged as the final theory. PCAC says that the divergence of axial weak currents associated with weak bosons are proportional to pions.

   Are the two pictures more or less equivalent? Virtual pion exchange could be regarded as a weak interaction! Also conserved vector current hypothesis (CVC) is part of this picture. This is not new: I have developed this picture earlier in an attempt to understand what the reported X boson with 17.5 MeV mass is in the TGD framework. Scaled down pion would be in question [L50].

4. What about the masses of quarks and proton? Since the flux loop would have considerably greater size than proton, the mass scale of u-anti-d state would be smaller than say MeV, and the contribution to mass of proton would be small.

5. Why the asymmetry for anti-quarks of sea? The generation u-anti-d loop would increase the charge of the core region by two 2 units and transform it to Δ. This looks neither plausible nor probable. Proton would be a superposition consisting mostly of the proton of good old QCD and neutron plus flux loop with quantum numbers of a scaled down pion.

6. Also the presence of scaled down ρ meson loops can be considered. Their presence would turn the spin of the core part of the proton opposite for some fraction of time. One can wonder whether this could relate to the spin puzzle of proton.

9.4 Pomeron and Odderon from TGD point of view

The following comments were inspired by a popular article telling about the empirical support for a particle christened Odderon (`https://cutt.ly/2xd7M7Y`). The article about Odderon by Csörgö *et al* is published in European Physics Journal C [C63]. As the name tells, Odderon is not well-understood in QCD framework.

Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it. Since the charge parity (see `https://cutt.ly/ixd78aS`) is $C = 1$ for Pomeron $C = -1$ for Odderon, these states are analogous to pion with spin 0 and ρ meson with spin 1.

Pomeron and Odderon have not been in the interests of the frontier of theoretical physics: they represent for an M-theorist a totally uninteresting and primitive low energy phenomenology - as all that we used to call physics before the first superstring revolution -, and does not therefore deserve the attention of an ambitious superstring theorist more interested in the marvels of brane words, landscape, swampland, and multiverse.

I have written about Pomeron for years ago. The following is something different since the view about low energy strong interactions according to TGD [L123] has developed considerably [L150, L143].

One can go first to Wikipedia to learn about Pomeron [C134, C10] (`https://cutt.ly/Wxd5eFq`).

1. Pomeron exchange appearing in the t-channel in elastic scattering was postulated to explain the slowly (logarithmically) rising scattering cross sections in proton-proton and proton-antiproton collisions. For quarks and gluons the scattering cross sections fall down rather rapidly with energy (by dimensional argument like inverse $1/s$ of cm energy squared) so that something else would be in question.

2. The total cross sections do not depend on the charges of the colliding baryons. The usual shower of Cerenkov radiation was missing from Pomeron exchange events. The absence of pions usually present was interpreted as absence of color charge.

   This suggests that quarks and gluons do not participate the Pomeron events. There is often also a large rapidity gap in which no outgoing particles are observed.

3. In the Regge theory which later was concretized in terms of the hadronic string model. Pomeron would correspond to a Regge trajectory for which the Reggeon would have quantum numbers of vacuum except for mass and angular momentum. Regge trajectory would satisfy the formula $M^2 = M_0^2 = \alpha(s)J$, M mass, J angular momentum. The exchange of the entire Regge trajectory would give rise to approximately constant cross section. Odderon would be Pomeron like state with an odd charge parity $C = -1$ instead of $C = 1$. Pomeron and Odderon could correspond $C = \pm 1$ parts of a Regge trajectory.

4. In the QCD picture Pomeron and Odderon are assumed to be associated with the gluonic exchanges, which should form Regge trajectories: this suggests a stringy picture and non-perturbative QCD. Pomeron *resp.* Odderon would be a many-gluon states with an even *resp.* odd number of gluons.

In the many-sheeted space-time of TGD, hadrons are many-sheeted objects.

1. There is a hadronic space-time sheet and quark and gluon space-time sheets are glued at this. There is a magnetic body (MB) of hadron having a layered structure. In particular, there are em/color/weak MBs consisting of flux tubes and "tentacles", which are U-shaped flux tubes.

   Low energy hadron physics would be described in terms of reconnections of these tentacles. This is a rather new element in the picture. In a reasonable approximation, flux tubes are strings and the reconnection of closed strings appears as a basic reaction vertex for closed strings. This gives a connection with the hadronic string model. TGD indeed emerged as a generalization of the hadronic string model 43 years ago (and also as a solution of the energy problem of GRT).

2. Most of the energy of hadron is assumed to be carried by color MB: quarks and gluons carry only a small part of energy. In QCD space-time dynamics is not present and the analog of hadron as space-time surfaces would be a gluon condensate of some kind.
3. Low energy hadron reactions would consist of reconnections of the U-shaped flux tubes of the colliding color MBs. Besides this there are also the collisions of quarks and gluons having approximate description in terms of QCD. The already mentioned connection with hadronic string model suggests a connection with Regge and string model descriptions of Pomeron/Odderon.
4. Hadrons have U-shaped flux tubes acting like tentacles and reconnect to form a bridge of two flux tubes between colliding hadrons. This topological interaction mechanism would be universal and occur in all scales. In biology the ability of reacting biomolecules to magically find each other in the dense molecular soup would rely on this mechanism. It would be also a mechanism of high Tc - and biological superconductivity.

Could this explain the basic properties of the Pomeron?

1. Charge independence and the absence of pion emission assignable to quark-gluon reactions can be understood. Gluons and quarks of colliding hadrons would not meet each other at all. The two colliding hadrons would just touch each other with their "tentacles" which would transfer some momentum between them in elastic collisions. This would explain the rapidity gap.
2. What about the slow dependence on collision energy? Why the cross section describing the probability of the formation of reconnection would not depend on collision energy?
   (a) One could visualize the cross section in cm frame geometrically as the area of a 2-D surface cylinder parallel to the line connecting the colliding particles. The area of this cylinder would tell the probability for the formations of reconnection. If I try to touch some object in darkness, its area tells how probable the success is.
   (b) In elastic scattering the t-channel momentum exchange would be orthogonal to this cylinder and have vanishing energy component. It would not change in Lorentz boosts increasing the cm collision energy. If the contribution to the cross section depends only on t, it would be independent of collision energy.

9.5 TGD based interpretation for the strange findings of Eric Reiter

I learned of rather interesting findings claimed by Eric Reiter hosting a public group "*A serious challenge to quantum mechanics*" (`https://cutt.ly/VlBgFk4`). There is a published article [L148, H7] `https://cutt.ly/rlBgOl1`) about the behavior of gammas emitted by heavy nuclei.

Background

Eric Reiter has studied the behavior of gammas emitted by heavy nuclei going through two detectors in tandem. Quantum theory predicts that only one detector fires.It is however found that both detectors fire with the same pulse height and firings are causally related. Depending on wavelength, the effect is reported to increase or decrease with distance between the source and detector. The pulse rate depends on the chemistry of the source, which does not conform with the assumption that nuclear physics and chemistry decouple from each other. Reiter has made analogous experiments also with alpha particles with the same conclusion. These findings pose a challenge for TGD, and in this article a TGD based model for the findings is developed.

On the basis of these findings, Reiter makes the rather provocative proposal that quantum theory is an illusion, and suggests a semiclassical theory known as loading theory represented originally by Max Planck. The theory states that the detectors fire only after they have loaded a sufficient amount of energy. The theory assumes that quantization of energy holds true only at the moment of emission but after that the energy disperses to the em fields describing the radiation.

In order that loading theory can explain the almost simultaneous and causally related firings, the loaded electromagnetic energy should achieve a critical value at the same time for both detectors. It seems that both detectors must start always in preloaded state and preloadings must be identical. It is not obvious to me how the loading theory can explain the success of quantum theory for visible photons. Reiter claims that this is possible.

Before continuing, let us make clear that although I am not a proponent of unquantum theory, I take the observations of Reiter seriously and regard them as an extremely interesting challenge also for TGD.

Basic observations of Reiter

The basic observations claimed by Reiter [L148, H7] `https://cutt.ly/rlBgOl1`) are the following.

1. Full pulses and half-pulses, which by definition have height smaller than 2/3 of the height of full pulse are recorded in both detectors. This in conflict with the prediction that only one detector should fire if pulses are caused by the absorbtion of the gamma. The pulses are causally related. The probability for half pulse pairs is by factor of 100 higher than by change. The probability for full pulse pairs is 4 times higher than by change. Both observations should correspond to 2 gammas in standard quantum theory. Only full pulses are considered in the analysis.

   Remark: One can ask whether the secondary gammas associated with the Compton scattering of gamma can propagate to the second detector and cause a pulse in it. The situations could correspond to half pulses whereas full pulses could correspond to the absorption of gamma.

2. For full pulses two gammas are absorbed. This challenges energy conservation and the assumption that single gamma enters the detector system. The proposal based on loading theory is that some kind of threshold effect is in question. When the loaded energy reaches a critical value, absorption occurs. Not only the energy of the secondary gamma but also the energy loaded to the D2 would be released and give rise to pulse pairs with total released gamma energy exceeding the energy of the incoming gamma. Preloading is the term used: preloading would be a continuous parameter,call it P. The values of P for the two detectors should be the same. P should be analogous to temperature and the detectors should be in state analogous to thermal equilibrium.

Can one explain the unquantum effect in standard physics?

The experiment of Reiter uses gamma scintillators (`https://cutt.ly/BvRdE1e`) to the primary detection of gammas. The signal is mostly generated by photoelectric absorption inducing ionization producing in turn photoelectrons and by Compton scattering of gamma inside an NaI crystal in the experiment to be considered in the following. The basic question is whether one can understand causal pulse pairs with the same pulse heights in the standard physics picture assuming a single incoming gamma.

1. Energy conservation challenges the standard physics explanation. The estimates for the total gamma release of gamma energy give total energy exceeding that for the incoming gamma. This has motivated the idea that energy is loaded to the D2 so that the total energy released exceeds the energy of the incoming gamma.
2. If the gamma is absorbed in the first detector (D1), a causal pulse pair is not obtained. Since the gamma must get through as a secondary gamma, one can restrict the consideration to Compton scattering. Note that Compton scattering produces also ionized atoms but this is not essential for what follows.
3. The pulse height is assumed to be determined by the part E_1 of the energy E_{lost} lost by the gamma to which the detector responds. If the detection is a local process, $E_1 < E_{lost}$ is true. $E_{lost} = E$ is true if the detector is thick enough. If the detection is a local process, Compton scattering can produce pulses with constant heights.
4. From **Fig. 9.1** of Appendix one learns that the D1 is 4 mm thick and much thinner than the attenuation length of the detector which is of order 10 cm. This means that the pulse height for Compton scattering in D2, which is thicker than the D1 differs from that in D1. Could a gamma, which is Compton scattered in D1 and absorbed in D2, produce an equal height

pulse pair? This would require $E_{lost} = E/2$ in D1. The maximum of E_{loss} in the Compton scattering from a free electron is however $2E/7$ for $D = 100$ kV (see Appendix) and occurs for back-scattering so that this situation is not possible.

The gamma which gets through the detectors spends 1.2×10^{-12} seconds to get through the D1. Several sub-pulses from Compton scattering are possible and they sum up to a single pulse from the entire detector. If the pulse were produced locally, the time resolution of the detector should be about $\tau = 10^{-12}$ seconds. The actual resolution is about $\tau = 10^{-7}$ seconds. During this time the gamma propagates 30 meters, which strongly suggests that the pulse detection is non-local process in both detectors.

5. One can therefore assume that the energy E_{lost} indeed determines the pulse height. In the D1 only part of E is lost and the energies of causal pairs are in general different and one does not have a natural explanation for the causal pulse pairs with equal pulse height.

9.5.1 Basic ideas concerning the TGD based explanation of the Reiter's effect

I am not an experimentalist and I am not at all sure whether I have understood correctly the description of the experiments and results. With these cautions in mind, consider first a thought experiment forgetting the belief that the incoming particles are ordinary gammas and quantum theory holds true.

1. In 2-1 cases the pulses correspond to separate incoming gammas. At least two gammas should arrive at the D1.
2. One can understand simultaneous pulses with equal pulse heights, if a considerable number of gammas instead of a single gamma arrive the detector simultaneously. The particle from gamma source would not be gamma but a particle decaying to N nearly parallel gammas with the energy of ordinary gamma. These photons for a subset of them would be distributed between the detectors and average pulse heights could be identical.

The challenge is to see whether this picture can be realized in TGD framework. The key questions are the following.

1. What are the particles which would decay to N gammas before the detector or inside it.
2. Why pairs of full pulses and pairs of half pulses are observed?

Hierarchy of effective Planck constants and the notion of N-photon and N-nucleus

The TGD inspired model involves two new physics effects predicted by TGD.

1. In the TGD framework classical physics is an exact part of quantum physics and essential for the interpretation of quantum theory. $M^8 - H$ duality which is central element of TGD realizes kind of quantum-classical duality: both M^8 and $H = M^4 \times CP_2$ are needed. At the level of M^8 having interpretation as analog of momentum space, everything is quantal: there are no classical fields and space-time is analog of Fermi ball. At the level of $H = M^4 \times CP_2$ one has space-time as dynamical entity and classical fields.
2. TGD predicts a hierarchy of Planck constants $h_{eff} = nh_0$, $h = 6h_0$ is the value of h_0 suggested by the findings of Randel Mills [D58] [L42]. For a given frequency $E = h_{eff}f$ means that the frequency for a given energy is scaled down by $h/h_{eff} = 1/n$ in $h \rightarrow h_{eff}$. $n = 2$ would give period doubling.
3. Large values of h_{eff} allow quantum coherence in arbitrarily long scales since quantum coherence lengths increase with h_{eff} [L194]. This makes possible Bose-Einstein (B-E) condensate like N-particle states behaving like single particle: N-protons, N-ions, N-photons... A number theoretical phenomenon that I have christened as Galois confinement would be in question.

   N-photon as analog of BE-condensate-like state of N photons behaving like a single particle. Quantum coherent state can be regarded as superposition of N-photon B-E condensates of this kind.

N-photons play a central role in TGD inspired quantum biology. For instance, biophotons would be ordinary photons resulting from decay of dark 3N-photons to ordinary photons [L121, L137]. Baryons as 3-quark states provide the analogy: color confinement forces the 3 quarks to behave like a single particle.

Also condensed matter could realize these N-particle states states. Ordinary DNA would be accompanied by dark DNA which would consist of sequence of dark 3-protons realizing genetic code and providing also counterparts for RNA, tRNA, and amino-acids [L88].

The dark 3-protons combine to form similar 3N-proton states representing genes and emitting 3N-photons in collective cyclotron transitions and providing representations of genetic codons and coupling resonantly to corresponding genes. An interesting possibility is that for $h_{eff}/h_0 = n > N$ the N nuclei reside at different sheets of n-fold covering defined by the space-time region.

These considerations motivate the question whether the gammas could originate from N-gammas, which decay to ordinary gammas possibly having $h_{eff} > h$? Could this guarantee that both detectors receive a signal and average pulse heights are same.

Quantum criticality and unquantum effect

The proposed model assumes that the response of the detector is yes-no response. In critical systems the response is almost independent of the stimulus, kind of yes/no response. The incoming stimulus is like a small perturbation generating a phase transition.Therefore the intuitive idea is that quantum criticality is crucial.

A good metaphor is control knob: the response does not depend on how hard you push the knob. The role of the magnetic body in TGD inspired biology is to control the biological body. The control action pushes a knob generating a phase transition.

How to realize the control action?

1. Quantum criticality is accompanied by long range correlations and fluctuations implied by the quantum coherence in long scales. $h_{eff} = nh_0 > h$ indeed increases the scale of quantum coherence. The natural first guess is that $h_{eff} > h$ is true for the N gamma rays from N-gamma. $h_{eff} > h$ photons behave like dark photons in the sense that they do not interact directly with the ordinary matter.
2. The interaction with ordinary matter requires the transformation of the dark photon to ordinary photon with $h_{eff} = h$ after which the interaction can occur in the usual manner. The Feynman diagrams describing the interaction containing in the incoming photon line a vertex describing this transition.

   A very rough description of the transformation of the dark photon to ordinary photon is in terms of a transition probability p, which does not depend on the detector. A more refined description would be in terms of mixing of ordinary and dark photons. This requires that the mass squared of dark photon is non-vanishing but very small. Nothing happens in the detector unless this transition takes place.
3. Consider now what happens in the detector if the probability p is very small: $p << 1$. The dark photon detection rate $R_{d,1}$ in the D1 is given in the first approximation by $R_{d,1} = pR_1$, where R_1 characterizes the rate for the detection of ordinary gamma.

   In the D2 the "dark" detection rate is $R_{d,2} = p(1-p)R_2 \simeq pR_2$. $1-p$ characterizes the attenuation of the "single photon beam". If the detectors are ideal yes/no detectors then $R_1 = R_2$ and the ratio of the dark rates is $(1-p_1) \simeq 1$. This requires that the detector response is determined only by the first dark photons of the conical dark gamma beam serving in the role of control knob.

To sum up, the prediction is that for ideal detectors of dark gammas the detection rates are the same in both detectors and independent of the values d_i of the detector thickness. This prediction allows the testing of the dark photon hypothesis.

There is an interesting connection of quantum criticality with an effect discovered by Podkletnov and Modanese [H20] discussed from TGD point of view in [L28]. In Modanese-Podkletnov effect the electric discharges of a capacitor for which the second plate is super-conductor are reported to generate a pulse of unidentified radiation inducing the oscillation of test penduli. What is strange is that the beam of radiation does not seem to be attenuated. This suggests that the effect is caused by a dark photon beam which serves in the role of control knob in a quantum critical system and does not provide energy causing the oscillation of the penduli. Therefore the effect would have obvious resemblance to what is reported to happen in the tandem experiment of Reiter.

9.5.2 TGD based model for the findings of Reiter

In the experiment of Reiter [H7] detectors are in series. The detectors are scintillators in which the incoming gamma can suffer Compton scattering, become absorbed, or transform to an electron-positron pair. Electron can also absorb gamma. It is assumed that full pulses are due to the gamma absorption and that Compton scattering gives rise to what is called half-pulses.

The scintillators are crystals. Compton scattering and gamma absorption by electron lead to secondary processes, which can generate gammas. For instance, after the absorption of gamma the electron dissipates its energy and this effect is amplified in photo-multipliers. Scattered gamma can suffer further scatterings.

The surprising observation is that the responses of the two detectors identical in the measurement resolution used [H7].

1. If there is only a single incoming gamma, it should be absorbed in either detector. If the secondary gammas created in the D1 do not enter the D2, the presence of pulses of same pulse height in both detectors does not conform with the standard physics picture. Even if they enter to theD2, the pulse heights are not expected to be the same.
2. If the N-gamma decays to N ordinary or dark gammas, it might be easier to understand why the pulse heights are the same.

It is a good to start with an objection. That pulse heights are the same for both detectors, could be simply due to the fact that detectors are ideal yes-no detectors, which are (quantum) critical systems in the sense that incoming gamma rays serve as a control acting producing the same response irrespective of their number and energies. In this case, the secondary gamma rays from the D1 could induce the same response in the D2.

It turns out that the detectors could be ideal for the detection of dark gammas but not not for the detection of the ordinary gammas. The detailed model shows that standard physics picture cannot explain the causal pulse pairs with the same pulse height.

There are other observations of Reiter, which strongly suggest that new nuclear physics is involved.

The dependence of the unquantum effect on the chemistry of the gamma source

Unquantum effect depends on the chemistry of the source [H7]. This is observed when ^{109}Cd is used as a source. ^{109}Cd appears as salt or metal and salt produces 5 times larger unquantum effect, i.e. the rate of counts is 5 times higher. The proposed interpretation is that gamma waves from salt are more coherent. This behavior suggests that gamma emission is not a single-nucleus effect as standard nuclear physics would predict but involves many nuclei. Hence new nuclear physics would be involved.

Why would the nuclei of ^{109}Cd salt form larger quantum coherent structures? What these structures could be?

1. That several nuclei would be involved with the emission of gammas conforms with the N-gamma model in which N parallel gammas are emitted simultaneously as N-gamma in quantum coherent N-nucleus transition. N-gamma beam is analogous to B-E condensate of N gammas that is an N-photon state with identical photons. Intensity of N-gamma beam from different nuclei higher.
2. Also coherent states of gammas as superpositions of N-gammas for various values of N can be considered. This state would behave as classically as possible. Intuitively the unquantum effect indeed corresponds to effective classicality.

   Putting it more precisely, coherent state is an eigenstate of the annihilation operator of the photon and has the form $exp(\alpha a^\dagger)|0\rangle$, where α is a complex parameter. The expectation

value and variance of photon number N are given by $|N| = |\alpha|^2$ and $|\Delta N^2| = |\alpha|^2$. $|\alpha|^2$ is analogous to field intensity. The larger its value, the more classical the state is.
The value of $|\alpha|^2$ should be larger for ^{109}Cd salt than for ^{109}Cd metal. The coherence of gammas would directly reflect the quantum coherence of ^{109}Cd as a many-nucleon system: this coherence is impossible in standard physics picture.

The larger the size of quantum coherence length in the gamma source, the larger the value of N if every nucleus emits identical gamma simultaneously. The scale of quantum coherence scales like h_{eff} and N like $(h_{eff}/h)^3(L_n/L_a)^3$ if the coherence region is spherical. Here $L_n \sim 10^{-14}$ m is nuclear scale and $L_a \simeq 10^{-10}$ m is atomic scale. One must $h_{eff}/h >> h_{eff,min}/h = (L_n/L_a)^3 = 10^{12}$ for the spherical option and $h_{eff}/h >> h_{eff,min}/h = (L_n/L_a) = 10^4$ for the linear option.

A couple of remarks are in order.

1. In TGD inspired quantum biology [L194] flux tubes carrying dark protons define linear coherence regions giving $N \propto (h_{eff}/h) \times (L_n/L_a)$.
2. In cold fusion the distance of dark protons at flux tube is about electron Compton length $L_e \simeq 10^{-12}$ m, one has $h_{eff}/h \simeq m_p/m_e \simeq 2000$ [L117, L27].

The dependence of the unquantum effect on the detector-source distance and gamma wave length

The intensity of the unquantum effect depends on the wavelength λ of gamma and distance d between source and detectors [H7].

1. ^{241}Am emits gammas with energy $E = 59.5$ keV, which corresponds to wave length $\lambda = 2.1 \times 10^{-11}$ m. The UQ effect is enhanced as the distance d between the source and detector decreases.
2. ^{1}37Cs produces gammas with a shorter wavelength λ (gamma energy and wavelength are $E = .6617$ MeV and $\lambda 1.86 \times 10^{-12}$ m). UQ effect is enhanced when d increases.

What enhanced UQ effect means is not quite clear. Does the height or the rate for pulses increase? From private communications I learned that the correct identification of enhancement is as an increase for the rate of pulses.

How to understand this behavior? Distance d is certainly a relevant variable. But is this true for λ? N correlates with the size of the nuclear quantum coherent state. Could N be the relevant variable instead of λ. It is best to build a concrete view for what happens in the decay of N-gamma to N gammas.

1. N-gamma is analogous to B-E condensate of N gammas which have $h_{eff} > h$. B-E condensate is formed from ordinary photons which in general do not have parallel momenta and identical energies. The phase transition however creates this kind of state. The phase transition occurs by addition of photons to the B-E condensate and takes some time.
2. Does this phase transition occur before the detectors or inside the detectors and is perhaps induced by the interaction with the detector materials?

Consider the option for which the decay occurs before the detector.

1. The decay of N-gamma is the reversal of Bose-Einstein condensation. Therefore the N-gamma must decay during some time interval to N gammas which do not have exactly parallel momenta. These gammas move inside a cone with some opening angle. The intensity of the gamma beam decreases with distance like $1/r^2$, where r is the distance from the point of phase transition. The number of (possibly dark) gammas, which arrive the detector decreases with the distance d of the detector from the phase transition region. If more than one gamma contributes to the pulse, one can understand why the height of the peak is reduced with the distance. If only one, the reduction does not occur.
2. On the other hand, the detector must be far enough from the source so that the phase transition to ordinary gammas has already occurred. If the decay of N-gamma to gammas takes place gradually and only the gammas interact with the detector the peak height increases with the distance from the phase transition. This is true if the interaction of the still existing

M-gamma state ($1 < M < N$) with the detector is so weak that it goes through the detector without interaction with a high probability.

The prediction of the model depends on whether the N gammas produced by the decay of N-gamma produce single pulse or separate pulses which can be distinguished from each other.

1. Suppose that the gammas interact simultaneously to produce a single pulse. In this case, the two constraints imply that there is some distance at which the *pulse height is maximal*. For Am having larger gamma wavelength d would be larger than the optimal distance and forCs with smaller gamma wave d would be smaller than optimal distance d_{opt}. Note that the optimal distance depends on N and therefore the size scale of coherent regions of nuclei. Intuitively it seems clear that the optimal distance increases with N since the decay time of a larger B-E condensate is expected to be longer. The dependnce of pulse height on distance does not conform with Reiter's report.
2. If the gammas have slightly different directions within the cone, they arrive at slightly different times to the detector. If the gammas give rise to separate pulses, the *pulse rate* should depend on the distance as reported by Reiter. The time to travel a distance of say 30 cm defining the detector's transversal scale is about 1 ns. Therefore the gammas resulting from single N-gamma would give rise to separate pulses.

Consider next a more concrete model based on a modification of Reiter's own interpretation. The transversal width of the gamma wave packet is proportional to $d\lambda$, $d = ct$ is the distance travelled. This what Schrödinger equation as a diffusion type equation suggests for massive particle - λ would be in this case Compton wave-length $\hbar/m$. Reiter argues that maximal effect is obtained when $d\lambda$ is equal to theCompton area of the electron.

TGD inspires a modification of Reiter's idea.

1. Massless extremals (MEs) serve as classical correlates for radiation. They are very general 4-surfaces of form $F(s, k \cdot m, \epsilon \cdot m) = 0$. m denotes M^4 coordinates, s CP_2 coordinates, k is light-like vector in M^4 and ϵ is a polarization vector orthogonal to wave vector. More general MEs with $\epsilon \cdot m$ replaced with arbitrary function of coordinate of plane orthogonal to k meaning local polarization orthogonal to k are also possible.
2. The simplest ME would be cylindrical but much more general - say cone-like - MEs are possible. Quantum classical correspondence suggests that the area S of the transversal cross section of ME increases during the propagation like $\lambda t = \lambda d/c$: an analog of conical wave would be in question.
3. Suppose that ME contains N dark gammas produced by the decay of BE-condensate. All dark gammas should reach the detector to obtain maximum number of pulses. S should be as small as possible but contain the detector area. This implies optimal values $S = S_{opt}$ and $d = d_{opt}$ for S and d.
4. If ME contains the N gammas from the decay of N-gamma, the different directions of motion for gammas could imply that the gammas generate separate pulses. 1 ns was the rough estimate for the time difference of pulses.

One can consider also the option that the N-gamma decays inside the detector volume rather than before it and produces a *single* pulse consisting of N simultaneous pulses. In this case the N-gamma delocalized into the transversal cross section of ME does not always interact with the detector material for $S > S_{opt}$ minimal so that the rate decreases with increasing $d > d_{opt}$. For $d < d_{opt}$, one has $S < S_{min}$ and the number of N-gammas entering detector does not depend on d so that the pulse rate should not decrease with decreasing d. This does not conform with the report of Reiter.

Why the pulse heights in the two detectors are the same?

Pulse heights in the two detectors are reported to be the same. This explanation might involve both new physics and understanding of the functioning of the detector.

It would seem that the conical beam consisting of N gammas is not considerably attenuated in the D1 which is a thin crystal. If the gammas are dark, the interaction with the detector would involve transformation of dark gamma to ordinary gamma and the probability for this process is expected to be low. This alone could explain why the beam is not considerably attenuated in the D1.

Since the D2 is thicker, also an additional condition must be satisfied. Only the gammas arriving absorbed by electrons (or possibly Compton scattered for half pulses) during some time interval ΔT can contribute to the pulse. The detector would therefore have a time resolution ΔT in the sense that the gammas arriving after this time would not affect the height of the pulse. Detector would be analogous to a neuron which has some dead time after the arrival of the nerve pulse.

Effectively the detector would serve as a yes-no detector telling whether dark N-gamma arrived or not and would be analogous to a quantum critical systemwhose response does not depend on the strength of control action but only on its existence.

Suppose that a conical beam of N (possibly dark) gammas arrives the D1.

1. If only the gammas arriving during ΔT and interacting with electrons of the detector contribute to the pulse, the same pulse height is obtained in both detectors if the number M of interacting gammas is high enough. This suggests that N must be large enough so that the product $M = pN$ is large enough. Here p is the probability of dark-to-ordinary transition. The detector would not react to later gammas.
2. The value of M decreases with the distance of the detector from the phase transition regions by the conical character of the beam. It is however essential that the detectors are not too far from each other. This could be tested.

One cannot exclude the possibility that the secondary gammas, which are ordinary gammas, from the D1 cause a pulse in the D2. In this case, one cannot expect identical pulse heights.

If $h_{eff} > h$ is true for gammas, one can imagine that one prevents the arrival of the secondary gammas from the D1 to the second one. Dark gammas could however get through and cause detection. This could be used to see whether the primary gammas are dark.

Does unquantum effect disappear as the source is aged?

9.5.3 Does unquantum effect disappear or get more pronounced as the source is aged?

The basic feature of quantum coherence is that it is eventually lost. Since the energy of the state increases with h_{eff} as other parameters are kept constant, the increase of h_{eff}requires energy feed. Since h_{eff} tends to be reduced spontaneously, its preservation requires energy feed. In living matter this corresponds to metabolic energy feed [L24, L194].

This predicts that quantum coherence of the source is gradually lost so that for an old enough source the effect is eventually lost. If the number N of dark nuclei gradually decreases with time, the height of the maximal pulse gradually decreases. Note however that also the ordinary nuclei decay and it can happen that the loss of N-nuclei by decay and loss of quantum coherence is slower in which case the effect can become easier to detect.

What could induce the quantum coherence by energy feed?

1. In Pollack effect induced by energy feed by say photons [I18, L24, I29, I26] called exclusion zones (EZs) having negative charge are formed. IR photons with an energy corresponding to room temperature are the most effective.The effective stoichiometry of water molecules is $H_{1.5}O$ suggesting that every fourth water molecule loses a proton and becomes negatively charged.
2. The TGD based interpretation is that every fourth water molecule loses a proton which transforms to a dark proton with $h_{eff} = nh_0 > h$ sequences of dark protons - dark nuclei - are formed at the flux tubes. Quantum coherence would be caused by a feed of photons. The sequences of dark protons have a total energy slightly larger than the energy for protons bound to water molecules.
3. A dark analog of the nuclear binding energy would be involved but would be scaled down by the ratio of p-adic length scales of the nucleus and dark nucleus. eV as the scale of molecular binding energies would be a natural unit for the dark nuclear binding energy.

The binding of dark protons at the flux tube would be by meson-like flux tube bonds in a shorter scale. The energy of the bond would be inversely proportional to its length and therefore much smaller than for ordinary nuclei which would also be nuclear strings [L4].

4. Also the TGD based model of "cold fusion" [L27, L54, L117] involves the analog of Pollack effect. The spontaneous transformation of dark nuclei to ordinary ones would liberate almost all nuclear binding energy. The model suggests a generalization also to the case of dark ions.

It came as a surprise to me, that the ageing of the source can make the effect more pronounced. If the dark N-nuclei have a considerably longer life-time than ordinary nuclei, the exponential decay of ordinary nuclei can lead to a situation in which only dark N-nuclei decay and the firing of both detectors due to gamma pair from a simultaneous decay of two ordinary nuclei or due to gamma from an ordinary nucleus and cosmic gamma ray is negligible.

The following simple model describes the situation quantitatively

1. For ordinary gammas the production rate is

$$R_1 = \frac{d\gamma_1}{dt} = -k_1 n_1 = -k_1 n_1(0) e^{-k_1 t} \quad ,$$

where n_1 refers to the number of ordinary nuclei.

For N-gammas γ_N one has

$$d\frac{d\gamma_1}{dt} = k_N n_N = k_N n_N(0) e^{-k_N t} \quad .$$

n_N is the density of the N-nuclei in the source. In both cases, the rate decreases exponentially.

2. The ratio of the rates is

$$\frac{R_1}{R_N} = \frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)} \times N e^{(-k_1 + k_N)t} \quad .$$

$n_N(0)$ is expected to be much smaller than $n_1(0)$.

3. For small values of time t exponentials not matter and one has

$$\frac{R_1}{R_N} = \frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)} \quad .$$

For $(k_1/k_N) * (n_1(0)/n_N(0)) < 1$, the rate of firings of both detectors due to pairs of photons associated with N-gammas can be masked by the accidental pairs of this kind.

For large values of t N-gammas dominate for $k_N < k_1$ and double firings due to N-gammas becomes more pronounced. N-gammas begin to dominate for

$$t > t_{cr} \sim \frac{1}{k_1} \times log[\frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)}] \quad .$$

Here $t_1 = 1/k_1$ ja $t_N = 1/k_N$ are the lifetimes for ordinary nucle and N-nuclei. Since the logarithm grows very slowly this can happen even for $n_N(0)/n_1(0) \leq\leq 1$.

It would be interesting to check what one can conclude from the known life times for various sources.

In principle, one can also consider the possibility that the loaded states of Reiter correspond to N-gammas formed at detectors. The dependence of the pulse rate on the chemistry of the source and on the distance between the source and detector are however not consistent with this hypothesis.

Quantitative model for the unquantum effect

TGD based model assumes N-gamma decaying to N dark gammas with $h_{eff} > h$ before the D1. Both Compton scattering and absorption are preceded by a transformation of dark gamma to ordinary gamma occurring with probability p. These events follow binomial distribution $B(p, N)$.

One can also consider a situation in which 2 or more gammas are absorbed within a time interval Δt so short that they create only a single pulse but with a height, which is twice the height of a single gamma pulse. Higher multiples with n-fold pulse height are also possible.

A rough estimate for Δt is of order 1 ns. Let the probability for the co-incidencebe p_{coind}. The probability distribution of this kind of events for a sample of M pulses from N-gamma obeys binomial distribution $B(p_{coind}, M)$. In the following only the first case is considered.

1. Assume that N dark gammas enter the D1 and $M_{1,a} \equiv M_1 < N$ dark gammas transform to ordinary gammas and are absorbed. Besides this there are $M_{1,c}$ gammas suffering Compton scattering and possibly ending up to the D2. This gives a contribution similar to that of a beam of $M_{1,c}$ Compton scattered gammas. In the following only the situation in which $M_{1,c} = 0$ is considered. The number of dark gammas entering the D2 is in this case $N_1 = N - M_1$. Assume $M_1 << N$.

   If the pulse height depends on $E_{lost} = E$ only and does not depend on the detector thickness d, the pulse heights of single absorbed dark gamma is the same in the two detectors. This would give rise to causal pulse pairs with the same pulse height.

   If the D2 is so thick that $E_{lost} = E_1$ in Compton scattering, the pulse heights are nearly the same if $E_1 \simeq E$ is true.
2. Restrict the consideration to M absorbed gammas in both detectors. For a linear response,the absorbed energy is $E_{lost,1} = M_1 E$ in the D1 and $E_{lost,2} = M_2 E$ in the D2. The total pulse height is N_i times that for a single gamma. The linearity assumption is not essential: also non-linear response function gives a quantized response.
3. The detection gives rise to causal pulse pairs (M_1, M_2) labelled by the numbers M_1 and M_2 of absorbed dark gammas. By previous arguments the individual M_i pulses should sum up to a single pulse.
4. One should explain the dominance of (M_1, M_1) causal pairs. The probability that M_1 dark gammas are absorbed depends on M_1 and and a good first guess is that one obtains a Gaussian distribution concentrated around $M_{1,max}$ and $M_{2,max}$ in the two detectors. $M_{1,max} = M_{2,max}$ is in good approximation true if N and $N - N_1$ are nearly the same.

The estimation of M_{max} is straightforward by noticing that the number of absorbed dark gammas obeys binomialdistribution.

1. The probability that M_1 dark gammas are absorbed and nothing happens to the remaining $N - M_1$ gammas is given by

$$P(M_1 : N) = Bin(N, M_1)p^{M_1} \times (1-p)^{N-M_1} \quad , \quad Bin(N, M_1) = \frac{N!}{M_1!(N-M_1)!} \ . \quad (9.5.1)$$

   p is the probability that a single dark gamma transforms to ordinary gamma.
2. One can estimate the maximum of $P(M_1 : N)$ by approximating M_1 with a continuous variable so that maximum satisfies the condition$dP(M_1 : N)/dM_1 = 0$. This gives the following condition for the logarithmic derivative of binomial coefficient $Bin(N, M_1)$:

$$\frac{dlog[Bin(N, M_1)]}{dM_1} = log(\frac{1-p}{p}) \ . \quad (9.5.2)$$

   By using Stirling approximation for $log(M!) \simeq log(c) + M^{M+1/2} - M$, where c is constant, one obtains in the case$N >> 1$ ja $M_1 >> 1$

$$M_{max:N} = pN \ . \quad (9.5.3)$$

   The result could have been guessed.

3. An improved approximation can be obtained by iterating the formula

$$M_{max:N} = pN \times exp(-\frac{1}{2M_{max:N}}) \ .$$

The next approximation is

$$M_{max:N} = pN \times exp(-\frac{1}{2pN}) \ . \tag{9.5.4}$$

4. The ratio of the probabilities $P(M_1)$ and $P(M_1+1)$ is given by

$$\frac{P(M_1+1:N)}{P(M_1:N)} = \frac{p}{1-p}\frac{N-M_1}{M_1} \ .$$

At the maximum this gives in the first approximation

$$\frac{P(M_{max}+1)}{P(M_{max})} = \frac{p}{p+\frac{1}{N}} < 1 \ .$$

By stationarity the values are near to each other.

5. Binomial distribution concentrates strongly around the maximum and allows an approximation as Gaussian distribution with mean (maximum) $M_{max:N} = pN$ and variance $\sigma^2 = Np(1-p)$ (`https://cutt.ly/ov0QZ3o`). The Gaussian approximation is given by

$$P(M_1:N) \simeq \frac{1}{\sqrt{2\pi Np(1-p)}} exp[\frac{(M_1-pN)^2}{2Np(1-p)}] \ . \tag{9.5.5}$$

6. The probability distribution $P(M_1, M_2)$ for the pulse heights of causal pairs is a product of gaussians associated with N and $N - N_1 \simeq N$ and strongly concentrated around $M_{1,max}, M_{2,max}$ with $M_{1,max} \simeq M_{2,max}$. Hence the model predicts the observed causally related pulse pairs of the same height.

The discussed model is over-simplified since all M dark gammas transforming to ordinary gammas were assumed to suffer absorption.

1. The model based on the binomial distribution applies to the number of M gammas transforming to ordinary gammas also when $M_c \leq M$ of these gammas suffer Compton scattering.
2. Also the $M_c \leq M$ Compton scattered pulses obey binomial distribution. The parameter p is replaced with the probability p_c for Compton scattering. $1 - p_c$ is the probability for the absorption.

   In this case the most probable number of Compton scattered photons is

$$N_{c,max} = p_c M = p_c N_{max} = p_c pN \ . \tag{9.5.6}$$

3. In Compton scattering, the energy lost in the detector volume is in general smaller than in the absorption and the total energy lost in the detector is smaller. Therefore causal pulse pairs can have different energies and pulses have a height lower than maximal.Theformulafor $N_{c,max}$ allows to estimate the energy lost in the most probable event and therefore also the pulse height in terms of average energy lost in Compton scattering parameterizable as $E_{lost,c} = xE$, where E is gamma energy.
4. Pulse pairs of the same full pulse height could correspond to the most probable pairs with lost energy which is the sum of the energy $E_{lost,a}$ lost by absorption and the energy $E_{lost,c}$ lost in Compton scattering:

$$E_{lost} = E_{lost,a} + E_{lost,c} = pN[1 - p_c + p_c x]E \ . \tag{9.5.7}$$

   This phenomenon could relate to the appearance of half pulses (with height, which is by definition less than 2/3 of that for full pulse) although also gammas which leak from the D1 couldbe involved.

Beam splitter experiments involving gammas and alphas

Reiter has also carried out experiments involving beam splitter causing thesplitting of the beam to reflected and refracted beams going to two separatedetectors. Experiments with both gamma beam splitter [?]nd with alpha ray beams (appendix II of [?]plitter have been carried out. For alpha rays only half pulse heights are observed.

Standard quantum theory predicts that either a reflection or refraction occurs and for single gamma either detector fires.

1. In 2-1 cases when energy is conserved, the pulses correspond to separate incoming photons. At least two photons arrive at the beam splitter.
2. One can understand simultaneous pulses with equal pulse heights, if a N gammas instead of a single gamma-ray arrives at the beam splitter simultaneously. The incoming particle couldbe N-gamma decaying to N gammas either before the beam splitter or in the beam splitter. The N gammas would be distributed between the two detectors and two separate pulses would be obtained. The average pulse heights would be identical if the probability p for the reflection is the same as the probability $1-p$ for transmission. This would give $p = 1/2$.

   The total energy going to detectors should correspond to the energy of gamma and this is found for half-pulses. The numbers k and $N-k$ are determined by binomial distribution having appromation as Gaussian distribution and the numberof gammas going to the two detectors would be pN gammas and $1-pN$. Same height for pulses would require $p = 1/2$. It is not clear why $p = 1/2$ is favored but it is not clear how this could be possible.
3. One can also consider the possibility that N-gamma splits in physical sense into $N-k$- and k-gammas in the beam splitter and that the two parts go to separate detectors. In this case the average pulse heights should be identical. The maximum of the Gaussian pulse height distribution would correspond to $N/2$ in both detectors.

The model should also explain similar beam splitter findings for alpha particles [?]ehaving like bosons. The direct generalization of the N-gamma model in the case of beam splitter would require that atoms in the alpha source ^{241}Am (Americium is used as alpha source in smoke detectors) form a quantum coherent state in a scale longer than atomic size scale. This state could be an atomic B-E condensate of N atoms and emit N entangled possibly dark alphas simultaneously. This B-E condensate would decay to dark or ordinary alphas.

The decay could happen before the detector, or inside the beam splitter as a genuine physical decay of N gamma to $N-k$ gamma and k-gamma caused by the interaction with the beam splitter. In this case one would not have a quantal beam splitting and the reported energy conservation supportsthis. If the probability distribution for the pair $(k, N-k)$ gamma is a Gaussian centered around $k - N/2$, then $k = N/2$, and for the most probable pulse pulses have the same heights.

To my opinion, the notions of gamma and alpha beam splitter are far from trivial since the wavelengths for gammas are about 10^{-11} m and far below the optical range 10 nm -1 mm and for 5 MeV alpha equal 1.1 fm.

For optical mirrors (`https://cutt.ly/ebQqdJs`), the wavelength range varies from 10 nm to 1 mm. Quite generally, beam splitting involves notions like reflection and refraction which require coherence in scales much longer than atomic length. More precisely, a selection of single direction in the elastic Compton scattering from the beam splitter requires destructive interference and this is possible only if there is quantum coherence in a scale of few hundred atoms so that amplitudes from separate atoms, which are essentially Fourier transforms along the coordinate parallel to the beam splitter interfere. This coherence looks far from obvious for wavelengths considerably shorter than 10 nm.

X-ray mirrors and beam splitters and even gamma ray mirrors exist [D131] (`https://cutt.ly/dbQqbXR`). Also a discovery of a gamma ray lense [C17] (`https://cutt.ly/ObQqQn3`) has been reported. Gamma ray lense has been regarded as impossible and the discovery was a total surprise.

These observations raise the question whether gamma ray mirrors are possible in standard physics. Could it be that the required coherence is provided by a large value of h_{eff} at the space-time sheet of the dark gamma. Although the interaction with ordinary matter would probably involve reduction $h_{eff} \rightarrow h$, the quantum coherence would induce the needed coherence. $h_{eff} \sim 10^5$ would imply that gamma coherence length would be of order μm and one would have optics. In the case of α particles the quantum coherence scale would be of order atomic length scale.

The difference between X-ray mirrors and gamma-ray mirrors is that, unlike in the case of optical mirrors, the grazing angle θ of the beam must be very small so that the beam is almost parallel to the plane of the mirror.

If one imagines the beam as a tube having a finite transversal area, the length r of the projection of the tube to the mirror stretches to $R = r/tan(\theta)$ so that the coherence area S scales to $S/tan(\theta)$ and makes possible interference effects for small enough θ. If the transverse cross section is disk, it stretches to an ellipsoid.

Optical wavelengths are above $d_{opt} = 10$ nm, which suggests that one must have $R \geq d_{opt}$. If the radius r of tube is of order $r = \lambda = 10^{-11}$ m, the maximum grazing angle corresponds to $R = r/tan(\theta) \sim d_{opt}$ or $\theta \sim 10^{-3}$ or $\theta_{max} \sim .006$ degrees.

The thinness of the tube is a possible problem: $r \sim \lambda = 10^{-11}$ m allows gamma the tube to cover the Bohr radius of valence electron proportional to $(Z/n)^2$ but the fraction of the covered atomic volume with radius $a \sim 10^{-10}$ m is $(n/Z)^6(a_0/a)^3$, which is very small number for $Z = 53$ and $n = 5$ so that most tubes fail to hit the atom.

In the TGD framework, quantum classical correspondence suggests that flux tube corresponds to ME with transversal scale determined by λ scaling like h_{eff}/h so that for dark gammas $tan(\theta_{max})$ is scaled by a factor h_{eff}/h. For $h_{eff}/sim10^5$, one has $\lambda \sim 1$ μm so that the situation would reduce to optics for visible light. Even $h_{eff}/sim10^3$ is enough to guarantee this.

9.5.4 Connection with TGD based views about superfluidity, nuclear physics, and quantum biology

In this section possible connections with the h TGD based views about superfluidity, nuclear physics, and quantum biology are discussed.

Is quantum coherence associated with dark superfluidity?

What comes to mind is that the quantum coherence is associated with a dark variant of superfluid with ^4He or ^3He atoms replaced by heavy atoms. An old proposal is that since TGD predicts the possibility of long range classical Z^0 fields, the superfluidity could have interpretation as Z^0 superconductivity and relate to the large weak isospin due to the neutron surplus possible for heavy nuclei.

1. The dimension analytic estimate for the critical temperature for the transition to 3-D superfluidity is of the following general form [D124] (`https://cutt.ly/4v619RJ`):

$$T_{cr} = k\frac{\hbar M}{n}{}_3^{2/3} \quad M = Am_p \quad k = 3.31 \ . \tag{9.5.8}$$

   The value of k follows from a model assuming ideal gas above critical temperature. For ^4He mass number is $A = 4$. The density $\rho = 125$ kg/m^3 of ^{4}He gives $n_3 = \rho/Am_p$ and the resulting estimate is $T_{cr} \simeq 3$K to be compared to the actual critical temperature $T_{cr} = 2.17$ K.

2. In 1-D case corresponding to dark flux tube superfluidity for heavy nuclei or atoms, the formula generalizes

$$\begin{array}{lll} T_{cr} = \frac{k}{A}r\frac{\hbar}{m_p}n_1^2 \quad r = \frac{\hbar_{eff}}{\hbar} & & n_1 = \frac{X}{a} \ , \\ a = 10^{-10} \ m \ , \quad m_p = .938 \times 10^9 eV \ . & & \end{array} \tag{9.5.9}$$

3. The condition that the critical temperature exceeds room temperature gives

$$\begin{array}{ll} T_{cr} = \frac{kX^2}{A}rYm_p \geq T_{room} \ , & Y = (\frac{\hbar}{m_p a})^2 \ . \\ T_{room} = 3 \times 10^{-2} \ eV & Ym_p = 4.1 \times 10^{-3} \ eV \ . \end{array} \tag{9.5.10}$$

   The condition gives

$$r \geq \frac{7.32}{kX^2} \times A \ . \tag{9.5.11}$$

For $k = 3.31$ (this estimate need not be realistic) this would give $r \geq 2.2A/X^2$. For $A = 137$ this gives $r \geq 301/X^2$. The value is consistent with the earlier estimate of order $2^8 = 256$.

4. For N-dimensional case with $N = 2, 3$ the formula generalizes to

$$r \geq \frac{7.32}{kX^{2/N}} \times A \ . \tag{9.5.12}$$

Since X is near unity, the estimate is not expected to change much.

The condition that the quantum coherence length increases in the scaling by $r = h_{eff}/h$ from the size scale of heavy nucleus about 10^{-14} m (this corresponds to the nuclear p-adic length scale $L(113)$) to at least atomic scale about $a = 10^{-10}$ m (this corresponds to p-adic length scale $L(137)$) gives the condition $r \geq L(137)/L(113) = 2^{137-113}/2 = 2^{12} \sim 4000$. This would give

$$T_{cr} \geq \frac{2^{12}kX^2}{7.32A} T_{room} \ .$$

Critical temperatures higher than room temperature are possible. For $A = 137$ one has $T_{cr} \geq kX^2 \times 4.1 \times T_{room}$.

Connection with "cold fusion" and TGD view about nuclear reactions

What could be the mechanism leading to the formation of superfluid regions consisting of gamma emitting isotope (`https://cutt.ly/1bwAjTe`)? The sources used (57Co, 109Cd,137Cd) can be obtained by an irradiation of a sample of a material which is an isotope with the same atomic number by thermal neutrons in a nuclear reactor. It is also possible to a nucleus with different mass number and charge by protons or deuterons inducing nuclear reactions leading to the source nucleus, which canbe in an excited state and can suffer gamma emission or beta decay or electron capture followed by gamma emission. 137Cd is also obtained in the fission of a heavier nucleus such as uranium or plutonium induced by a neutron bombarded in a nuclear reactor.

The mechanism for the formation of the superfluid state should be general and independent of the production mechanism.

One can imagine at least two mechanisms.

1. The superfluid state is created by electron capture occurring coherently. If the electrons- say conduction electrons - form a macroscopic quantum state with h_{eff}, which is so large that it corresponds to a length scale larger than atomic size scale for the nuclei, N-capture of electrons could occur and lead to a super fluid state of a nuclear isomer.
2. The energy needed to create the superfluid state comes from the irradiation process. The formation of the superfluid state is analogous to a local melting of the crystal state.

   One can guess that the energy needed for the melting is of the order of 10 keV per nucleus since this energy corresponds to the energy assignable to a photon with wavelength given by atomic length scale $a = .1$nm by Uncertainty Principle. To generate a volume containing $N \sim 100$ dark nuclei, an energy of order MeV is needed and this is the nuclear energy scale.

Consider in more detail the latter option. What can one say of the detailed mechanism for the formation of the superfluid regions by - say - neutrons coming from a nuclear reactor?

1. Since isotope number and even atomic number change, the formation of an N-nucleon state requires absorption of N-something: N-neutron, N-proton, N-deuteron, etc.. The standard picture about nuclear reactions does not support this. The TGD based model for "cold fusion" [L103, L54, L117] based on the notion of dark nucleus however inspires the notion of dark super-nucleus - N-nucleus- as a sequence of dark protons, neutrons, and even heavier nuclei at magnetic flux tube and behaving like single quantum coherent unit - just like N-gamma.

   In the Pollack effect the dark nuclei - N-protons - would be created from ordinary protons and the nuclear binding energy would be scaled down to energy measured using eV as a natural unit. The decay of dark nuclei to ordinary nuclei would liberate almost all nuclear binding energy.

What would happen as crystal N-absorbs (say) N-neutron and N-neutron absorption occurs? The scaled up Compton length of dark neutrons of N-neutron should be atomic scale. The neutrons of the dark nuclear flux tube should fuse with the nuclei of the irradiated crystal. The target nuclei must become dark before fusion: this requires their transfer to the dark flux tube of N-neutron. This picture generalizes to more general N-nuclear reactions.

2. There is an important delicacy involved. The dark protons of N-proton are connected by flux tube bonds behaving like mesons. They can be analogs of neutral pions but also charged pions are possible.

   A long-standingopen question [L4]is whether the neutrons inside nuclei are actually protons accompanied by a negatively charged flux tube bond.For large values of h_{eff} also weak boson Compton scales are scaled up and they behave like massless particles below Compton length which can be even biological scale.

   This could explain the mystery of large parity breaking effects in biology manifesting themselves as chiral selection. This would make possible fast change of the charge of the flux tube bonds by an emission of effectively massless dark W boson.

3. The findings of Prof. Holmlid [C23, L48] were important in the development of the model. Holmlid proposed that "cold fusion" involves a formation of a super dense phase of deuterium nuclei. The distance between nuclei would be of order electron Compton length and by roughly two orders of magnitude smaller than atomic size scale .1 nm.

   The TGD explanation [L27, L48, L54, L117] is that sequences of dark nuclei at flux tubes are formed as "super-nuclei" (N-nuclei). For nucleon (p or n) sequences - dark nuclei - the nuclear binding energy associated with the bonds connecting nucleons of the ordinary nucleus is reduced by the ratio m_e/m_p of proton and electron Compton lengths. For a sequence of heavier nuclei the bonds carry the dark nuclear energy but nuclei have the ordinary binding energy.

4. This picture led to a model for the tunneling [L103, L120] assumed to make possible nuclear reactions at energies roughly two orders of magnitude below the Coulomb wall. As a matter of fact, this model of tunneling applies to all interactions. In phenomenological potential models tunneling is described in terms of Schrödinger equation. The TGD based model also providesa new vision about pre-stellar and stellar evolution [L103].

   In TGD framework tunneling would correspond in zero energy ontology (ZEO) a pair of "big" (ordinary) state function reductions (BSFRs) in which the arrow of time changes. The first BSFR would createthe intermediate "tunneling" state from the initial state nuclei and the second BSFR would initiate its decay to the final state nuclei. In the intermediate quantum critical state one would have $h_{eff} > h$ making possible long range correlations characterizing critical state. Super-nuclei (N-nuclei) would be formed also in the ordinary nuclear reactions in intermediate states.

   The formation of these dark time-reversed intermediate states is possible in ordinary nuclear reactions only if the colliding nuclei have high enough kinetic energies so that the nuclear bond energy can be reduced in the scaling induced by $h \rightarrow h_{eff}$. The formation of N-nuclei as an explanation of "cold fusion" would be the basic mechanism behind all nuclear reactions. In "cold fusion" there would be no nuclear binding energy in the initial state so that it could occur at low temperatures: "cold fusion" would serve as a "warm-up band" in prestellar evolution [L103].

   This picture would suggest that dark N-nuclei assequences of dark protons, neutrons, deuterons or even heavier nuclei - N-protons, N-neutrons, N-deuterons, etc... can be produced also in nuclear reactions as intermediate states. They can emit N-gammas and can split into lighter N-nuclei. Ordinary nuclear physics could be perhaps replaced in these states by the physics of N-nuclei.

5. Prof. Holmlid [L48] has reported some "impossible" observations supporting this view. He found that in "cold fusion" also muon with mass of 105.6 MeV and mesons such as kaon with mass around 490 MeV are observed. This is impossible in the ordinary nuclear reactions, where 1 MeV is the natural energy scale.

   Hadronic interactions are clearly required. Could N-nucleus consisting of N nuclei emit N-gamma which transforms to ordinary gamma, which annihilates to hadrons? N-gamma with

$N = 200$ and single gamma energy of 1 MeV would have energy of 1000 MeV - about proton mass - and decayto a kaon pair.

Connection between Pollack effect and bio-superconductivity

The model in terms of superfluidity was inspired by the model of Pollack effect involving flux tubes carrying dark protons. Could the model for Pollack effect in turn be formulated in terms of superfluidity/superconductivity?

1. The model of genetic code based on dark proton triplets as a representation for genetic codons correctly predicts the numbers of various basic biomolecules as also genetic code [L36, L88]. There is however a problem: Bose-Einstein condensate requires Cooper pairs but proton triplets are fermions.
2. The TGD based model of high Tc bio-superconductivity [K85, K86] and possibly also of bio-super-fluidity as Z^0 superconductivity relies on flux tube pairs, which are also associated with DNA double strands. Cooper pairs are pairs of dark fermions located at separate parallel flux tubes.
3. The number theory based model [L194] for the dark variant of DNA double strand as a helically winded pair of magnetic flux tubes assumes that the dark 3-proton codons at flux tubes are paired. This pairing would induce the base pairing of the ordinary DNA strands accompanying the dark strands. The paired dark codons would represent the Cooper pairs.
4. The number theoretic interpretation is in terms of Galois confinement analogous to color confinement [L194, **?**]. Codons themselves are analogous to baryons as color confined quark triplets.

   There is a hierarchy of Galois groups correspond to a hierarchical representation of an extension E of rationals as extension E_n of extension E_{n-1} of ... extension E_1 of rationals giving rise to the Galois group G of E as an extension of rationals. G is the product of Galois groups $G(E_i, E_{i-1})$characterizing E_i as extension of E_{i-1} in the sequence [L125].

   Color confinement is replaced with Galois confinement with respect toa Z_3 subgroup of G. The pairs of two dark proton triplets in turn form Galois singlets with respect to a Z_2 subgroup of G. Genes correspond to Galois singlets with respect to a larger subgroup of G assignable to the 4-surface defined by the gene.Genes and smaller sub-units behave as quantum coherent units.

   Also the dark photon realization of the genetic code relies on Galois confinement so that dark N-photons behave like a single particle as would also dark N-codons do. N-nucleus and N-gamma could be even more than analogs of genes since in the TGDUniverse genetic code could be realized universally in terms of the hyperbolic geometry of the light-cone hyperboloid H^3 [L137] and be based on the tetra-icosahedral tessellation defining the simplest tessellationof H^3.

9.5.5 Conclusions

One can divide the findings of Reiter into two classes.

1. The observations that the pulse rate depends on the chemistry of the gamma source and on the distance between detector and source strongly suggest the presence of new nuclear physics and nuclear quantum coherence above atomic scale. In the TGD framework, the notion of N-gamma as an analog of B-E condensate and the model for its decay to N gamms explain these findings.

   What is important that these findings can be made without the presence of the D2.
2. The observation that the pulse heights for causal pairs are the same, does not have an explanation in terms of a secondary gamma from the D1 generating a pulse in the D2.
3. TGD based model explains the the causal pairs with identical pulse heights but predicts a distribution of pulse height pairs which is product of two binomial distributions with nearly the same maximum and variance and allowing approximation as bimnomial distributions. Causal pairs of same height correspond to maxima of these distributions.

The TGD based explains also the reported dependence of the pulse rate on the chemistry of the source and and on the distance between source and detectors. One can imagine two experimental arrangements for testing this explanation.

1. One can imagine at least a thought experiment using a scintillator, which is a network of conducting wires allowing to observe the positions of gammas inducing response and to see whether the input contains several gammas. This could directly provide support for the N-gamma hypothesis.
2. If it is possible to prevent the leakage of the secondary gamma rays from the D1 to the D2 (simply by making the first NaI detector thicker than the attenuation length L), the observation of causally related pulses in both detectors could be seen as a direct support for the hypothesis that N-gamma decays to N dark gammas.

Could X ray fluorescence of Iodine cause co-incidences?

In private communications I learned that the X ray fluorescence of Iodine could cause X rays passing from D1 through the tin foil to D2 or vice versa and cause pulses which might be perhaps confused with the gamma ray pulses.

Fluorescence is due to the dropping of an electron to the vacancy created by the ionization of an electron of the Iodine atom. This can happen only for the inner electrons below the $n=5$ valence shell, where n is the principal quantum number labelling the rows of the Periodic Table. In the Bohr model, the energy for the shell labelled by n is given by $E(n)=(Z/n)^2E_H$, $E_H=13.6$ eV.

For Iodine one has $Z=55$. X ray with s maximal energy is liberated if $n=1$ electron is kicked out in the ionization and $n=5$ valence electron fills the vacancy. In the Bohr model the energy of the X ray is very near to 34 keV, which is roughly 1/3 times the energy of 100 keV gamma ray. If the detector response is linear in energy, the pulse height is about 1/3 from that of gamma so that the experimental arrangement should exclude these pulses.

Acknowledgements: I want to thank Marko Manninen for the information about Reiter's experiments and for interesting discussions.

9.5.6 Appendix: About Compton scattering and absorption of gammas

In the following simple quantitative picture about Compton scattering and absorption of gammas is developed. Also the attenuation of the gamma beamis discussed.

Quantitative estimates related to the absorption and Compton scattering of gammas

Some comments about gamma absorption and Compton scattering are in order to clarify the physical situation.

1. For the absorption of gamma the cross section is proportional to $\alpha \simeq 1/137$ whereas for Compton scattering it is proportional to α^2. The very rough estimate is that the cross section is by two orders of magnitude higher for absorption. The energy dependence for the graph of attenuation coefficients for low enough energies is consistent with this.
2. Does the absorption of gamma lead to ionization of the atom of the detector material? In the Bohr orbit model, the binding energy for the valence electron with principal quantum number n labelling the row of the periodic table for atomic number Z is $E_n \simeq (Z/n)^2E_H$, $E_H=13.7$ eV. For 109Cd *resp.* 57Co the gamma energies are 88 keV *resp.* 122 keV. The condition $E_n<E_\gamma$ gives $(Z/n)^2<E_{gamma}/E_H$. For 57Co the condition is $Z/n<80$ and for 109Cd $Z/n<95$. For Iodine with $Z=53$ and $n=5$ one has $Z/n=53/5\simeq 10$ so that the condition is satisfied and gamma absorption leads to ionization.
3. One can consider the situation also at the level of condensed matter. Photoelectrons in photoelectric effect can correspond to free electrons from a surface of conductor produced by ionizing absorption or Compton scattering of gamma rays. In this case, the final state electron can be regarded as a free electron outside the surface of the detector material.

For conductors the energies of valence electrons form conduction bands, the situation is effectively continuous as far energy is considered, Compton scattering of gamma can kick the electron to a higher conduction band or lead to ionization.

Diffraction effects are possible only if the momentum change in Compton scattering corresponds to a wavelength about atomic size scale. This is possible for X rays but not for gamma rays. For gamma rays interference terms in the scattering rate as a modulus squared $|A|^2$ of the scattering amplitude A as a sum over scattering amplitudes over the lattice atoms sum up to zero and the situation reduces to the level of single atom.

It is instructive to study the situation for the absorption in more detail.

1. The absorption of gamma by a free electron is kinematically impossible but possible for atomic electrons since momentum conservation does not pose and additional condition. For the absorption of gamma the energy given to the detector is maximal and leads to ionization whereas in the case of Compton scattering the energy is not totally lost. The atom can be however ionized. th this.
2. The ionized state of electron behaves like Bessel function at large distances and has a period determined by radial wave vector k. At large distances the energy of the final state electron is given by $E_{e,f} = \hbar^2 k^2/2m_e$. Energy conservation gives $E_\gamma - E_{e,B} = E_{e,f}$, where E_γ is gamma energy and $E_{e,B}$ is the binding energy of electron in the initial state.

   The energy of gamma is 88 keV or 122 keV in the situations considered and considerably larger than the binding energy $E_B \simeq 1.5$ keV for $n = 5$ state for Iodine. Therefore the approximation $E_\gamma \simeq E_{e,f}$ is good.
3. Interference effects are not significant at the level of a single atom. The wavelengths of gammas with 100 keV energy is 1.24×10^{-11} m. The atomic size as the radius of the Bohr orbit of the valence electron is $r_n = (n/Z)^2 a_0$. The scale of this orbit determines the size of the region which contributes to the transition amplitude significantly. This is the case also in ionization although the final state wave function has considerably larger size.

   For Iodine with $n = 5$ and $Z = 53$ this gives $r_5 \simeq 5.3 \times 10^{-13}$ m so that gamma wave function is essentially constant inside atom and the absorption amplitude can be calculated by using dipole approximation as a matrix element of dipole moment operator between the initial and final states.

Attenuation for a beam of gammas

Suppose that a beam of ordinary gammas enters the D1. In TGD picture gammas could be also dark.

1. The leakage of gammas through a good scintillator is small meaning that gamma loses its energy by Compton scattering and photoelectric effect. If the gamma scintillator is good in this sense, the generation of causally related pulse pairs should be small. The first NaI detector used by Reiter is however thin and and not good in this sense.

   Remark: Photoelectric effect need not mean absorption of gamma: also the analog of Compton scattering producing an ionization is possible.
2. The response of a good scintillator depends strongly on gamma energy to optimize energy resolution and is linear in the energy region of interest. **Fig. 9.1** gives various attenuation coefficients as a function of gamma energy E for NaI detector.

   Since the density ρ of the detector material is known, one can estimate the attenuation length L.
3. **Fig. 9.1** represents also the total attenuation coefficient A for gamma rays as a function of energy for various processes for an NaI crystal scintillator.

   From **Fig. 9.1**, one finds that for Compton scattering the attenuation coefficientdepends only weakly on the energy whereas for photo-electric effect the attenuation coefficientincreases sharply with decreasing energy.

   In the case Cd109 (88 keV) and Co57 (122 keV), the gamma ray energies are in the range .01, .1 MeV and near to .1 MeV for which attenuation coefficient is $A \sim .4$ cm^2/g for photoelectric absorption and .16 cm^2/g for Compton scattering. For Cs109 with $E = .662$ MeV, the coefficients for photoelectric absorption and Compton scattering have same values.

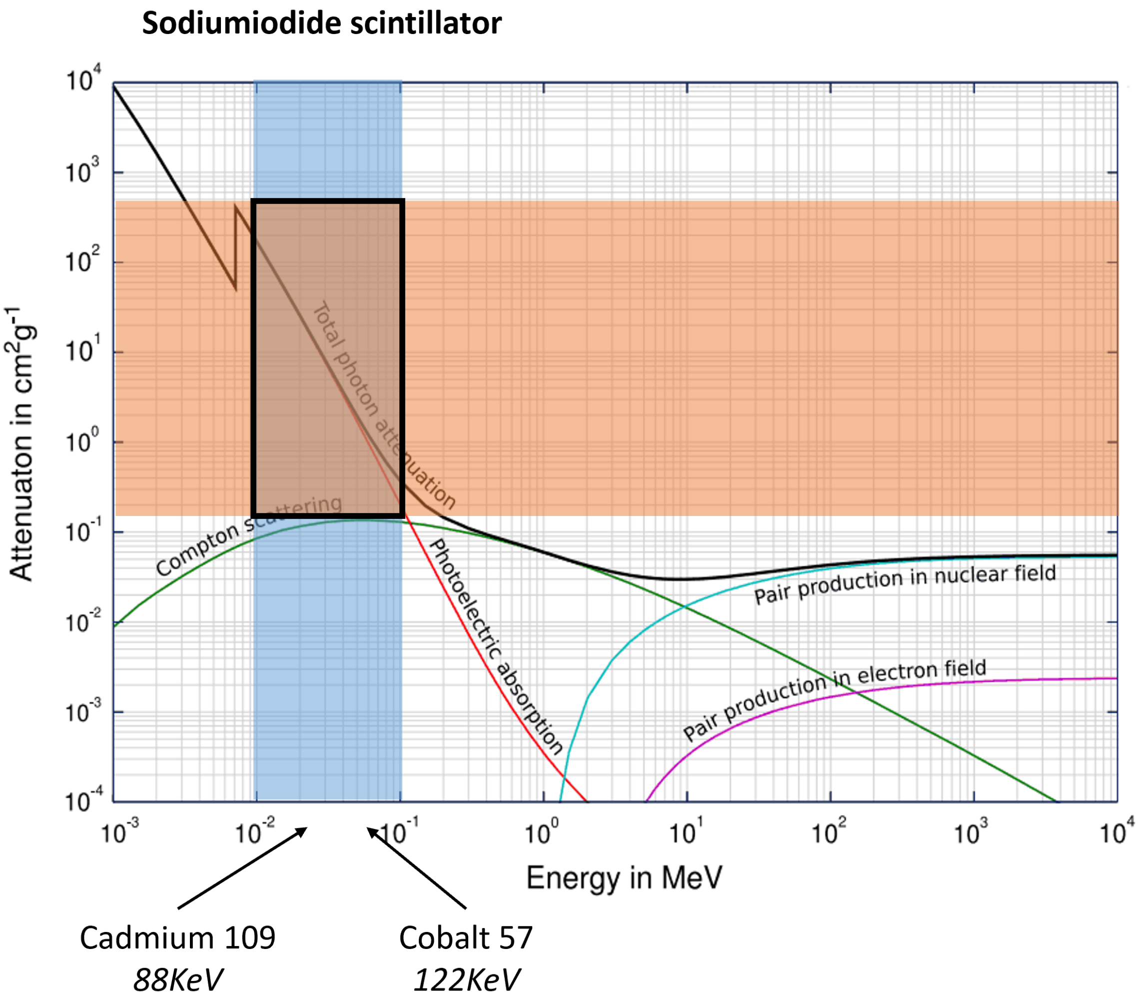

Figure 9.1: The attenuation coefficients for NaI detector used in Reiter's experiment

The number $N(x)$ of arriving gammas of beam is reduced exponentially in the detector as a function of the travelled distance:

$$\frac{dN}{dx} = -\frac{x}{L} \quad , \quad L = \frac{1}{A\rho} \quad .$$

ρ is the density of the detector material. The density of NaI is 3.67 g/cm^3.

From the thickness d of the detector volume, one canestimate the probability for the leakage of gamma without interactions. The D1 should have $d_1 < L$ and D2 $d_2 > L$.

Table 9.1 gives gives the attenuation length for Cd109, Co57 and Cs137. The $d_1 = 4$ mm, $d_1 < L$ is true for all cases. For Cd and Cs the D2 satisfies the condition $d_2 > L$. For Cs137, L is slightly larger than d_2.

Gamma ray cascades from beta decays and Reiter's findings

Multiple gamma emissions of excited states of nuclear isomers (`https://cutt.ly/fbOZbqc`) can produce correlated pairs of gamma rays. A final state nuclear isomer with two excited states

Nucleus	E/keV	A/cm^2g^{-1}	L/cm	p
Cd109	88	.4,	.7	.57
Co57	122	.4	.7	.57
Cs137	662	.06	4.5	.91

Table 9.1: Gamma ray energy E, attenuation coefficient A for NaI scintillator, and attenuation length L for photoelectric effect for Cd109, Co57 and Cs137. Also the probability p to get through the D1 with thickness $d = 4$ mm without photoelectric effect is given

resulting in a beta decay would be enough to produce a correlated pair. Could this explain the findings of Reiter?

The burst would be initiated by a beta decay producing an excited isomer of the nucleus decaying by gamma emission. If the spins of the initial and final state differ by one unit, the ages of these states by gamma decay are or order 10^{-12} s. If the difference of the nuclear spins of the initial and final states is higher than one unit, the emitted gamma ray must carry orbital angular momentum, so that the rate is lower. Typically the rates of the metastable states are of order 1 ns but can be so long that the decays cannot be detected.

Since 1 ns corresponds to a distance of 33 cm, one can ask whether subsequent gammas from the decay of an excited isomer could induce a correlated firing of the two detectors in the tandem experiment of Reiter. In this case, the energies of the gamma rays in general differ. Shell model predicts that the excitation energies obey a harmonic oscillator spectrum and are thus multiples of the basic unit so that the energies are the same in the most probable case. Also pulses with a height, which is double or even higher multiple of the basic pulse height are in principle possible, although they are predicted to be rare.

In this case, the members of the correlated gamma pair can have widely different momentum directions. Reiter however reports that gamma pairs with different momentum directions have not been detected. Note that this finding conforms with the notion of N-gamma predicting that its decay produces nearly parallel gammas.

The interpretation of Δt histograms?

The time differences between the pulses in the two detectors mean that the scale of time differences is by a factor of order 10^3 longer than expected on the basis of dimensions of detectors. Can this be true or is there something wrong in the determination of the time differences?

1.Coincidence counting

The identification of the correlated pulse pairs is performed by a coincidence counting. This method is however not completely straightforward.

1. In the picture of Reiter one would expect that the classical wave associated with gamma moves with light velocity. Also in the TGD based model it is assumed that gammas resulting from N gamma move with maximal signal velocity.
2. If the absorption of gamma ray or the first Compton scattering can be located into a definite position x_i inside detector D_i, $i = 1, 2$, the distance d_{12} between these positions is $x_{12} + x_1 - x_2 + d_{12}$, where d_{12} is the distance between the detectors.

   If the thickness for the detector is $d_1 = .4$ cm *resp.* $d_2 = 4$ cm and the mutual distance is $d_{12} = 1$ cm x_{12} varies in the range $[x_{12,min}, x_{12,max}] = [d_{12}, [d_1 + d_2 + d_{12}] = [1.0, 5.4]$ cm. The time t_{12} between pulses varies in the range $[t_{12,min}, t_{12,max}] = [x_{12,min}/c, x_{12,max}/c] = [.03, .18]$ ns.

What is the criterion for being a co-incident pair?

1. The criterion for accepted pulse pairs is statistical. Pulse pairs must be correlated and even causal in both models. If there is no correlation, the rate for the pairs can be written as $R_{12} \propto R_1R_2$ in the two detectors. If not, the product form does not apply. If the pulses are in a causal relation, the rate for pairs is $R_{12} = R_1$.

2. One can also use the following criterion for being a correlated pair. Source can emita pair during interval T and if this possibility is neglected and only external sources are considered, these pairs can be counted as correlated pairs. If the rate of these pairs is subtracted from the observed rate of pairs, only correlated pairs remain.

   Accept all pairs in the time window T so narrow that the rate for gamma pairs from the source during T is low enough. If R is the activity of the source and Ω the solid angle spanned by the detector with respect to source, the rate for single gamma detections is $R_1 = R\Omega$.

3. To estimate the rate for a detection of pairs during time interval T, one must characterize the detector by its dead time τ following a detection. The model is obtained by dividing detection time T to intervals of length $\tau = T/N$. τ could also correspond to time bin used. It cannot be smaller than τ.

   The probability for a detection of just a single pair in intervals i and j is given $p^2(1-p)^{N-2}$, where one has $p = R_1\tau$. Since the pair can correspond to any pair of N intervals the total probability to observe a pair during T is given by binomials $P(N,2) = Bin(N,2)p^2(1-p)^{N-2}$. The rate for pairs is therefore given by

$$\begin{array}{l} R_2 = \frac{p(N,2)}{T} \simeq \frac{N^2}{2}p^2(1-p)^{N-2} = R^2T(1-R\tau)^{\frac{T}{tau}-2} \simeq R^2T(1-RT)/2 \ , \\ , \\ p = R_1\tau \ , \\ N = \frac{T}{\tau} \ . \end{array} \tag{9.5.13}$$

   This rate should be smaller than the background and this gives an estimate for T. If N is large enough, R_2 is independent of τ in a good approximation and conforms with the naive guess $R_2 = R_1RT$. This contribution to the background has been indeed taken into account as chance rate R_c.

4. If one believes this picture, t_{12} for accepted pulse pairs should be restricted to be below, say, .5 ns. However, the reported co-incidence distribution for $\Delta t \equiv t_{12}$ varies in the range with duration about 200 ns, which is roughly 1000 times longer than $t_{12,max}$. If the real time difference for accepted pulse pairs were so long, a lot of false pairs could be accepted. As will be discussed below, the pulses are delayed and this explains the widening of the Δt histogram.

5. The determination of t_{12} involves also problems since the identification of t_1 and t_2 is problematic. The produced pulses have a duration below 200 ns. How can one tell when the pulse begins? If I have understood correctly, the "construction" of the pulse guarantees that it is a square pulse so that one can identify the time for the beginning of the pulse precisely. I do not know how much information processing this involves and how largeerrors this brings in.

   One can get rid of the problem by giving up the attempt to identify t_i and increase the acceptance window to say 200 ns but this brings in the possibility of false pairs and one must rely on statistics.

2. Delay of pulses explains the widening of Δt histograms

Δt histograms giving the distribution for t_{12} for the correlated co-incidences are discussed in [H6]. Their width is of order 300 ns. In the ideal situation with the assumptions described, the diagram should look like a bar of width of order .1 ns. How can one understand this?

The only reasonable interpretation is that the process leading to a representation of the co-incidences scales up t_{12} by a factor order 1000. Could a delay for the pulse from detector 2 or different delays for pulses from both detectors be involved and induce a lengthening of Δt by a constant amount of about, say, 300 ns?

This seems to be the correct interpretation (`https://cutt.ly/xny3XDi`). Reiter indeed mentions (`https://cutt.ly/0ny3BFq`) "In preparation for the Δt plot, adjustments on delay controls on SCA1 and SCA2, and a gate delay adjustment on the DSO must be performed".

3. Why Δt histograms allow negative values of $t_2 - t_1$?

There is still one interpretational problem. The Δt histogram looks like a Gaussian symmetric with respect to the origin of Δt axis. One would naively expect a bar starting at origin is widened to half-Gaussian caused by the processing. It could of course happen that the processing causes errors and leads to change of the sign of Δt.

The criterion for co-incidence is that the pulses from D1 and D2 overlap and the scaled up time difference can be defined as difference $\Delta t = t_1 - t_2$ with t_i identified for instance as center point or the pulse. If the pulse widths are different, the sign of Δt can become negative. t_i could be also defined as time for starting of the square pulse. Also in this case the information processing could change the order of pulses which are actually very near to each other temporally.

The order of pulses could however change also at the fundamental level.

1. What comes to mind is that 2 gammas arrive in D2. γ_1 is absorbed and γ_2 experiences a Compton scattering in backwards direction, travels to D1 since the tin foil cannot stop gamma rays like electrons, and is absorbed in D1.

   The differential cross section for the backwards Compton scattering is proportional to $(E_f/E_i)^2$ times an expression symmetric with respect to E_i and E_f. Energy-momentum conservation gives $E_f/E_i = 1/(1+2E/m_e) \simeq 5/7$ for $E = 100$ keV so that the differential cross section is by a factor $(5/7)^2$ smaller in the backward direction as forward directions [B22]. The energy of backwards scattered γ_1 in D1 would be by a factor 5/7 smaller than the energy of γ_1 so that the pulses have roughly the same height.

   This picture is natural in the N-gamma model, which also explains the observed double pulses which can occur in both detectors. Also $n > 2$-pulses are possible but their probability decreases rapidly with n.

   One expects that the fraction of time reversed events is smaller than for events in which absorption occurs in both detectors in the normal time order. The cross section for the backwards Compton scattering is proportional to α^2, $\alpha = 1/137$. Since the rate for the absorption is proportional to α. The ratio for the rates of these two kinds of event pairs would be proportional to α. It is not clear whether the ratio of the remaining factors in the cross section can compensate for α. Note also that backwards Compton scattering must occur to a rather small solid angle which further reduces the size of the cross section.

2. The time reversed event pair has an interpretation also in ZEO. Ordinary state function reductions change the arrow of time in ZEO. In the above model the arrow of time of the backwards scattered γ_1 in D2 would change. From the point of view of an observer with a standard arrow of time would travel from D2 to D1, where it would be absorbed. γ_2 would be absorbed in D2.

4. Estimate for the probability of Compton backscattering

One must estimate the probability for the reflection of the incoming (dark) gamma by backward scattering from D2 so that it can return to D1 where it can be absorbed or Compton scatter.

One must specify first the geometry. The radius r of the hole through which the gammas arrive from detector to D1 is typically $r = 1$ cm. Both D1 and D2 have rectangular cross sections with a side with length $l = 4$ cm. D1 has length $D1 = .4$ cm and D2 has length $D2 \equiv D = 4$ cm in the experiments considered. To simplify the order of magnitude estimates, assume that the cross sections of D1 and D2 are circular disks of radius $d = 4$ cm, say.

The point at the midline of the cylinder of radius d with distance $L < d$ from the hole has a solid angle which corresponds to $cos(\theta) \equiv u = L/\sqrt{L^2+d^2}$. The corresponding solid angle is

$$\Omega(L) = 2\pi(1-u) = 2\pi\frac{L}{\sqrt{L^2+d^2}} \quad . \tag{9.5.14}$$

One must estimate the total probability that the gamma is reflected back from D2. This probability is the sum over the probabilities for back-scattering to $\Omega(L)$ from the atoms in a cylinder of atomic radius and length D.

1. The atomic volume $V = 4\pi a^3/3 = 1/n_{atom} = Am_p/\rho$ contains Z electrons. The generalization to the case of NaLi detector is obvious. Since the energy of gamma is rather large,

one can assume that the backscattering occurs as if atomic electrons were free. This makes it possible to use a well known expression for Compton scattering cross section [B22] to get at least a rough estimate.

2. Geometric intuition suggests that the backscattering probability for a single atom at position L inside the cylinder can be taken to be the ratio of the total backward scattering cross section to the transversal area:

$$P(\Omega(L)) = \frac{\sigma(\Omega(L),tot)}{S} \quad , \quad \sigma(\Omega(L),tot) = Z\sigma(\Omega(L)) \quad , \tag{9.5.15}$$

The backscattering can occur from Z electrons and the total cross section is Z times the cross section fora single electron.
If the photon is dark with $h_{eff} = nh_0 > h$, one must multiply P with p:

$$P \rightarrow pP \quad , \tag{9.5.16}$$

where p is the probability for the dark photon to transform to the ordinary gamma.

3. One can think that one has $N = D/a$ scattering planes of transversal area $S = \pi a^2$. The number of scattering planes in the cylinder of atomic radius is $N(L) = n_{atom}SL$ and there density is $dN/dL = n_{atom}S$.
The total backscattering probability is sum over products of probabilities $P_{free}(L)$ for getting to a distance L without interaction and $P(\Omega(L))$:

$$P(D) = \int_0^D P_{free}(L)P(\Omega(L))\frac{dN}{dL}\, dL \quad . \tag{9.5.17}$$

4. $P_{free}(L)$ is the product of probabilities to progate without interactions through the $N(L) = L/a$ scattering planes and is given by

$$\begin{aligned} P_{free}(L) &= (1-P_{tot})^{L/a} exp(log(1-P_{tot})\tfrac{L}{a}) \quad , \\ P_{tot} &= Z\tfrac{\sigma_{tot}}{S} \quad . \end{aligned} \tag{9.5.18}$$

Since $P_{tot} << 1$ is true one can write in good approximation $log(1-P_{tot})) \simeq -P_{tot}$ and one obtains

$$P_{free}(L) = exp(-P_{tot}\frac{L}{a}) = exp(-Z\frac{\sigma_{tot}L}{Sa}) = exp(-\frac{4}{3}Z\sigma_{tot}n_{atom}L) \quad . \tag{9.5.19}$$

This factor gives an exponential damping for large values of L. The damping is not very significant for $L = 4$ cm. In the case of dark gammas, the presence of the multiplicative factor p in σ_{tot} reduces the damping further. In the first approximation, one can assume $P_{free}(L) = 1$ for dark gammas.

5. With these assumptions one obtains

$$P(D) = \int_0^D \frac{4}{3}pZ\sigma(\Omega(L))n_{atom}\, dL \quad . \tag{9.5.20}$$

Consider now a quantitive estimate for the backscattering probability.

1. The differential cross section for Compton scattering [B22] is given by

$$\begin{aligned} \frac{d\sigma}{d\Omega} &= \frac{\alpha^2}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) \\ x_{if} &= \frac{E_f}{E_i} \ , \end{aligned} \tag{9.5.21}$$

   Conservation of energy and momentum gives

$$x_{if} = \frac{1}{1+(E_i/m)(1-u)} \ , \quad u = cos(\theta) \ , \tag{9.5.22}$$

   The energy loss $E_i - E_f$ of gamma is given by

$$E_i - E_f = E_i(1 - x_{if}) \tag{9.5.23}$$

   is maximal for backwards scattering. One has for $E_i = 100$ keV $E_f/E_i \simeq 5/7$ for backwards scattering so that 29 % of the energy is lost. Therefore the absorption of the backscattered photon in D1 preceeded by an absorption of second dark photon in D2 before the backscattering may give a pulse pair with heights which do not differ too much.

2. The cross section $\sigma(\Omega(L))$ in laboratory frame is given by

$$\begin{aligned} \sigma(\Omega(L)) &= \frac{\alpha^2 2\pi}{4m_e^2} \int_0^{u(L)} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) du \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{9.5.24}$$

   ϵ_i *resp.* ϵ_f is the polarization of initial *resp.* final gammas.

3. The integrand is a rational function and can be integrated analytically. The dependence of the integrand on u is rather weak so that one can make the approximation $u = -1$ giving $x_{if} = 5/7$. One obtains

$$\begin{aligned} \sigma(\Omega(L) &= \frac{\alpha^2 2\pi}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2)(1 - u(L)) \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{9.5.25}$$

4. One obtains for the total back-scattering probability the following expression:

$$\begin{aligned} P(D) &= XY \ , \\ X &= p\frac{4}{3} Z n_{atom} \frac{\alpha^2 2\pi}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) \ , \\ Y &= \int_0^D (1 - \frac{L}{\sqrt{L^2+d^2}}) dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ . \end{aligned} \tag{9.5.26}$$

   For $d = D/2$ and gives $Y = 4 - 2log(5) = .782D$

5. The order of magnitude is determined by the factor

$$pZ\frac{4}{3}\frac{\alpha^2 2\pi}{4}\frac{L_e^2}{a^2}\frac{D}{a} \simeq 1.0 \times pZ \ . \tag{9.5.27}$$

For NaI detector the basic unit is NaI molecule for which one has $Z = 53 + 11 = 64$. In this approximation, the probability of backscattering could be near unity $pZ \sim 1$ and one cannot exclude the possibility that the correlated pairs with a wrong arrow of time can be explained as backscattering. Of course, the attenuation reduces the probability of backscattering.

6. This calculation is only a rough order of magnitude estimate and has neglected the rapid increase of the photoelectric absorption cross section after then back-scattering. The backscattered gamma can suffer photoelectric absorption in D2 and never reach D1. From **Fig. 9.1** one sees that the attenuation length decreases by a factor 1/6 in $E = 100$ kV $\rightarrow$ 71 kV taking place in backscattering.

   If the attenuation for ordinary gamma ray for travelled distance L is e^{-kL}, it is scaled to e^{-6kL}. For $kD \simeq 1$ the probability that the backscattered gamma gets back to D1 is $exp(-6L/D)$ in this case.

   The total probability for a return to D1 by back-scattering has the same approximate expression as above but with Y replaced with

$$Y = \int_0^D exp(-\frac{6L}{D})(1 - \frac{L}{\sqrt{L^2+d^2}})dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ . \qquad (9.5.28)$$

   Instead of $Y = .782D$, the approximation for Y obtained by replacing $\sqrt{L^2 + d^2}$ with $d = D/2$ is $Y/D \simeq (2 - e^{-6})/18 \simeq .11D$. The value is about 14 per cent from the naive estimate. Backscattering probability with a successful return would be about $.11pZ$ and equal to $7p$ for $Z = 64$ (NaI). This does not kill the hypothesis.

A couple of comments are in order.

1. The small value of p for dark photons might be essential. Otherwise, the attenuation of the gamma beam could reduce the backscattering probability considerably.

2. According to Reiter, the number of detection events in D1 is by an order of magnitude larger than in D2. This looks strange. The trivial explanation would be that only the events for which count appears in D1 are counted. A partial explanation is that a considerable part of the beam from D1 misses D2 as becomes clear by visualizing the geometric situation. On the other hand, the length 4 cm of D2 is by a factor 10 longer than the length .4 cm of D1. If these explanations fail, one must seriously consider the possibility that the backscattering from D2 plays a significant role.

Chapter 10

Cosmic string model for the formation of galaxies and stars

10.1 Introduction

The view about the role of new nuclear physics predicted by TGD in the model of solar interior [L103] gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles.

10.1.1 Brief description of the model for for the formation of galaxies and stars

TGD based cosmology predicts that the primordial cosmology was dominated by cosmic strings identified as 4-surfaces having 2-D M^4 projection in $H = M^4xCP_2$. CP_2 projection is a complex surface of CP_2. The dimension of M^4 projection is unstable against perturbations and during cosmological evolution the M^4 projection thickens. This leads to a model for the formation of galaxies as tangles along cosmic strings in turn containing stars and even planets as sub-tangles.

1. Twistor lift of TGD [L41] predicts that cosmological constant at the level of space-time surface (to be distinguished from that associated with GRT limit of TGD) is length scale dependent. This solves the basic problem caused by the huge value of cosmological constant in the very early Universe. In zero energy ontology length scale dependent Λ having spectrum coming in some negative powers of 2 characterizes the space-time sheets assignable to individual system and the corresponding causal diamond (CD) and is determined by its p-adic length scale.

   For instance, Sun has its own cosmological constant predicted by the model solving the puzzle due to larger abundances obtained in solar-seismological determinations than in spectroscopic and meteoritic determinations. Dark nuclear states of nuclei inside solar core contribute also to the nuclear abundances [L103].

2. The energy of flux tubes consists of Kähler magnetic energy and volume energy. Quantum classical correspondence strongly suggests that this energy is identifiable as dark matter even for minimal value of h_{eff}.

3. Phase transitions reducing the value of cosmological constant are possible. Cosmic strings (or rather their M^4 projections) start to thicken and lose magnetic energy by transforming to ordinary matter. This is analogous to the decay of the inflaton field to matter. This generates Einsteinin space-time with space-time surfaces having large and increasing 4-D M^4 projection. Flux tubes and cosmic strings are however still present.

   The expansion of flux tubes in phase transitions reducing Λ gives rise to a jerk-wise accelerated expansion at the level of astrophysical objects. For given phase transition the accelerated expansion eventually stops since the expansion increases volume energy. The expansion periods however repeat being induced by phase transitions reducing length scale dependent quantized cosmological constant Λ associated with the volume action coming as powers of 2 and making flux tubes unstable against thickening and transformation of magnetic energy to ordinary matter. The recent accelerated expansion corresponds to this kind of period being thus analogous to inflation and is predicted to stop since volume energy increases. The expansion rate is predicted to oscillate so that the expansion takes place as jerks and there is evidence for this [E40] (see (http://tinyurl.com/oqcn2hp) discussed from TGD point of view in [K63].

4. In particular, the TGD counterpart of inflation would have led from cosmic string dominated primordial cosmology in which Einsteinian space-time does not make sense to a radiation dominated phase in which Einsteinian space-time makes sense. Expanding Earth model [L76] allowing to understand Cambrian Explosion is one application of TGD based quantum cosmology.

10.1.2 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L41].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L41] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L83].

Evidence for the anisotropy of the acceleration of cosmic expansion has been reported (see http://tinyurl.com/rx4224f). Thanks to Wes Johnson for the link. Anisotropy of cosmic acceleration would fit with the hierarchy of scale dependent cosmological constants predicting a fractal hierarchy of cosmologies within cosmologies down to particle physics length scales and even below. The phase transitions reducing the value of Λ for given causal diamond would induce accelerated inflation like period as the magnetic energy of flux tubes decays to ordinary particles. This would give a fractal hierachy of accelerations in various scales.

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see http://tinyurl.com/k4bwlzu). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L48, L54]: this requires $h_{eff} \sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L103] (see http://tinyurl.com/y38m54ud) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see http://tinyurl.com/y5ukv2wt) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see http://tinyurl.com/y3n78tjs)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

Starting from this picture, one ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

10.2 Blackholes, quasars, and galactic blackholes

I have discussed a model of quasars in [L83] (see http://tinyurl.com/y2jbru4k) . The model is inspired by the notion of MECO and proposes that quasar has a core region analogous to black hole in the sense that the radius is apart from numerical factor near unit $r_S = 2GM$. This comes from mere dimensional analysis.

10.2.1 Blackholes in TGD framework

In TGD the metric of blackhole exterior makes sense and also part of interior is embeddable but there is not much point to consider TGD counterpart of blackhole interior, which represents failure of GRT as a theory of gravitation: the applicability of GRT ends at r_S. The following picture is an attempt to combine ideas about hierarchy of Planck constant and from the model of solar interior [L103] deriving from the 10 year old nuclear physics anomaly [E7, E43].

1. The TGD counterpart of blackhole would be maximally dense spaghetti formed from monopole flux tube. Stars would not be so dense spaghettis. A still open challenge is to formulate precise conditions giving the condition $r_S = 2GM$. The fact that condition is "stringy" with $T = 1/2G$ taking formally the role of string tension encourages the spaghetti idea with length of cosmic string/flux tube proportional to r_S.
2. The maximal string tension allowed by TGD is determined by CP_2 radius and estimate for Kähler coupling strength as $1/\alpha_K \simeq 1/137$ and is roughly $T_{max} \sim 10^{-7.5}/G$ suggesting that in blackhole about $10^{7.5}$ parallel flux tubes with maximal string tension and with length of about r_S give rise to blackhole like entity. Kind of dipole core consisting of monopole flux tubes formed by these flux tubes comes in mind. The flux tubes could close to short flux tubes or flux tubes could continue like flux lines of dipole magnetic field and thicken so that the energy density would be reduced.
3. This picture conforms with the proposal that the integer n appearing in effective Planck constant $h_{eff} = n \times h_0$ can be decomposed to a product $n = m \times r$ associated to space-time surface which is m-fold covering of CP_2 and r-fold covering of M^4. For $r = 1$ m-fold covering property could be interpreted as a coherent structure consisting of m almost similar regions projecting to M^4: one could say that one has field theory in CP_2 with m-valued fields represented by M^4 coordinates. For $r = 1$ each region would correspond to r-valued field in CP_2.

   This suggests that Newton's constant corresponds apart from numerical factors $1/G = m\hbar/R^2$, where R is CP_2 radius (the radius of geodesic circle). This gives $m \sim 10^{7.5}$ for gravitational flux tubes. The deviations of m from this value would have interpretation in term of observed deviations of gravitational constant from its nominal value. In the fountain effect of super-fluidity the deviation could be quite large [?].

   Smaller values of h_{eff} are assigned in the applications of TGD with the flux tubes mediating other than gravitational interactions, which are screened and should have shorter scale of quantum coherence. Could one identify corresponding Planck constant in terms of the factor r of m: $h_{eff} = r\hbar_0$? TGD leads also to the notion of gravitational Planck constant $\hbar_{gr} = GMm/v_0$ assigned to the flux tubes mediating gravitational interactions - presumably these flux tubes do not carry monopole flux.
4. Length scale dependent cosmological constant should characterize also blackholes and the natural first guess is that the radius of the blackhole corresponds to the scaled defined by the value of cosmological constant. This allows to estimate the thickness of the flux tube by a scaling argument. The cosmological constant of Universe corresponds to length scale $L = 1/\sqrt{\Lambda} \sim 10^{26}$ m and the density ρ of dark energy corresponds to length scale $r = \rho^{-1/4} \sim 10^{-4}$ m. One has $r = (8\pi r)^{1/4}\sqrt{Ll_P}$ giving the scaling law $(r/r_1) = (L/L_1)^{1/2}$. By taking $L_1 = r_s(Sun) = 3$ km one obtains $r_1 = .7 \times 10^{-15}$ m rather near to proton Compton length 1.3×10^{-15} m and even nearer to proton charge radius $.87 \times \times 10^{-15}$ m. This suggests that the nuclei arrange into flux tubes with thickness of order proton size, kind of giant nucleus. Neutron star would be already analogous structure but the flux tubes tangled would not be so dense.

   Denoting the number of protons by N, the length of flux tube would be $L_1 \simeq Nl_p \equiv xr_S$ (l_p denotes proton Compton length) and the mass would be Nm_p. This would give x as $x = (l_p/l_{Pl})^2 \sim 10^{38}$. Note that the ratio of the volume filled by the flux tube to the M^4 volume V_S defined by r_S is

$$\frac{V_{tube}}{V_S} = \frac{3}{8}(\frac{l_P}{l_{Pl}})^2 \times (\frac{l_p}{r_S})^2 \sim 10(\frac{r_S(Sun)}{r_S})^2 \ . \qquad (10.2.1)$$

The condition $V_{tube}/V_S < 1$ gives a lower bound to the Schwartschild radius of the object and therefore also to its mass: $r_S > \sqrt{10} r_S(Sun)$ and $M > \sqrt{10} M(Sun)$. The lower bound means that the flux tube fills the entire M^4 volume of blackhole. Blackhole would be a volume filling flux tube with maximal mass density of protons (or rather, neutrons -) per length unit and therefore a natural endpoint of stellar evolution. The known lower limit for the mass of stellar blackhole is few stellar masses (see `http://tinyurl.com/ycd4w4m4`) so that the estimate makes sense.

5. An objection against this picture are very low mass stars with masses below $.5M(Sun)$ (see `http://tinyurl.com/ceoo6sj`) not allowed for $k \geq 107$. They are formed in the burning of hydrogen and the time to reach white dwarf state is longer than the age of the universe. Could one give up the condition that flux tube volume is not larger than the volume of the star. Could one have dark matter in the sense of n_2-sheeted covering over M^4 increasing the flux tube volume by factor n_2.

6. This picture does not exclude star like structure realized in terms of analogs of protons for scaled up variants of hadron physics M_{89} hadron physics would have mass scale scaled up by a factor 512 with respect to standard hadron physcs characterized by Mersenne prime M_{107}. The mass scale would correspond to LHC energy scale and there is evidence for a handful of bumps having interpretation as M_{89} mesons. It is of course quite possible that M_{89} baryons are unstable against transforming to M_{107} baryons.

7. The model for star [L103] inspired by the 10 year old nuclear physics anomaly led to the picture that protons form at least in the core dark proton sequences associated with the flux tube and that the scaled up Compton length of proton is rather near to the Compton length of electron: there would be zooming up of proton by a factor about $2^{11} \sim m_p/m_e$. The formation of blackhole would mean reduction of h_{eff} by factor about 2^{-11} making dark protons and neutrons ordinary.

10.2.2 Can one see also stars as blackhole like entities?

The assignment of blackholes to almost any physical objects is very fashionable, and the universality of the flux tube structures encourages to ask whether the stellar evolution to blackhole as flux tube tangle could involve discrete steps involving blackhole like entities but with larger Planck constant and with larger radius of flux tube.

1. Could one regard stellar objects as blackholes labelled by various values of Planck constant h_{eff}? Note that h_{eff} is determined essentially as the dimension n of the extension of rationals [L56, L62]. The possible p-adic length scales would correspond to the ramified primes of the extension. p-Adic length scale hypothesis selects preferred length scales as $p \simeq 2^k$, with prime values of k preferred. Mersennes and Gaussian Mersennes would be in favoured nearest to powers of 2.

   The most general hypothesis is that all values of k in the range $[127, 107]$ are allowed: this would give half-octaves spectrum for p-adc length scales. If only odd values of k are allowed, one obtains octave spectrum.

2. The counterpart of Schwartchild radius would be $r_S(k) = (L(k)/L(107))^2 r_S$ corresponding to the scaling of maximal string tension proportional to $1/G$ by $L(107)/L(k)^2$, where k is consistent with p-adic length scale hypothesis.

   The flux tube area would be scaled up to $L(k)^2 = 2^{k-107} L(107)^2$, and the constant $x \equiv x(107)$ would scale to $x(k) = 2^{k-107} x$. Scaling guarantees that condition $V(tube)/V_S$ does not change at all so that the same lower bound to mass is obtained. Note that the argument do not give upper bound on the mass of star and this conforms with the surprisingly large masses participating in the fusion of blackholes producing gravitational radiation detected at LIGO.

3. The favoured p-adic length scales between p-adic length scale L_{107} assignable to black hole and $L(127)$ corresponding to electron Compton length assignable to solar interior are the p-adic length scale $L(113) = 8L(127)$ assignable to nuclei, and the length scale $L(109)$, which corresponds to p near prime power of two.
   (a) For $k = 109$ (assignable to deuteron) the value of the mass would be scaled by factor 4 to a lower about 12 km to be compared with the typical radius of neutron star about 10 km. The masses of neutron stars around about 1.4 solar masses, which is rather near to the lower bound derived for blackholes. Neutron star could be seen the last phase transition in the sequence of p-adic phase transition leading to the formation of blackhole.
   (b) Could $k = 113$ phase precede neutron stars and perhaps appear as an intermediate step in supernova? Assuming that the flux tubes consist of nucleons (rather than nuclei), one would have $r_S(113) = 64r_S$ giving in the case of Sun $r_S(113) = 192$ km.
   (c) For $k = 127$ the p-adic scaling from $k = 107$ would give Schwartschild radius $r_S(127) \sim 2^{20}r_S$. For Sun this would give $r_S(127) = 3 \times 10^9$ m is roughly by factor 4 larger than the radius of the solar photosphere radius 7×10^8 meters. $k = 125$ gives a correct result. This suggests that $k = 127$ corresponds to the minimal value of temperature for ordinary fusion and corresponds to the value of dark nuclear binding energy at magnetic flux tubes. The evolution of stars increases the fraction of heavier elements created by hot fusion and also temperatures are higher for stars of later generations. This would suggest that the value of k is gradually reduced in stellar evolution and temperature increases as $T \propto 2^{(127-k)/2}$. Sun would be in the second or third step as far the evolution of temperature is considered. Note that the lower bound on radius of star allows also larger radii so that the allowance of smaller values of k does not lead to problems.

10.2.3 Magnetars in TGD framework

There is an interesting popular article about magnetars in Quanta Magazine (`http://tinyurl.com/uh5r3az`). The article tells about the latest findings of Zhou and Vink and colleagues [E32] (`http://tinyurl.com/s24dq23`) giving hints about the mechanism generating the huge magnetic fields of magnetars.

Neutron stars have surface magnetic field of order 10^8 Tesla. Magnetars have surface magnetic field stronger by a factor 1000 - of order 10^{11} Tesla. The mechanism giving rise to so strong magnetic fields at the surface of neutron star is poorly understood. Dynamo mechanism is the first option. The rapidly rotating currents at the surface of neutron star would generate the magnetic field. Second model assumes that some stars simply have strong magnetic fields and the strength of these magnetic fields can vary even by factor of order 1000. Magnetars and neutron stars would inherit these magnetic fields. The model should also explain why some stars should have so strong magnetic fields - what is the mechanism generating them. In Maxwellian world currents would be needed in any case and some kind of dynamo model suggests itself.

Dynamo model requires very rapid rotation with rotation frequency measured using millisecond as a natural unit. The fast rotation rate predicts that magnetars are produced in more energetic explosions than neutron stars. The empirical findings however support the view that there is no difference between supernovas producing magnetars and neutron stars. Therefore it would seem that the model assuming inherited magnetic fields is favored.

What says TGD? TGD view about magnetic fields differs from Maxwellian view and this allows to understand the huge magnetic without dynamo mechanism and could give a justification for the inheritance model.

1. TGD predicts that magnetic field decomposes to topological field quanta - flux tubes and sheets - magnetic flux tubes carry quantized magnetic flux. Flux tubes can have as cross section either open disk (or disk with holes) or closed surface not possible in Minkowskian space-time. The cross section can be sphere or sphere with handles.
2. If the cross section is disk a current at its boundaries is needed to create the flux. If the cross section is closed surface, no current is needed and magnetic flux is stable against dissipation and flux tube itself is stable against pinching by flux conservation. These monopole fluxes could explain the fact that there are magnetic fields in cosmological scales not possible in Maxwellian theory since the currents should be random in cosmological scales.

This also solves the maintenance problem of the Earth's magnetic field. Its monopole part would stable and 2/5 of the entire magnetic field $B_E = .5$ Gauss from TGD based model of quantum biology involving endogenous magnetic field $B_{end} = .2$ Gauss identifiable in terms of monopole flux.

The model for the formation of astrophysical objects in various scales such as galaxies and stars and even planets and also for quantum biology relies crucially on monopole fluxes.

1. The proposal made in [L91] is that stars correspond tangles formed to long monopole flux tube. Reconnection could of course give rise to closed short flux tubes and one would have kind of spaghetti.

   The interior of Sun would contain flux tubes containing dark nuclei as nucleon sequences and one ends up to a modification of the model of nuclear fusion based on the excitation of dark nuclei [L103]. The model solvs a 10 year old anomaly of nuclear physics of solar core [E7, E43]. From the TGD based model of "cold fusion" one obtains the estimate that the flux tube radius is of order electron Compton length, and thus about $h_{eff}/h_0 \simeq m_p/m_e \sim 2000$ times longer than proton Compton length. This has been assumed also in the model of stars discussed in [L91].

2. The final states of stars could correspond to a volume filling spaghettis of flux tube analogous to blackhole. They would be characterized by the radius of the flux tube, which would naturally correspond to a p-adic length scale $L(k) \propto 2^{k/2}$: one could speak of various kinds of blackhole like entities (BHEs). There radius of the flux tube would be scaled up by the value of effective Planck constant $h_{eff} = n \times h_0$ so that one would have $n \propto 2^{k/2}$ in good approximation.

3. The p-adic length scales $L(k)$, with k prime are good candidates for p-adic lengths scales. Most interesting candidates correspond to Mersenne primes and Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$. Ordinary blackhole could correspond to a flux tube with radius of order Compton of proton corresponding to the p-adic length scale $L(107)$.

   For neutron star the first guess would be as the p-adic length scale $L(127)$ of electron from the model of Sun. $L(113)$ assignable to nuclei and corresponding to Gaussian Mersenne is also a good candidate for magnetar's p-adic length scale. $L(109)$ assigned to deuteron would correspond to an object very near to blackhole corresponding to $L(107)$ [L91]. Also the surface and interior of BHE would carry enormous monopole fluxes 32 times stronger than for magnetars.

   The are just guesses but bringing in quantized monopole fluxes together with p-adic length scale hypothesis allows to develop a quantitative picture.

Consider first the flux quantization hypothesis more precisely.

1. The observation that to the vision about monopole magnetic fields and hierarchy of Planck constants now derivable from adelic physics was that the irradiation of vertebrate brain by ELF frequencies induces physiological and behavioral effects which look like quantal. As if cyclotron transitions in endogenous magnetic field $B_{end} = 2B_E/5 \simeq 0.2$ Gauss would have been in question. The energies of photons involved are however ridiculously small and cannot have any effects. The proposal was that the effective value of Planck constant is quantized: $h_{eff} = nh_0$ and can have very large values in living matter. The energies $E = h_{eff}f$ of photons could thus be over thermal threshold and have effects. The matter with non-standard value of h_{eff} would correspond to dark matter.

2. One can make the picture more quantitative by considering the quantization of flux. The radius r of a flux tube carrying unit magnetic flux is known as magnetic length $r^2 = \Phi_0/e\pi B$, where Φ_0 corresponds to minimal quantized flux $\Phi_0 = BS = B\pi r^2 = n \times \hbar/eB$ for flux tube having disk D^2 as cross section. If B_{end} is ordinary Maxwellian flux one obtains for $B_{end} = 0.2$ Gauss $r = 5.8$ μm which is rather near to $L(169) = 5 \times 10^{-6}$ μm Cell membrane length scale $L(151) = 10$ nm corresponds to the scaling $B_{end} \rightarrow 2^{18}B_{end} \simeq 5$ Tesla and 1 Tesla corresponds to the magnetic length $r = 2.23 \times L(151)$.

   One can argue that one must have quantization of flux as multiples of h_{eff}. The geometric interpretation is that $\hbar_{eff} = n\hbar_0$ corresponds to n-sheeted structure (Galois covering) and the above quantization gives flux for a single sheet. The total flux as sum of these fluxes is indeed proportional to $\hbar_{eff}$.

3. For monopole flux tubes disk D^2 is replaced with sphere S^2 and the area $S = \pi \times r^2$ in magnetic flux is replaced with $S = 4\pi r^2$. This means scaling $r \rightarrow r/2$ for the magnetic length. The p-adic length scale becomes $L(167)$, which corresponds to Gaussian Mersenne is indeed the scale that might have hoped whereas the ordinary flux quantization giving $L(169)$ was a disappointment. This gives a solution to a longstanding puzzle why $L(169)$ instead of $L(167)$ and additional support for monopole flux tubes in living matter. As a matter of fact, there are four Gaussian Mersennes corresponding to $k \in \{151, 157, 163, 167\}$ giving rise to 4 p-adic length scales in the range [10 nm, 2.5 μm] in the biologically most important length scale range. This is a number theoretic miracle.

It is useful to list some numbers for monopole flux by using the scaling $\propto 1/L^2(k) \propto 2^{-k/2}$ to get a quantitative grasp about the situation for magnetars and other final states of stars.

1. For monopole flux $L(151)$ corresponds to $2^{16}B_{end}(k = 167) \simeq 1.28$ Tesla. For ordinary flux it corresponds to 2.56 Tesla. A good mnemonic is that Tesla corresponds to $r = 1.13 \times L(151)$.
2. For neutron star one has $B \sim 10^8$ Tesla. For monopole flux this would correspond for ordinary flux magnetic length $r \simeq 1.13$ pm roughly $2.8L_e$, where $L_e = .4$ pm is electron Compton length. Note that the corresponding p-adic length scales is $L(127) = 2.5$ pm $\simeq 2.2r$ so that also interpretation in terms of $L(125)$ can be considered. For non-monopole flux one would have roughly $r = 2.26$ pm. Neutron star would be formed when all flux tubes become dark flux tubes and perhaps form single connected volume filling structure.
3. For magnetar one has magnetic field about $B = 10^{11}$ Tesla roughly 1000 times stronger than for neutron star. For monopole flux this would give $r = 30$ fm to be compared with the nuclear p-adic length scale $L(113) = 20$ fm. Could the p-adic length scale $L(109) = 2L(107) = 5$ fm correspond to a state rather near to blackhole? $L(109)$ would would have 16 times stronger surface magnetic field $B \simeq .45 \times 10^{12}$ Tesla than magnetar. For the TGD counterpart of ordinary blackhole having $k = 107$ the surface magnetic field $B \simeq 1.8 \times 10^{12}$ Tesla would be 32 times stronger than for magnetar.

All these estimates are order of magnitude estimates and p-adic lengths scale hypothesis only says something about scales.

10.2.4 What about blackhole thermodynamics?

Blackhole thermodynamics is part of the standard blackhole paradigm? What is the fate of this part of theoretical physics in light of the proposed model?

TGD view about blackholes

Consider first the natural picture implied the vision about blackhole as space-filling flux tube tangle.

1. The flux tubes are deformations of cosmic strings characterized by cosmological constant which increases in the sequence of increasing the temperature of stellar core. The vibrational degrees of freedom are excited and characterized by a temperature. The large number of these degrees of freedom suggests the existence of maximal temperature known as Hagedorn temperature at which heat capacity approaches to infinity value so that the pumping of energy does not increase temperature anymore.

   The straightforward dimensionally motivated guess for the Hagedorn temperature is suggested by p-adic length scale hypothesis as $T = x\hbar/L(k)$, where x is a numerical factor. For blackholes as $k = 107$ objects this would give temperature of order 224 MeV for $x = 1$. Hadron physics giving experimentally evidence for Hagedorn temperature about $T = 140$ MeV near to pion mass and near to the scale determined by Λ_{QCD}, which would be naturally relate to the hadronic value of the cosmological constant Λ.

   The actual temperature could of course be lower than Hagedorn temperature and it is natural to imagine that blackhole cools down. The Hagedorn temperature and also actual temperature would increase in the phase transition $k \rightarrow k - 1$ increasing the value of $\Lambda(k)$ by a factor of 2.

2. The overall view about the situation would be that the thermal excitations of cosmic string die out by emissions assignable perhaps to black hole jets and also going to the cosmic string until a state function reduction decreasing the value of k occurs and the process repeats itself. The naïve idea is that this process eventually leads to ideal cosmic string having Hagedorn temperature $T = \hbar/R$ and possible existing at very low temperature: this would conform with the idea that the process is the time reversal of the evolution leading from cosmic strings to astrophysical objects as tangles of flux tube. This would at least require a phase transition replacing M_{107} hadron physics with M_{89} hadron physics and this with subsequent hadron physics. One must of course consider also all values of k as possible options as in the case of the evolution of star. The hadron physics assignable to Mersenne primes and their Gaussian counterparts could only be especially stable against a phase transition increasing $\Lambda(k)$.

Quantitative support for the model of blackhole-like object as flux tube spaghetti

The TGD based model for blackhole-like object is as monopole flux tube spaghetti [L91] containing one proton per proton Compton length and filling the entire volume. There is no need to emphasize that the models means giving up the standard view of blackhole-like objects.

Consider now the estimation of the total mass of the flux tube spaghetti.

1. Assuming additivity and neglecting self-gravitation, the total mass in units of m_p is M/m_p (here $m_p \simeq m_n$ is proton mass, the star would consist of neutrons).
2. Self gravitation for a spherically symmetric mass constant distribution inside sphere of radius R and given as $\rho = M/Vol(R)$ created by the flux tube spaghetti gives to the stationary metric contribution $\Delta g_{tt} = -\Phi_{gr}$, where one has

$$\Phi_{gr}(r) = 2G\frac{2M(r)}{r} = \frac{8\pi}{3}\frac{GM}{Vol(R)}r^2 = 2GM\frac{r^2}{R^3} \quad .$$

The gravitational potential energy of the mass distribution is in Newtonian appproximation given by

$$E_{gr} = -\int \rho(r)\Phi_{gr}(r)dV = -\frac{6GM^2}{5R} \quad .$$

For $R = r_S = 2GM$ this gives

$$E_{gr} = -\frac{6GM^2}{10GM} = -\frac{3}{5}M \quad .$$

Therefore the observed mass M_{obs} using m_p as a unit is given

$$M_{obs} = \frac{E_{tot}}{m} = \frac{2}{5}\frac{M}{m_p} \quad .$$

3. Suppose that the flux radius of thickness R contains a single proton per length zR so that one proton fills the volume $\pi * zR^3$. Suppose R corresponds to the proton Compton length $L_p = h/m_p$.
Assume that $h_{eff} \neq h$ is possible so that L_p is scaled by $y = h_{eff}/h$. One would have

$$L_p(h_{eff}) = yL_p \quad .$$

4. The total mass M using m_p as unit and neglecting gravitational potential energy is given by the ratio of the volume V of the blackhole regarded as region of Minkowski space to the volume V_p taken by a single proton:

$$\frac{M}{m_p} = \frac{V}{V_p} = \frac{4}{3zy^3}(\frac{r_S}{L_p})^3 \quad .$$

Taking into account gravitational potential energy, one obtains

$$\frac{M_{obs}}{m} = \frac{2}{5}\frac{V}{V_p} = \frac{8}{15zy^3}(\frac{r_S}{L_p})^3 \quad .$$

One can test the model for the Sun. One has $M_S = 2\times 10^{30}$ kg and $r_S = 3$ km. Proton has mass $m_p = 1.6\times 10^{-27}$ kg and Compton length $L_p = 1.3\times 10^{-15}$ m. Substituting the values to the above formula, one obtains $(y,z) = (1,.992) \simeq (1,1)$. In the above formula M_{obs}/m on r.h.s decreases slightly in $m_p \rightarrow m_n$ and $1/L_p^3$ also increases on t l.h.s in $m_p \rightarrow m_n$. The changes of l.h.s and r.h.s are proportional to $-\epsilon\times l.h.s$ and $3\epsilon\times r.h.s$, where one has $\epsilon = (m_n - mp)/m_p \simeq .1.811\times 10^{-3}$. This requires $\Delta(1/z) \simeq -4\epsilon(1/z)$ so that $z = .992$ is replaced with $z_{new} = (1+4\epsilon)z \simeq .9992$, which deviates from unity by -8×10^{-4}.

The conclusion is that the simple flux tube model for $h_{eff} = h$ and neutron taking a volume of Compton length, which is definitely different from the general relatistic model, is surprisingly realistic.

What happens to blackhole thermodynamics in TGD?

Blackhole thermodynamics (see `http://tinyurl.com/y7pvj23x`) has produced admirable amounts of literature during years. What is the fate of the blackhole thermodynamics in this framework? It turns out that the dark counterpart of of Hawking radiation makes sense if one accepts the notion of gravitational Planck constant assigned to gravitational flux tube and depending on masses assignable to the flux tube. The condition that dark Hawking radiation and flux tubes at Hagedorn temperature are in thermal radiation implying $T_{B,dark} = T_H$. The emerging prediction T_H is consistent with the value of the hadronic Hagedorn temperature.

1. In standard blackhole thermodynamics the blackhole temperature T_B identifiable identifiable as the temperature of Hawking radiation (see `http://tinyurl.com/md6mmvg`) is essentially the surface gravity at horizon and equal to $T_B = \kappa/2\pi = \hbar/4\pi r_S$ is analogous to Hagedorn temperature as far as dimensional analysis is considered. One could think of assigning T_B to the radial pulsations of blackhole like object but it is very difficult to understand how the thermal isolation between stringy degrees of freedom and radial oscillation degrees of freedom could be possible.
2. The ratio $T_B/T_H \sim L_p/4\pi r_S$ would be extremely small for ordinary value of Planck constant. Situation however changes if one has

$$T_B = \frac{\hbar_{eff}}{4\pi r_S} \ , \tag{10.2.2}$$

   with $\hbar_{eff} = n\hbar_0 = \hbar_{gr}$, where $\hbar_{gr}$ is gravitational Planck constant.

   The gravitational Planck constant $\hbar_{gr}$ was originally introduced by Nottale [E9] [K96, K78] assignable to gravitational flux tube (presumably non-monopole flux tube) connecting dark mass M_D and mass m (M and m touch the flux tubes but do not define its ends as assumed originally) is given by

$$\hbar_{gr} = \frac{GM_D m}{v_0} \ , \tag{10.2.3}$$

   where $v_0 < c$ is velocity parameter. For the Bohr orbit model of the 4 inner planets Nottale assumes $M_D = M(Sun)$ and $\beta_0 = v_0/c \simeq 2^{-11}$. For blackholes one expects that one has $\beta_0 < 1$ is not too far from $\beta_0 = 1$.

   The identification of M_D is not quite clear. I have considered the problem how v_0 and M_D are determined in [L72, L71] [K10]. For the inner planets of Sun one would have $\beta_0 \sim 2^{-11} \sim m_e/m_p$. Note that the size of dark proton would be that of electron, and one could perhaps interpret $1/\beta_0$ as the $h_{eff}/\hbar$ assignable to dark protons in Sun. This would solve the long standing problem about identification of β_0.
3. One would obtain for the Hawking temperature $T_{B,D}$ of dark Hawking radiation with $h_{eff} = h_{gr}$

$$T_{B,D} = \frac{\hbar_{gr}}{\hbar} T_B = \frac{1}{8\pi\beta_0} \times \frac{M_D}{M} \times m \ . \tag{10.2.4}$$

For $k = 107$ blackhole one obtains

$$\frac{T_{B,D}}{T_H} = \frac{\hbar_{gr}}{\hbar} \times T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi\beta_0(107)} \times \frac{M_D}{M} \times \frac{L(107)m}{x\hbar} \quad . \tag{10.2.5}$$

For $m = m_p$ this gives

$$\frac{T_{B,D}}{T_H} = \frac{\hbar_{gr}}{\hbar} T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi x\beta_0(107)} \times \frac{M_D}{M} \times \frac{m_p}{224 \ MeV} \quad . \tag{10.2.6}$$

The order of magnitude of thermal energy is determined by m_p. The thermal energy of dark Hawking photon would depend on m only and would be gigantic as compared to that of ordinary Hawking photon.

4. Thermal equilibrium between flux tubes and dark Hawking radiation looks very natural physically. This would give

$$\frac{T_{B,D}}{T_H} = 1 \tag{10.2.7}$$

giving the constraint

$$\frac{\hbar_{gr}}{\hbar} T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi x\beta_0} \times \frac{M_D}{M} \frac{m_p}{224 \ MeV} = 1 \quad . \tag{10.2.8}$$

on the parameters. For $M/M_D = 1$ this would give $x\beta_0 \simeq 1/6.0$ conforming with the expectation that β_0 is not far from its upper limit.

5. If ordinary stars are regarded as blackholes in the proposed sense, one can assign dark Hawking radiation also with them. The temperature is scaled down by $L(107)/L(k)$ and for Sun this would give factor of $L(107)/L(125) = 2^{-9}$ if one requires that $r_S(k)$ corresponds to solar radius. This would give

$$T_B(dark, k) \rightarrow \frac{\hbar_{gr}}{\hbar} \times \frac{L(107)}{L(k)} T_B = \frac{2^{(k-107)/2}}{8\pi\beta_0} \times \frac{M_D}{M} \times m \quad . \tag{10.2.9}$$

For $k = 125$ and $M_D = M$ this would give $T_B(dark, 125) = m/2\pi$.

The condition $T_{B,D} = T_H$ for $k = 125$ would require scaling of $\beta_0(107)$ to $\beta(125) = 2^{-9}\beta_0(107) \simeq 2^{-11}$. This would give $\beta_0(107) \simeq 1/4$ in turn giving $x \simeq .66$ implying $T_H \simeq 149$ MeV. The replacement of $m_p = 1$ GeV with correct value $m_p = .94$ GeV improves the valueThis value is consistent with the value of hadronic Hagedorn temperature so that there is remarkable internal consistency involved although a detailed understanding is lacking.

6. The flux of ordinary Hawking thermal radiation is $T_B^4/\hbar^3$. The flux of dark Hawking photons would be $T_{B,dark}^4/\hbar_{gr}^3 = (\hbar_{gr}/\hbar)T_B^4$ and therefore extremely low also now also. In principle however the huge energies of the dark Hawking quanta might make them detectable. I have already earlier proposed that $T_B(h_{gr})$ could be assigned with gravitational flux tubes so that thermal radiation from blackhole would make sense as dark thermal radiation having much higher energies.

   One can however imagine a radical re-interpretation. BHE is not the thermal object emitting thermal radiation but BHE plus gravitational flux tubes are the object carrying thermal radiation at temperature $T_H = T_B$. For this option dark Hawking radiation could play fundamental role in quantum biology as will be found.

7. What about the analog of blackhole entropy given by

$$S_B = \frac{A}{4G} = \pi \frac{l_{Pl}^2}{T_B^2} \ , \qquad (10.2.10)$$

where $A = 4\pi r_S^2$ is blackhole surface area. This corresponds intuitively to the holography inspired idea that horizon decomposes to bits with area of order l_P^2?

The flux tube picture does not support this view. One however ask whether the volume filling property of flux tube could effectively freeze the vibrational degrees of flux tubes. Or whether these degrees of freedom are thermally frozen for ideal blackhole. If so, only the ends of he flux tubes at the surface or their turning points (in case that they are turn back) can oscillate radially. This would give an entropy proportiona+l to the area of the surface but using flux tube transversal area as a unit. This would give apart from numerical constant

$$S_B = \frac{A}{4L(k)^2} \ . \qquad (10.2.11)$$

Constraint from $\hbar_{gr}/\hbar > 1$

When mass m can interact quantum gravitationally and are thus allowed in h_{gr} for given M_D?

1. The notion of h_{gr} makes sense only for $h_{gr} > h$. If one has $h_{gr} < h$ assume $h_{gr} = h$. An alternative would be $h_{gr} =\rightarrow h_0 = h/6$ for $h_{gr} < h_0$. This would given $GM_Dm/v_0 > \hbar_{min}$ ($\hbar_{min} = \hbar$ or $\hbar/6$) leading

$$m > \frac{\beta_0 \hbar}{2r_S(M_D)} \times \frac{\hbar_{min}}{\hbar} \ . \qquad (10.2.12)$$

This condition is satisfied in the case of stellar blackholes for all elementary particles.

2. One can strengthen this condition so that it would satisfied also for gravitational interactions of two particles with the same mass ($M_D = m$). This would give

$$\frac{m}{m_{Pl}} > \sqrt{\beta_0} \ . \qquad (10.2.13)$$

For $\beta_0 = 1$ this would give $m = m_{Pl}$, which corresponds to a mass scale of a large neuron and to size scale 10^{-4} m. $\beta_0(125) = 2^{-11}$ gives mass scale of cell and size scale about 10^{-5} meters. $\beta_0(127) \simeq 2^{-12}$ corresponding to minimum temperature making hot fusion possible gives length scale about 10^{-6} m of cell nucleus. A possible interpretation is that the structure in cellular length scale have quantum gravitational interaction via gravitational flux tubes. Biological length scales would be raised in special position from the point of view of quantum gravitation.

3. Also interactions of structures smaller than the size of cell nucleus with structures with size larger the size of cell nucleus are possible. By writing the above condition as $(m/m_{Pl})(M_D/m_{pl}) > \beta_0$, one sees that from a given solution to the condition one obtains solutions by scaling $m \rightarrow xm$ and $M_D \rightarrow M_D/x$. For $\beta_0(127) \simeq 2^{-11}$ corresponding to the scale of cell nucleus the atomic length scale 10^{-10} m and length scale 10^{-4} m of large neuron would correspond to each other as "mirror" length scales. There would be no quantum gravitational interactions between structures smaller than cell nucleus. There would be master-slave relationship: the smaller the scale of slave, the larger the scale of the master.

Quantum biology and dark Hawking radiation

The scaling formula $\beta_0(k) \propto 1/L(k)$ with flux tube thickness scale given by $L(k)$ allows to estimate $\beta_0(k)$. In this manner one obtains also biologically interesting length scales. An interesting question is whether the scales for the velocities of Ca waves (see `http://tinyurl.com/qs3j5cp`) and nerve pulse conduction velocity could relate to v_0.

1. The tube thickness about 10^{-4} m, which corresponds to ordinary cosmological constant being in this sense maximal corresponds to the p-adic length scale $k = 171$. The scaling of $\beta_0 \propto 1/L(k)$ gives $v_0(171) \sim 4.7$ μm/s In eggs the velocity of Ca waves varies in the range 5-14 μm/s, which roughly corresponds to range $k \in \{171, 170, 169, 168\}$.

   In other cells Ca wave velocity varies in the range 15-40 μm/s. $k = 165$ corresponds to 37.7 μm/s near the upper bound 40 μm/s. The lower bound corresponds to $k = 168$. $k = 167$, which corresponds to the larges Gaussian Mersenne in the series assignable to $k \in \{151, 157, 163, 167\}$ the velocity is 75 μm/s.

2. For $k = 127$ gives $v_0 \sim 75$ m/s. $k = 131$ corresponds to $v_0 = 18$ m/s. These velocities could correspond to conduction velocities for nerve pulses in accordance with the view that the smaller the slave, the larger the master.

I have already earlier considered that dark Hawking radiation could have important role in living matter. The Hawking/Hagedorn temperature assuming $x = 1/6.0$ $k = L(171)$ has peak energy 38 meV to be compared with the membrane potential varying in the range 40-80 meV. Room temperature corresponds to 34 meV. For $k = 163$ defining Gaussian Mersenne one would have peak energy about .6 eV: the nominal value of metabolic energy quantum is .5 eV. $k = 167$ corresponds to .15 eV and 8.6 μm - cell size. Even dark photons proposed to give bio-photons when transforming to ordinary photons could be seen as dark Hawking radiation: Gaussian Mersenne $k = 157$ corresponds to 4.8 eV in UV. Could CMB having peak energy of .66 meV and peak wavelength of 1 mm correspond to Hawking radiation associated with $k = 183$? Interestingly, cortex contains 1 mm size structures. To sum up, these considerations suggest that biological length scales defined by flux tube thickness and cosmological length scales defined by cosmological constant are related.

10.2.5 Zero energy ontology and stellar and galactic evolution

Zero energy ontology (ZEO) replaces ordinary ontology in TGD based view about quantum states and quantum jump [L105].

1. In ZEO zero energy states are superpositions of space-time surfaces inside causal diamond (CD) identified as preferred extremals of the basic action principle of TGD. CD is cartesian product of causal diamond cd of M^4 and of CP_2. The preferred extremals analogous to Bohr orbits have boundaries - ends of space-time - at the light-like boundaries of CD. There is a fractal hierarchy of CDs and given CD is an embedding space correlate for a conscious entity - self - consciousness is universal.

2. Zero energy states can be seen as superpositions of state pairs with members assigned to the opposite boundaries of CD. ZEO predicts that in ordinary or "big" state function reductions (BSFRs) the arrow of time of system changes and remains unaffected in "small" state functions (SSFRs), which are TGD counterpart for "weak" measurements and associated with a sequence of unitary evolution for the state assignable to the active boundary CD, which also shifts farther from the passive boundary. Passive boundary is unaffected as also members of state pairs at it.

3. Subjective time is identified as a sequence of SSFRs and correlates strongly with clock time identifiable as the distance between the tips of CD and increasing in statistical sense during the sequences of SSFRs.

4. BSFR corresponds to state function reduction at active boundary of CD which becomes passive. This forces the state at passive boundary to change. Passive boundary becomes active. BSFR means the death of self and reincarnation with an opposite arrow of time. Thus the notion of life cycle is universal and life can be lieved in both directions.

5. What happens to CD in long run? There are two options.

   (a) The original assumption was that the location of formerly passive boundary is not changed. This would mean that the size of CD would increase steadily and the outcome would be eventually cosmology: this sounds counter-intuitive. Classically energy and other Poincare charges are conserved for single preferred extremal could fail in BSFRs due to the fact that zero energy states cannot be energy eigenstates.

   (b) The alternative view suggested strongly $M^8 - H$ duality [L56] is that the size of CD is reduced in BSFR so that the new active boundary can be rather near to the new passive boundary. One could say that the reincarnated self experiences childhood. In this case the size of CD can remain finite and its location in M^8 more or less fixed. One can say that the self associated with the CD is in a kind of Karma's cycle living its life again and again. Since the extension of rationals can change in BSFR and since the number of extensions larger than given extension is infinitely larger than those smaller than it, the dimension of extension identifiable in terms of effective Planck constant increases. Since $n = h_{eff}/h_0$ serves as a kind of IQ, one can say that the system becomes more intelligent.

Cosmic redshift but no expansion of receding objects: one further piece of evidence for TGD cosmology

"Universe is Not Expanding After All, Controversial Study Suggests" was the title of very interesting Science News article (see `http://tinyurl.com/o6vyb9g`) telling about study, which forces to challenge Big Bang cosmology. The title of course involved the typical exaggeration.

The idea behind the study was simple. If Universe expands and also astrophysical objects - such as stars and galaxies - participate the expansion, they should increase in size. The observation was that this does not happen! One however observes the cosmic redshift so that it is too early to start to bury Big Bang cosmology. This finding is however a strong objection against the strongest version of expanding Universe. That objects like stars do not participate the expansion was actually known already when I developed TGD inspired cosmology for quarter century ago, and the question is whether GRT based cosmology can model this fact naturally or not.

The finding supports TGD cosmology based on many-sheeted space-time. Individual space-time sheets do not expand continuously. They can however expand in jerk-wise manner via quantum phase transitions increasing the p-adic prime characterizing space-time sheet of object by say factor two of increasing the value of $h_{eff} = n \times h$ for it. This phase transition could change the properties of the object dramatically. If the object and suddenly expanded variant of it are not regarded as states of the same object, one would conclude that astrophysical objects do not expand but only comove. The sudden expansions should be observable and happen also for Eart. I have proposed a TGD variant of Expanding Earth hypothesis along these lines [**?**]

Stars as reincarnating conscious entities

One can apply ZEO to the evolution of stars. The basic story (see `http://tinyurl.com/ceoo6sj`) is that the star is formed from he interstellar gas cloud, evolves and eventually collapses to a white dwarf, degenerate carbon-oxygen core, supernova or even blackhole if the mass of the remnant resulting in explosion throwing outer layers of the star away is in the range of 3-4 solar masses. Only very massive stars end up to supernovas. The type of the star depends on the abundances of various elements in the interstellar gas from which they formed and believed to contain heavier elements produced by earlier supernovas.

There are however several anomalies challenging the standard story. There are stars older than Universe (see `http://tinyurl.com/s698l86`). There is also evidence that the abundances of heavier elements in the early cosmology are essentially the same as for modern stars [E14] (see `http://tinyurl.com/qkk26dv`). TGD based explanation is discussed in [L103].

Karma's cycle option for the stellar evolution could explain these anomalies.

1. Stars would be selves in Karma's cycle with their magnetic bodies reincarnating with a reversed arrow of time in a collapse to blackhole/white hole like entity (BHE/WHE) - depending on the arrow of time. This would follow by a stellar evolution leading to an asymptotic state BHE/WHE corresponding to maximum size of CD followed by a collapse to BHE or WHE.

Also ordinary stars would correspond to BHEs/WHEs characterized by p-adic length scale $L(k)$ longer than $L(107)$ assignable to GRT blackholes. In standard time direction WHE would look like blackhole evaporation.

2. This would allow stars older than the Universe and suggests also universal abundances. Note however that the abundances would strongly depend on the abundances of the interstellar gas and matter produced by the magnetic energy of flux tube. "Cold fusion" as dark fusion could produce elements heavier than Fe and light elements Li, Be, B, whose abundances for fusion in stellar core is predicted to be much much smaller than the observed abundances in the case of old stars. The lifetimes of stars depend on their type. Also a universal age distribution of stars in stellar clusters not depending appreciably on cosmic time is highly suggestive. I remember of even writing about this. Unfortunately I could not find the article.

To put it more generally, the hierarchy of CDs implies that the Universe decomposes effectively to sub-Universes behaving to some degree independently. The view about Karma's cycles provides a more precise formulation of the pre-ZEO idea that systems are artists building themselves as 4-D sculptures. In particular, this applies to mental images in TGD based view about brain.

1. One could perhaps say that also quantum non-determinism has classical correlates. CDs would be the units for which time-reversing BSFRs are possible. Also SSFRs affecting CDs could have classical space-time correlates. M^8-H duality [L56] predicts that the time evolution for space-time surface inside CDs decomposes to a sequence of deterministic evolutions glued together along M^4 time $t=r_n$ hyperplanes of M^4 defining special moments in the life of self at which the new larger CD receives a new root $t=r_n$. The non-deterministic discontinuity could be localized to the 2-D vertices represented by partonic 2-surfaces at which the ends of light-like partonic orbits meet.
2. The M^4 hyperplanes $t=r_n$ correspond to the roots of a real polynomial with rational coefficients defining the space-time surfaces at the level of M^8 as roots for the real or imaginary part in quaternionic sense for the octonionic continuation of the polynomial. These moments of time could correspond to SSFRs.
3. The finite classical non-determinism is in accordance with the classical non-determinism predicted at the limit of infinitely large CD and vanishing cosmological constant at which classical action reduces to Kähler action having a huge vacuum degeneracy due to the fact than any space-time surface having Lagrangian manifold (vanishing induced Kähler form) as CP_2 projection is a vacuum extremal. The interpretation of this degeneracy interpreted in terms of 4-D spin glass degeneracy would be that at the limit of infinitely large CD the extension of rationals approaches to algebraic numbers and the roots $t=r_n$ becomes dense and the dynamics becomes non-deterministic for vacuum extremals and implies non-determinism for non-vacuum extremals.

No time dilation for the periods of processes of quasars

There are strange findings about the time dilation of quasar dynamics challenging the standard cosmology [E33]. One expects that the farther the object is the slower its dynamics looks as seen from Earth. Lorentz invariance implies red shift for frequencies and in time domain this means the stretching of time intervals so that the evolution of distant objects should look the slower the longer their distance from the observer is. In the case of supernovae this seems to be the case. What was studied now were quasars at distances of 6 and 10 billion years and the time span of the study was 28 years [E36]. Their light was red shifted by different amounts as one might expect but their evolution went on exactly the same rhythm. This looks really strange.

In GRT the redshift violates conservation of four-momentum. In TGD cosmic redshift reduces to the fact that the tangent spaces of the space-time surface for target and receiver differ by a Lorentz boost. Redshift does not mean non-conservation of four-momentum but only that the reference frames are different for target and observer. The size for the space-time sheets assignable to the systems considere must be large, of the order of the size scale L defined by the size of the recent cosmology to which one assigns the Hubble constant. In the flux tube picture this means that the flux tubes have length of order L but thickness would be about $R=10^{-4}$ meters - the size scale of large neuron. Photons arrive along flux tubes connecting distant systems. Note that CMB corresponds to 10 times longer peak wavelength.

I have already earlier discussed this time anomaly [K63] but what I have written is just the statement of the problem and and some speculations about its solution in terms of ZEO. A valuable hint is that the time anomaly appears for quasars- very heavy objects - but not for supernovae - much lighter objects. This suggests that the redshift depends on the masses of the objects considered.

1. One considers an approximately periodic process. It is quite possible that this process is not classical deterministic process at space-time level but that one has sequence of SSFRs (weak measurements) or even BSFRs for a subsystem of the target. These processes replace quantum superposition of space-time surfaces inside CD with a new one and SSFR also increases its size in statistical sense. A natural Lorentz invariant "clock time" for the target is the distance between the tips of CD - light-cone proper time. Both M^4 linear coordinates and light-cone Robertson-Walker coordinates are natural coordinates for space-time sheets with 4-D M^4 projection.

   "Clock time" must be mapped to M^4 linear time for some space-time sheet. The Minkowski coordinates for the CD are determined only modulo Lorentz boost leaving the light-like boundary of CD invariant. In general the M^4 coordinates of the target and observer are related by a Lorentz boost and this gives rise to cosmological redshift and also gravitational reshift.

2. The information about SSFR or BSFR at the target must be communicated to the observer so that the space-time sheets in question must be connected by flux tubes carrying the photons. CD must contain both systems and naturally has cosmological size given by L so that flux tubes have thickness about R. The M^4 time coordinate must be common to both systems. The natural system to consider is center of mass system (cm) in which the sum of the momenta of two systems vanishes.

Did cosmology have any “Dark Ages”?

A further potential time anomaly of the recent cosmology relates to the “Dark Ages” of the Universe. Between the decoupling of CMB radiation from matter and the formation of stars there should have been a “Dark Ages” during which there was only neutral hydrogen. Star formation generated radiation at energies high enough to ionize hydrogen and the ionized interstellar gas started to produce radiation.

The 21 cm line of neutral hydrogen serves as a signature of neutral hydrogen. This line is redshifted and from the lower bound for the redshift one can deduce the time when “Dark Ages” ended. The popular article tells (see `http://tinyurl.com/wzegzxk`) that the recent study using Murchison Widefield Array (MWA) radio telescope by Jonathan Pober and collaborators gave an unexpected result. Only a new lower upper bound for this redshift emerged: the upper bound corresponds to about 2 meters [E23] (see `http://tinyurl.com/qttq3gl`). The conclusion of the experimenters is optimistic: soon the upper bound for the redshift should be brought to light.

In TGD based view about cosmology and astrophysics [L91] (`http://tinyurl.com/tkkyyd2`) one can formulate two questions.

1. One can ask whether there were any “Dark Ages” at all!
2. An alternative question is whether the “Dark Ages” in distant geometric past are prevailing anymore! This would be like asking whether the Hitler of thirties is the Hitler we know anymore. The point is that in TGD framework one must distinguish between subjective time and geometric time and this leads to some rather dramatic modifications of the prevailing view about time. The following arguments encourage a positive answer to the first question and negative answer to the second question.

The following arguments encourage positive answer to the first question and negative answer to the second question.

The answer to the first question relies of TGD based view about nuclear physics solving anomalies of standard nuclear physics and leading to a new view about stellar evolution.

1. In TGD framework the formation of stars could have preceded by a pre-stellar period during which dark fusion giving rise to dark proton sequences - dark nuclei - at monopole flux tubes

happened: this is Pollack effect in biology. This would have been "cold fusion" period in the stellar evolution and would have occurred spontaneously at low temperatures. It would have already produced abundances, which are not far from modern ones and one of the recent surprises is that the abundances at very early period are already near to modern ones.

2. The model predicts also the possibility of neutral states for which electrons are at flux tubes parallel to dark proton flux tubes and have the same scaled up size (due to non-standard value of $h_{eff} = nh_0$, which is smaller by factor about 1/2000) as dark protons. In solar interior dark protons would have Compton size of electron so that h_{eff} for them would be about 2000 times higher $H = M^4 \times CP_2$ than h. Also smaller and larger value of h_{eff} are possible. For blackholes the protons at flux tubes would be ordinary: $h_{eff} = h$.
3. The transformation of dark nuclei having much smaller binding energy would have liberated nuclear binding energy and the resulting photons having energy up to gamma ray energies would have ionized the neutral hydrogen.

Zero energy ontology (ZEO) leads to a negative answer to the question whether "Dark Ages" still prevail in distant past.

1. In ZEO Universe consists at the level of embedding space $H = M^4 \times CP_2$ of a fractal hierarchy of $CD = cd \times CP_2$, where cd is causal diamond of M^4.*CDshaveinterpretationasahierarchyofsub−cosmologies.EachCDdefinesacorrelateforaconsciousentityandincreasesinsizeineach\small" statefunctio passive−asalsomembersofstatepairsatitdefiningzeroenergystates.Theactiveboundaryrecedesfartherawa*
2. In a "big" (ordinary) state function reduction (BSFR) the roles of boundaries of CD change. Active becomes passive and vice versa. The arrow of time changes. Self dies and reincarnates with opposite arrow of time. The simplest possibility is that the size of CD can decrease in BSFR meaning that the formerly passive boundary becomes much nearer to active. In this case CD begins to grow from a small size: self has "childhood". In this case it can happen that self never reaches a size larger than some upper bound and lives again and its life. Each life is more evolved since the extension of rationals involved with space-time surface increases in statistical sense in BSFR. This is nothing but Karma's cycle but in all scales.
3. At the level of stars this would mean that star could undergo evolution as Karma's cycle also in cosmological remote past as an object located at fixed point of H. The abundances would be more or less the same as for modern stars. This would explain the mystery of stars older than the Universe and solve also other time anomalies of the standard cosmology. This explanation is consistent with the first one and actually the first one is needed to explain abundances of nuclei heavier than Fe and the light nuclei Li, B, Be much higher than predicted by standard model. Thus both questions would have positive answer.

Observation of a time reversal of blackhole like object?

A very strange object behaving like time reversal of blackhole has been observed (`http://tinyurl.com/umzxaoe`). The blackhole in question is super-massive and in the middle of galaxy cluster. Usually blackhole eat the surrounding matter and also prevent the formation of stars since they are powerful emitters of gamma rays - this is not in accordance with the naïve view about blackholes. The weird blackhole does not emit gamma rays and the environment around it cools and this makes possible star formation. Instead of eating the surrounding matter it should feed matter to surroundings making possible the star formation.

The most obvious TGD identification of the mystery object relies on zero energy ontology allowing both arrow of time. The arrow of time chances in ordinary state function reduction - the "big" one as opposed to "small" one corresponding to weak measurement. This predicts time reversed blackhole like objects (BHEs) analogous to white holes: white hole like objects (WHEs).

WHEs could appear in the very early states of the galactic evolution. They could feed the magnetic energy of monopole flux tubes to environment transformed to ordinary matter in turn forming galaxies. As a matter of fact, monopole flux tubes portions emanating it much lines of magnetic field would be formed and their local thickening and formation of tangles would give rise to stars.

If the time reversal idea is taken very seriously WHEs should suck gamma rays from environment inducing cooling making the star formation easier. This would be dissipation in non-standard direction of time identifiable as the basic metabolic mechanism associated with all kinds of self-organization process: quantum coherence at the level of magnetic body would be essential and induce long range coherence of ordinary matter as forced coherence.

WHE could be also created in BSFR for a BHE.

Do quasars and galactic blackholes relate by time reversal in ZEO?

This picture combined with zero energy ontology (ZEO) based view about ordinary state functions changing the arrow of time and occurring even in astrophysical scales leads to a tentative view about quasars and galactic blackholes as time reversals of each other.

1. Quasars could be seen as analogs of white holes feeding the mass of cosmic string out to build the galactic tangle and part of the mass of thickening tangle would transform to ordinary matter. They would initiate the formation of galaxy meaning emergence of increasing values of h_{eff} in the hierarchy of Planck constant. Cosmic string would basically feed the mass and energy liberated in the decay of magnetic energy at cosmic strings thickening to flux tubes to ordinary matter and serving in the role of metabolic energy driving self-organization.
2. Galactic blackholes could be perhaps indeed analogs of blackholes as time reversals of quasars - "big" (ordinary) state function reduction would transform quasar as white hole to a galactic blackhole. Now the system would be drawing back the mass from the surroundings to the flux tube and maybe cosmic string. The process could be like breathing. In zero energy ontology breathing could indeed involve a sequence of states and their time reversals.

This raises also the question whether the evolution of stars could be seen as a time reverse for the formation of blackholes: kind of growth followed by a decay perhaps since the values of Planck constant h_{eff} would be reduced. The climax of his evolution would correspond to maximal values of h_{eff}. The evolution of life would be certainly this kind of climax.

An objection against the notion of dark energy

Nikolina Benedikovic gave a link to a popular article (`http://tinyurl.com/ydo2sna9`) describing a finding challenging the notion of dark energy. This finding made by a team of astronomers working at Yonsei University (Seoul, South Korea) is very interesting since twistor lift of TGD predicts length scale dependent cosmological constant.

Let us collect the basic facts first.

1. Standard candle property (`http://tinyurl.com/pn9goe2`) is essential assumption leading to dark energy hypothesis. It states that the distance corrected luminosity of SN Ia supernovae does not evolve with redshift that it is it depends only on distance.
2. Observation: The luminosity of SN Ia supernova correlates significantly with the population age of the host galaxy. The luminosity thus depends on the environment provided by the host galaxy.

   According to the article:

   > The team has performed very high quality spectroscopic observations to cover most of the reported nearby early-type host galaxies of SN Ia, from which they obtained the most direct and reliable measurements of population ages for these host galaxies. They find a significant correlation between SN luminosity and stellar population age at a 99.5 percent confidence level. As such, this is the most direct and stringent test ever made for the luminosity evolution of SN Ia. Since SN progenitors in host galaxies are getting younger with redshift (look-back time), this result inevitably indicates a serious systematic bias with redshift in SN cosmology. Taken at face values, the luminosity evolution of SN is significant enough to question the very existence of dark energy. When the luminosity evolution of SN is properly taken into account, the team found that the evidence for the existence of dark energy simply goes away (see Figure 1).
3. This is in conflict with the standard candle property if the population age of the host galaxy decreases with distance. This is obvious in standard cosmology. But is this true in TGD Universe obeying zero energy ontology (ZEO)?

In ZEO [L105] (http://tinyurl.com/yfjtmoq6) the situation might be different. ZEO provides a quantum measurement theory solving the basic paradox of standard quantum measurement theory and leads to a theory of consciousness.

1. The first prediction is that geometric time and experienced time identified as sequence of "small" state function reductions (SSFRs as counterparts of weak measurements) are not same. This is of course an empirical fact - thermodynamical time is irreversible unlike geometric time, etc... but in standard ontology these times are identified.
2. In small state function reductions (SSFRs) as counterparts of weak measurements) arrow of time does not change and their sequence defines self as conscious entity. In big (ordinary) state function reductions (BSFRs) the system "dies" and reincarnates with opposite arrow of time. The experiments of Minev *et al*l provide direct support for ZEO in atomic systems [L90] (http://tinyurl.com/yjbpoy3q). Libet's findings support this in neuroscience [J6].
3. Assume that the size of the causal diamond (CD) decreases in "reincarnation" that is self experiences "childhood". If so the size of CD can remain bounded. Irrespective of this assumption the temporal center of mass position of CD in embedding space $H = M^4 \times CP_2$ remains the same during the sequence of reincarnations.

   Most importantly: the steady motion towards future assumed in standard ontology with single arrow of time is replaced with forth-and-back motion in time with constant cm position of CD in H.
4. ZEO explains several time anomalies such stars older than the universe and the observation that the nuclear abundances of very distance stars seem to have nearly their modern values supporting the view that the population age of galaxy does not depend significantly on distance [L91](hhttp://tinyurl.com/ydlogkb4) .

   In particular, the age distribution for the populations of galaxies would not depend significantly on distance - standard candle hypothesis would be saved!

10.2.6 Objections against GRT blackholes

The basic theoretical objection against blackholes was due to Einstein himself. The collapse of matter to single point is simply impossible. This objection has been however forgotten since doing calculations is much more pleasant activity than hard thinking, and an enormous literature have been produced based on this idealization. There is no doubt that blackhole like entities (BHEs) with about Schwartschild radius exist, but general relativity does not allow to say anything about the situation inside possibly existing horizon.

Badly behaving blackholes

There is an excellent video (thanks to Howard Lipman for a link) challenging the standard view about blackholes. In the sequel list some arguments that I remember.

TGD was born as a solution to the fundamental difficulty of GRT due to the loss of classical conservation laws. In TGD framework BHEs correspond to *volume filling* flux tube tangles. Also galactic BHEs would correspond to a volume filling flux tube tangles.

In TGD framework also stars could be seen as BHEs having the flux tube thickness characterized by p-adic length scale as an additional parameter. GRT blackholes correspond to flux tube thickness about proton Compton length. For instance, Sun can be seen as a BHE and the size is predicted correctly [L91](see http://tinyurl.com/tkkyyd2) .

The model for BHEs makes large number of correct predictions.

1. The minimal radii/masses of GRT blackholes and neutron stars are predicted correctly.
2. Ordinary blackhole thermodynamics is replaced with the thermodynamics associated with monopole flux tubes carrying galactic dark mass characterized by Hagedorn temperature and the thermodynamics gravitational flux tubes characterized by Hawking temperature but for gravitational Planck constant h_{gr} so that it is gigantic as compared to the ordinary Hawking temperature.

   In thermal equilibrium these temperatures are same and this predicts hadronic string tension correctly.

Consider now the empirical objections against BH paradigm in light of TGD picture.

1. The observations by ALMA telescope show that stars can be formed surprisingly near to galactic BHEs (see `http://tinyurl.com/ry746pg`). For instance, 11 young stars just forming have been found at distance of 3 ly from galactic BHE of Milky Way. This is impossible since the intense tidal forces and UV and X ray radiation should make impossible the condensation of stars from gas clouds.

   TGD explanation: Galaxies are formed as tangles on long thickened cosmic string responsible for galactic dark matter as dark energy. Same mechanism give rise to stars as sub-tangles generating at least part of the ordinary matter as decay of the magnetic energy of the flux tube as it thickens. Ordinary matter already present could concentrate around the tangle.

   One learns from the discussion in the above link that star formation involves bipolar flow consisting two jets in opposite directions believed to take care of angular momentum conservation: the star formed is thought to be formed from a rotating gas cloud (rotation would be around flux tube) having much larger angular momentum and part of must be carried out by jets naturally parallel to the flux tube. Also this gives support for the view that stars are tangles along flux tube. There are also hundreds of massive and much older stars in the vicinity of galactic BHE.

   Note that in TGD also these stars could be seen as BHEs but with different p-adic length scale characterizing the thickened flux tube. The reason why galactic BHE does not swallow these objects could be that they are bound states around flux tube (or even cosmic string outside the star), which is rather rigid by its string tension.

   "Non-hungry" BHEs are found.

   TGD explanation: In zero energy ontology to which quantum TGD relies, one must distinguish between BHEs and their time reversals, white hole like objects (WHEs), analogous to white holes. WHEs would not be "hungry" but feed matter into environment. The counterparts or jets would flow into WHE and matter would flow out from WHE.

3. The standard theoretical belief is that in a dense star cluster only single blackhole can exist. If there are several blackholes, they start to rotate around each other and fuse to a larger blackhole. A case with two blackholes have been however observed.

   TGD explanation: A possible explanation is that the objets are WHEs and their behavior is time reversal of BHEs.

4. The velocities of particles in the jets associated with a galactic BHEs are near light velocity and require extremely high energies and thus strong magnetic fields. No strong magnetic field has been however observed.

   TGD explanation: In TGD Maxwellian magnetic fields are replaced with flux tubes carrying quantized monopole flux not possible in Maxwellian world. Their existence allows to understand the presence of magnetic fields in even cosmological scales, the maintenance problem of Earth's magnetic field, and the recent findings about the magnetic field of Mars [L93]. Ordinary magnetic fields correspond to vanishing total flux and are indeed weak: it is these magnetic fields outside the jet which would have been measured. Galaxies are tangles in monopole flux tube and this is the carrier of very strong magnetic field associated with jets parallel to the flux tube.

5. Very distant galactic blackholes with distances in scale of million light years have radio jets in the same direction. This is very difficult to understand in the standard view about cosmology.

   TGD explanation: The galactic BHEs would be associated with the same long cosmic string forming galaxies as tangles.

Too heavy blackhole in Milky Way

The standard model for blackhole formation predicts an upper bound on the mass of blackhole depending also on environment since the available amount of matter in environment is bounded. In the case of Milky Way the bound is about 20 solar masses. Now however a blackhole like entity (BHE) with mass about 70 solar masses has been discovered (see `http://tinyurl.com/w7xlb78`). I am grateful for Wes Johnson for the link. Also the masses of BHEs producing the gravitational radiation in their fusion have been also unexpectedly high, which suggets that standard view about BHEs is not quite correct.

The proposed model for BHEs as a volume filling flux tube gives correct lower bounds for masses of neutron star and TGD counterpart of blackhole but does not give upper bound for the mass. For time reversed BHEs - analogs of white holes (WHEs) possibly identifiable as quasars - the mass of WHE comes from a tangling long cosmic string and there is no obvious upper bound. Even galactic BHEs could correspond to WHEs, which have made quantum jump to BHEs at the level of magnetic body: in this state the flux tube forming counter the magnetic field is fed back from environment. A breathing spaghetti would be in question.

In standard model the mechanism for the formation of blackhole is different since there is no flux tube giving the dominant dark energy/dark matter contribution to the mass. Therefore the upper bound for mass - if there exists such - is expected to increase. In TGD framework the dominant contribution would come from the monopole flux tubes giving rise TGD counterpart of magnetic field which extends at least over the region containing stars assumed to correspond sub-tangles of the galactic flux tangle. Intuitively it seems clear that the upper bound is higher than in GRT. If the spaghetti straightens - the tangled flux tube would untangle- one could have upper bound.

The simplest model predicts that only the flux tube mass contributes to the mass of BHE. The mass of the ordinary matter going to BHE would transform back to dark energy/mass of the flux tube. The process would be time reversal of the process making sense in zero energy ontology [L105] in which the magnetic energy of flux tube transforms to ordinary matter: time reversal for the TGD counterpart of inflation.

10.3 A model for the formation of galaxies

I have proposed a general vision about galaxy formation as formation of tangles on cosmic strings carrying monopole flux. The strings can be long and also short. In the case of long string the model explains flat velocity spectrum of distant stars automatically. For closed short strings the velocity spectrum is not flat. There is however no detailed model for the galaxy formation. In particular, the complex structure of spiral galaxies is poorly understood. Even the question whether there is single long cosmic string orthogonal to the galactic plane or cosmic string parallel to the spiral structure in galactic plane - as proposed decades ago in the original model [K31, K99] - or both has remained open. In the sequel I make an attempt to collect the essential facts about elliptic and spiral galaxies and consider a qualitative model for the galaxy formation consistent with these facts. The goal is rather modest: just to develop an internally consistent view about the evolution of galaxies.

1. The simplest model for elliptic galaxy is as a closed string possibly reconnected as a loop from long string or as a tangle of a cosmic string having topology analogous to that of field lines of dipole magnetic field. Quasar would have preceded the formation of the tangle in which string would have thickened to flux tube and dark energy would have transformed to ordinary matter [E6] [L83]. Quasars would be time reversal of galactic blackhole like entity (GBHE).
2. In the case of spiral galaxies the existence of vast polar structures (VPOS) in the plane orthogonal to the galactic plane of spiral galaxy (`http://tinyurl.com/k553545`) strongly suggest [L68] that two cosmic strings are involved and that the spiral structure believed to correspond to a standing wave analogous to traffic jam is associated with dark matter of a long cosmic string. This model conforms with the fact that the stars of spiral galaxies are older than those of elliptic galaxies except inside the bulge.

   The asymmetry between the two planes suggests that the spiral arms are formed when an elliptic galaxy identified as a tangle of a long string $S_{||}$ formed via a quasar stage [L83] in the galactic plane has collided with a cosmic string $S_\perp$ orthogonal to the galactic plane. These collisions are unavoidable for non-parallel strings and gravitational attraction causes the needed relative motion.

   The differential rotation of portion of $S_{||}$ around $S_\perp$ would have deformed $S_{||}$ to a spiral shape. $S_{||}$ would have also generated the visible spiral arm pair in the transformation of dark energy to ordinary matter. Galactic bulge would correspond to the elliptic galaxy and galactic blackhole like entity (GBHE) would have formed from the matter in bulge: this conforms with the fact that elliptic galaxies have always galactic blackhole. The galactic bar could be analogous to the dipole of dipole magnetic field. In principle also the string orthogonal to the galactic plane could produce ordinary matter by thickening.

One open question relates to the fact that TGD predicts two kinds of cosmic strings with closed transverse cross section and having vanishing induced Kähler field or non-vanishing induced Kähler form carrying monopole flux. The latter are stable against splitting by the conservation of the monopole flux and have no counterpart in Maxwellian electrodynamics [L87]. The monopole flux tubes could correspond to the cosmic strings giving rise to galaxies, stars, and even planets as tangles. Non-monopole flux tubes might serve as gravitational flux tubes mediating gravitational interactions. Presumably both kinds of flux tubes are involved but their precise roles are not well-understood.

10.3.1 Some basic facts about galaxies

In the following I collect basic facts about galaxies.

Elliptic galaxies

The following facts about elliptic galaxies (`http://tinyurl.com/ayyvg9n`) are relevant for what follows.

1. 10-15 per cent of all galaxies are elliptic. The stars of elliptic galaxies are old and older than those of spiral galaxies outside the bulge.
2. The size of elliptic galaxies is typically 1-2 pc and therefore more than by order of magnitude smaller than that of spiral galaxies. Elliptic galaxies are essentially 3-D structures without sub-structures, and the central bulge of spiral galaxies resembles elliptical galaxy. There is no preferred galactic plane. Large enough elliptic galaxies have supermassive blackhole-like entity (BHE) at their center. Elliptic galaxies are populated by globular clusters. The motions of stars in elliptic galaxies are mostly radial.
3. Whether elliptic galaxies contain dark matter is not clear and the non-existence of dark matter cannot be excluded for elliptic galaxies (`http://tinyurl.com/s2wrd26`).

Basic structures for spiral galaxies

Most galaxies 85-90 per cent of galaxies are spiral galaxies. Spiral galaxies are highly structured.

Consider first the visible structure taking Milky Way as a representative example (also so called mini-spirals exist [L68]).

1. Stellar disk of spiral galaxy (`http://tinyurl.com/vx2hams`) has radius $R_D = 23 - 30$ kpc. In the case of Milky Way one can distinguish 3 different disks. The young thin disk contains young stars and has thickness of .1 kpc, which is also the size scale of globular clusters. The old thin disk has thickness of .325 pc. The thick disk has a thickness of 1.5 kpc. This gives some hints about the formation of the Milky Way.
2. Milky Way has 4 spiral arms. The arms begin from the ends of galactic bar with length 1-5 kpc. The interpretation of arms is as standing waves. Traffic jam is used analogy for arms: the stars rotating around the center of galaxy would slow down at the arm. The question is what causes the jam. For the second arm pair the number of stars is larger than for the second pair.
3. Spiral galaxies do not have bulge always (`http://tinyurl.com/tb7ca72` and `http://tinyurl.com/uv79o9x`). The bulge can contain also spiral sub-bulge in the galactic plane. The bulge is few kpc thick. Galactic blackhole (like entity) is present only if bulge is present and has in the case of Milky Way size scale of 10^4 ls (10^{-4} pc).
4. Vast polar structure - VPOS (`http://tinyurl.com/k553545`) is a disk in the plane orthogonal to the galactic plane containing satellites, which are dwarf galaxies and globular clusters and streams of stars and gas. The disk has radius 250 kpc considerably larger than stellar

disk in galactic plane. Its thickness is 50-60 kpc whereas the components of galactic disk have much smaller thickness.

5. There are also stellar nebulae containing hydrogen and acting as stellar nurseries.
6. Cold dark matter scenario (http://tinyurl.com/zv6wg4s) leads to the conclusion that galaxy involves dense dark core radius 2-3 times that of stellar disk and having constant density and behaving like rigid body in good approximation. Dark matter halo predicts that the density is peaked and this leads to core-cusp problem [E48]. The dark matter core could relate to the VPOS having the same thickness. Inside the core region rotation velocity should be constant if dark matter dominates.

Milky Way has a pair of Fermi bubbles located symmetrically at the opposite sides of the galactic plane and touching it. The diameter of bubble is 7.7 kpc. By the way, Earth is at the boundary of Fermi bubble (http://tinyurl.com/r9f8nee). The bubbles expand at velocity $v = 3.2 \times 10^{-3}c$. It is believed that the bubbles are a remnant of a very energetic event occurred for millions of years ago in the galactic center. The bubbles would not be a dynamical phenomenon rather than a morphological feature.

10.3.2 TGD based model

In the sequel the TGD inspired cosmology and model for the formation of galaxies is first briefly summarized, and after that a possible qualitative model for the formation of galaxies is discussed.

TGD inspired view about cosmology

TGD based model to be discussed relies on the general vision about cosmology.

1. Einsteinian space-time corresponds to space-time surfaces with 4-D M^4 projection. The many-sheetedness of space-time surface is lost at the QFT-GRT limit replacing the sheets with single region of M^4, whose metric is slightly deformed. The sums of the induced gauge potentials *resp.* deviations of the metric from M^4 metric define gauge fields of the standard model *resp.* metric of GRT space-time. This approximation fails for cosmic strings.
2. Cosmic strings come in two different varieties having closed transversal cross section as 2-D CP_2 projection and string world sheet as M^4 projection. The 2-D cross section can carry non-trivial monopole type Kähler flux or vanishing Kähler flux but non-vanishing electroweak gauge fields. Neither flux tube needs current to create the magnetic field since cross section is closed.

   In primordial cosmology cosmic strings of both types dominate. The cosmic strings are unstable against thickening of M^4 projection and during the analog of inflationary period meaning transition to a radiation dominated cosmology the M^4 projection becomes 4-D and Einsteinian space-time becomes a reasonable approximation in long length scales.

   Cosmic strings and thin flux tubes are however present also during Einsteinian period and cannot be completely neglected. For instance, monopole flux tubes explain the existence of magnetic fields in cosmic scales and also solve the maintenance problem of Earth's magnetic field [L30]. There are many open questions. For instance, it is not clear whether the flux tubes mediating gravitational interaction have nearly vanishing induced Kähler form and vanishing Kähler magnetic flux. It is assumed that long cosmic strings having galaxies as tangles carry monopole flux but even this assumption can be challenged.
3. Twistor lift of TGD plays a central role in the scenario. It predicts that the dimensionally reduced 6-D Kähler action for the 12-D product of twistor spaces of M^4 and CP_2 decomposes to a sum of 4-D Kähler action and volume term having cosmological constant Λ as a coefficient. Dimensional reduction is required by the induction of the twistor structure to the space-time surface as S^2 bundle.

   Λ has spectrum and is proportional to the inverse square of the p-adic length scale assumed to satisfy p-adic length scale hypothesis $p \simeq 2^k$: one can write $\Lambda = \Lambda(k)$. Thus any astrophysical system (say galaxy,star, or planet) as space-time sheet inside causal diamond (CD) is characterized by $\Lambda(k)$. This solves the basic problem due to the huge size of cosmological constant since cosmological constant goes to zero in long length scales. This also predicts the thickness of flux tubes. For "cosmological" cosmological constant the thickness is that of large neuron.

4. The thickness of the flux tube remains piecewise constant in cosmic evolution and increases in phase transitions reducing the value of $\Lambda(k)$. The simplest assumption is that the phase transitions are induced by the expansion of the larger space-time sheet at which the sub-system is glued by CP_2 sized wormhole contacts. In the formation of blackholes these phase transition would take place in opposite direction leading to contraction. For instance, in stars the thickness of flux tubes would be larger than in blackhole like entities (BHEs) defined by the volume filling flux tubes with thickness of proton Compton length [L91].

   For cosmic strings and primordial flux tubes the thickness would be presumably smaller and protons could be replaced with those of hadron physics characterized by a Mersenne prime smaller than M_{107} characterizing ordinary hadron physics. M_{89} is the Mersenne labelling the fractal copy of hadron physics in LHC energy scale and there are indications for the mesons of M_{89} hadron physics at LHC [K66, K67].

TGD based model for the formation of galaxies

In TGD framework the presence of VPOS (`http://tinyurl.com/k553545`) [L68] suggests the presence of long cosmic string $S_\perp$ orthogonal to the galactic plane containing dark matter and energy and at least one cosmic string $S_{||}$ thickened to flux tube parallel to the galactic plane. Single $S_{||}$ would suggest two spiral arms but there are four. Also the existence of 3 disks suggest that there are actually 2 flux tubes $S_{||,i}$, $i = 1, 2$, which would collided with $S_\perp$. Could gravitational force between cosmic strings have caused the formation of spiral structures and could visible galactic matter be generated from the thickening of these flux tubes?

One should also understand the flat velocity spectrum of distant stars. $S_\perp$ creates such a spectrum. Also $S_{||}$ creates such as spectrum for objects rotating in VPOS plane. Same is approximately true for the stars rotating in galactic plane since the dark mass of string plus its decay products within ball of given radius R (distance from the galactic center) is expected to be proportional to R. As a matter fact, the original proposal [K31, K99] was that there is only string in the galactic plane and corresponds to the spiral structure.

One should understand the morphologies of elliptic and spiral galaxies and how they were formed.

1. Elliptic galaxies are simple and older than spiral galaxies. A good guess is that they represent the primordial galaxies and are formed as tangles along cosmic strings thickening locally to flux tubes and producing the ordinary matter as dark energy and dark matter of string transforms to ordinary matter. Quasars as time reversals of blackholes would represent the primordial stages of elliptic galaxies [L83]. That there are also small elliptic galaxies without GBHE supports the view that time reversal is in question.

2. Spiral galaxies with much complex morphology would be an outcome of dynamical processes involving collisions. The bulge of the spiral galaxy resembles elliptic galaxy, which gives hints about the dynamics involved with the formation of the spiral galaxy.

   The presence of VPOS and strong asymmetry between the VPOS plane orthogonal to the galactic plane strongly suggests a collision of elliptic galaxy assignable to cosmic string $S_{||}$ with some object The simplest identification of this object is as $S_{||}$, which has remained mostly dark but shows itself as a preferred direction for galactic jets. Indeed, two strings not parallel to each other and moving with respect to each other are doomed to intersect and intersection would give rise to spiral galaxy. The relative motion would be caused by the gravitational attraction of the strings.

3. Spiral morphology should be understood. Why 4 spiral arms? Why a pair of dense spiral arms with members connected by galactic bar to connected structure? Why the pair of less dense spiral arms forming similar connected structure? Are the pairs separate structures or parts of the same structure and could bulge show the existence of sub-structure consistent with the fusion of two elliptic bulges. Could the existence the 3 disks with different ages and thicknesses relate to the existence of 3 strings?

   Could the VPOS cosmic string(s) $S_{||}$ ($S_{||,i}$) in the galactic plane have rotated differentially with respect to the cosmic string $S_\perp$ orthogonal to the galactic plane and given rise to a pair of spiral arms. Are 2 parallel strings $S_{II,1}$ and $S_{||,2}$ in galactic plane needed to explain both pairs of spiral arms.

One must understand the asymmetry between $S_\perp$ and $S_{||,i}$. Did $S_{||,i}$ contain a tangle giving rise to elliptic galaxy by the transformation of dark matter to ordinary matter. Did the elliptic galaxy become the bulge of the spiral galaxy? Did $S_\perp$ collide $S_{||,i}$. Did $S_{||,i}$ start differential rotation around the long string and give rise to spiral structure with two arms connected by the bar?

The gravitational attraction between $S_\perp$ and $S_{||,i}$ should have increased the probability of the collisions - 85-90 per cent of galaxies are spiral galaxies. Gravitational attraction could have made possible also the second collision in which the less dense pair of arms emerged and gave rise to the thin disk.

4. One should understand galactic bar. Bar brings in mind is dipole creating dipole magnetic field. Could one have the analog of dipole field with monopole flux tubes needing not current to generate it and perhaps assignable to $S_{||,i}$. Could dark flux tubes associated with $S_{||,i}$ give rise to flux tube structures with topology resembling that of dipole magnetic field?

   Remark: The dipole nature for dark monopole flux structure is somewhat ad hoc assumption since there would be no current as source. There are also flux tubes carrying vanishing total flux and correspond to thickening of flux tubes. A possible interpretation would be as flux tubes mediating gravitational interaction and characterized by very large value of $h_{eff} = h_{gr} = GMm/v_0$ [E9] [K96, K10] [L72]. The dipole like flux tube structure could correspond to these flux tubes.

5. What about galactic blackhole, which in TGD would correspond to galactic black-hole like entity (GBHE) identifiable as volume filling flux tube structure [L91]. TGD actually suggests a hierarchy of BHEs classifiable by the thickness of the volume filling flux tube and ordinary stellar blackholes would correspond to flux tubes for which proton Compton length would define the thickness. An important empirical input comes from the fact that GBHE is present only if also the galactic bulge is present, and that elliptic galaxies have GBHE as a rule. This also supports the view that GBHE is formed after the formation of elliptic galaxy which could take place via a formation of quasar in which dark matter transforms to ordinary matter in a process which is time reversal for the formation of blackhole: white hole like entity (WHE) might be appropriate term in the case of quasar [L83].

6. The presence of old thick disk, thin disk, and young thin disk suggest interpretation as bulge (elliptic galaxy), younger portion of the same string $S_{||,1}$ decaying to ordinary matter and leaving the string, and possibly portion of $S_{||,2}$ suffering similar decay. This interpretation would suggest that the dwarf galaxies and globular clusters in VPOS have been there from the beginning and are not generated from $S_{||,i}$.

7. How satellites - dwarf galaxies and globular clusters - are formed? Are they basically bound states of closed strings with VPOS string. Have they reconnected from VPOS string as separate loops? Did reconnections of this VPOS string produce dwarf galaxies or were they there from beginning as satellites. Note that the number of stars about one thousandth from that for galaxies and globular clusters have size scale .1 kPc.

The core-cusp problem of cold dark matter model [E48] gives guidelines for the model building. The existence of dark core (DC) with approximately constant density with radius 2-3 times that of stellar disk is suggestive: it should have density peaked at center instead of constant density: this leads to the halo-cusp problem.

1. TGD suggests that the dark matter of astrophysical objects have as asymptotic states volume filling flux tube spaghettis [L91] (`http://tinyurl.com/tkkyyd2`). The size R of the spaghetti correlates with the thickness r of the flux tube. Dark matter dense core associated with strings should form a spaghetti with size $R \sim 90$ kpc few times the size of the stellar disk. GBH would be spaghetti with radius about $R_{GBH} \sim 10^{-4}$ pc with flux tube thickness given by proton Compton wavelength $L_p \sim 10^{-15}$ m.

   By scaling the thickness L_p of flux tube of GBH by factor $R/R_{GBH} \sim 10^9$ one obtains dark flux tube radius about $r \sim 10^{-6}$ m - the size scale of cell nucleus by the way. Recall that flux tube thickness 10^{-4} m corresponding the size scale of large neutron is assignable with "cosmological" cosmological constant Λ. Note that $\Lambda(k)$ is length scale dependent in TGD and characterizes the system's causal diamond as "sub-cosmology".

2. There are several open questions. Either $S_{||,i}$ or $S_\perp$ could give rise DC. Which of them? $S_\perp$ makes itself visible only via the presence of galactic jets and as structures along which galaxies form linear structures. Why so passive role? Does dense core correspond to a flux tube tangle possibly having the topological structure of field lines of a dipole magnetic field? Can the flux tube structure be disjoint from the long string - perhaps formed in reconnection?

10.3.3 Support for the proposed model of galaxies

In the following some empirical support for the proposed model is discussed.

Evidence for 3 different temperatures at galactic halo

The model for Milky Way suggests the presence of 3 cosmic strings thickened to flux tubes. Galactic disk has indeed 3 components with different thickness. There is support for the presence of 3 components also in the Milky Way halo [E24] (`http://tinyurl.com/ssxl3ux`, thanks to Wes Johnson for the link) as gas at different temperatures, and perhaps assignable to 3 different cosmic strings.

The information was gained by studying X rays from a blazar, very active energetic core of a distant galaxy emitting intense beams of light. The blazar was at distance of 5 billion light years. The light passed through the galactic halo and the temperature of the halo was determined from the properties of light received at Earth.

The halo was expected to have single temperature in the range between $10^4 - 10^6$ K. It was however found to contain 3 components at different temperatures, and the hottest component had temperature about 10^7 K. The unexpectedly high temperature is proposed to be due to the winds emanating from the disc of stars of MW. It was also found that the halo contains besides hydrogen also significant amounts of heavier elements suggesting that the halo has received material created by certain stars during their lifetime and final stages.

In TGD framework "cold fusion" [L54] outside stellar interiors could have generated at least part of the heavier elements. "Cold fusion" proceeds by a formation of dark nuclei identifiable as dark nucleon sequences at magnetic flux tubes with $h_{eff}/h \simeq m_p/m_e \sim 2000$ and having radius of electron Compton length. Nuclear binding energy is scaled down by a factor of about 1/2000 to keV range. Dark nuclei would have transformed to ordinary nuclei liberating practically all nuclear binding energy outside stellar nuclei. This process would serve as a kind of warm-up band in the pre-stellar evolution leading eventually to the ordinary fusion [L54, L103, L91].

Evidence for the presence of monopole flux tubes

Monopole flux is the key property of flux tubes proposed to be behind various astrophysical structures. Is there any direct evidence for this? Evidence has emerged for the existence of giant clouds with size about 100 AU in the vicinity of the supermassive GBHE of Milky Way [E17] (`http://tinyurl.com/sukomc6` and `http://tinyurl.com/tz2hta5`). These objects - called G objects - look like gas clouds but behave like stars. G objects stretch longer when nearer to GBHE but get their original shape when farther away. One would expect that they are torn apart by the enormous tidal forces created by GBHE.

The identification could be as visible matter assignable to a spaghetti like structure formed by monopole like flux tube, which could have also produced the visible matter in the thickening of the flux tube. By flux conservation the monopole flux prevents the flux tubes from splitting even in the huge gravitational field of supermassive GBHE. Without monopole flux tubes to which visible matter is gravitationally bound the structure would be torn to pieces. In Maxwellian world monopole flux tubes are not possible. In biology the behavior of gels (the contents of an egg is the basic example) could be based on monopole flux tubes connecting the cells together.

Cosmic strings and angular momentum problem of General Relativity

Vladimir Nechitailo took contact and asked for comments about his World-Universe model (WUM) (`http://tinyurl.com/vm2k7hb`). In the following my reaction to the claim

"The angular momentum problem is one of the most critical problems in BBM. Standard Cosmology cannot explain how Galaxies and Extra Solar systems obtained their substantial orbital and rotational angular momenta, and why the orbital momentum of Jupiter is considerably larger than the rotational momentum of the Sun. WUM is the only cosmological model in existence that is consistent with the Law of Conservation of Angular Momentum. "
appearing in the abstract of his article.

I cannot quite agree with this statement.

I have not explicitly considered the problem of large angular momenta in TGD. I do not think that the problem is non-conservation - note however that general relativity has problem with classical conservation laws which led to the idea about space-times as surfaces in $M^4 \times S$.

The challenge is to explain naturally the large angular momenta, which obey the analog of stringy mass formula: mass squared proportional to angular momentum. In TGD framework monopole flux tubes made possible by the homology of CP_2 lead to a picture in which cosmic strings with huge string tension carrying magnetic and volume energy thicken to flux tubes, and in this process lose magnetic energy transform to ordinary matter.

Cosmic strings [K31, K99, K63] explain dark matter and energy: galaxies are associated as tangles to long cosmic strings and the gravitational field of long cosmic string explains the flat velocity spectrum of distant stars [L53, L68, L91] (http://tinyurl.com/tkkyyd2. The rotation of the galactic matter around the long cosmic string explains the large angular momenta. For halo models one does not obtain this prediction. Large angular momenta are of course associated also to distant stars with constant velocity.

WUM as primordial period of cosmology is in TGD replaced with cosmic strings as non-Einsteinian 4-D space-times surfaces with with 2-D M^4 projection and complex manifold of CP_2 as CP_2 projection would dominate the primordial cosmology transforming to radiation dominated cosmology by the thickening of M^4 projection of cosmic string to 4-D [K63, L53]. This period would be the analog of inflation in TGD but without inflaton fields. Dark matter would correspond to $h_{eff} = n \times h_0$ phases at flux tubes present in all scales - even biological and also hadronic scales - as remnants of the primordial period.

Too young to be so heavy

The model should also allow to understand quasars and in [L83] (http://tinyurl.com/y2jbru4k) I considered a model of quasars as precedessors of galaxies. And additional support for the proposed picture came from a rather thought provoking article (http://tinyurl.com/sz9n72n) telling about a particular quasar identified as a super-massive blackhole with mass $.780M(Sun)$ ($M(Sun)$ is solar mass). Quite generally quasar masses vary in the range $10^8 - 10^9\ M(Sun)$. Galactic blackholes have mass in the range $10^5 - 10^9\ M(Sun)$. Milky Way blackhole has much smaller mass about $4 \times 10^6 M(Sun)$ (http://tinyurl.com/7wtza99).

Remark: I prefer to talk about blackhole like entities (BHEs): the TGD view about BHEs see is described in [L91] (http://tinyurl.com/tkkyyd2).

1. The first question considered by the researches is what burned away the neutral fog around the BHE: it is known that re-ionization (http://tinyurl.com/y8xodylx) must have burned away the fog ending the "dark ages" during which the Universe was transparent but there were no sources of light, which we could see (cosmic redhsift). Dark ages ended when re-ionization took place by light burning away the fog - perhaps light coming from dwarf galaxies and high energy photons from quasars did this. Despite re-onization the light could propagate since the density of matter absorbing it was so low.

2. There is also second deep problem: quasar - if indeed BHE - is too massive quite too early. This problem is met for all quasars - the age of the universe is measures using 1 billion years as a natural time unit for the observed quasars. If the galactic blackholes were former quasars, their masses should be larger than for quasars. The mass of Milky Way BHE is however of order $10^6 M(Sun)$ and much smaller than for quasars.

   From the list of blackholes (http://tinyurl.com/s3e223q) one gets an idea about the masses of galactic BHEs. Typically masses are considerably lower than quasar masses. There is however lenticular (between elliptic and spiral galaxy having disk but not spiral structure) galaxy NGC 1277 with galactic blackhole with mass about $1.7 \times 10^{10} M(Sun)$.

The smaller mass scale makes it is difficult to believe that galactic blackholes could be former quasars. One can also ask whether very old lenticular galaxies, which posses neither spiral structure but have galactic plane could be formed from quasars and whether the central object could be quasar.

These problems challenge the interpretation of quasars as BHEs and TGD suggests an interpretation of all quasars as time reversals of BHEs - whitehole like entities (WHEs). Zero energy ontology (ZEO) of TGD indeed allows time reversed states and the arrow of time changes in ordinary, "big" state function reductions (BSFRs), which in TGD Universe can occur even in astrophysical scales so that even BHEs could be time reversals of WHEs. BSFRs would occur routinely in living matter, and self-organization as a process in apparent conflict with second law could be based on time reversal at magnetic body (MB) carrying dark matter as $h_{eff} = n \times h_0$ phases. Self-organization would be based on dissipation with reversed arrow of time at MB and violate standard arrow of time. In accordance with experimental facts, it would require energy feed since the creation of states with non-standard value of h_{eff} requires energy feed.

ZEO allows to imagine two solutions to the problem of "too-young-to- be-so-heavy" problem.

1. Quasars could be WHEs [L83] (`http://tinyurl.com/y2jbru4k`) and they would feed matter to environment rather that eating it (there was not much to eat yet!). The dark energy and matter of a tangled of cosmic string would transform to ordinary matter eventually creating the visible galaxy as the tangle thickens to magnetic flux tube and loses its energy. The precedessors of quasars would be generated during inflationary period as tangles of cosmic strings of primordial cosmology started to thicken and Einsteinian space-time with 4-D M^4 projection in $H = M^4 \times CP_2$ was created. Before this it was 2-D string world sheet. The fog, presumably hydrogen around the quasar formed from cosmic string energy, was formed from the energy of cosmic string.

   The huge energy emission by quasars could accompany a reduction of length scale dependent cosmological constant leading to the emission of volume energy whose density is proportional to cosmological constant.

2. One can also imagine that quasars were indeed BHEs which got their mass from the material produced by the decaying cosmic strings before stars were even formed. This would be less radical option than the first one and require that BHEs of galactic nuclei started to form much later than quasars and have therefore much smaller masses. They are however present in all elliptic galaxies except dwarfs. Elliptic galaxies are rather old and could have perhaps formed as self-intersections of the flux tube tangle giving rise to the elliptic galaxy.

Surprises from Milky Way

The continual feed of unexpected observations has forced a critical re-evaluation of what we really know about galaxies and their formation. The standard wisdom that they are due a condensation of matter under gravitational attraction is challenged.

Even the Milky Way is yielding one surprise after another. It is amusing to witness how empirical findings are gradually leaving TGD as the only viable option. The surprise that inspired these comments, came from Science Alert (`https://cutt.ly/KQPo8ZV`). The article tells at layman level about the findings reported in an article accepted to The Astrophysical Journal Letters [E20] (`https://cutt.ly/MQPpq4V`).

The discovery of the largest gas filament in our Galaxy, or a new spiral arm?

Cattail is a gigantic structure with a length which can be as much as 16,300 light-years, discovered in the Milky Way. It is a filament which does not seem to be analogous to a spiral arm since it does not follow the warping of the galactic disk which is thought to be an outcome of some ancient collision. In the TGD framework this structure would be associated with a cosmic string, which has in some places thickened to a flux tube and generated ordinary matter in this process.

Also the spiral arms might be accompanied by cosmic strings. In any case, there would be a long cosmic string orthogonal to the galactic plane (jets are parallel to it quite generally) having galaxies along it and generated by the thickening of the cosmic string generating blackhole-like entities as active galactic nuclei.

Just yesterday I learned that the Milky Way also offers other surprises (`https://cutt.ly/pQPpyJo`). One of them is that the galactic disk contains old stars that should not be there but in the outskirts of the galaxy which is the place for oldies whereas younger stars live active life in the galactic disk. This if one assumes that the usual view about the formation of galaxies is correct. This applies also to the weird filaments mentioned above.

In the TGD Universe, galaxies are not formed by a condensation of gas but by a process replacing inflaton decay with a process in which cosmic strings thicken and their string tension - energy density - is reduced [L83, L91, L149]. The liberated energy forms the ordinary matter giving rise to the galaxy. This solves the dark matter problem: strings define dark matter and energy and no halo is needed to produce a flat velocity spectrum of distant stars. The collisions of cosmic strings are unavoidable in 3-D space and could have induced the thickening process creating the active galactic nuclei (quasars).

This process would be opposite to what is believed to occur in the standard model. What comes to mind is that the oldies in the disk are formed from a cosmic string portion in the galactic plane. The tangle of the cosmic string can indeed extend in the galactic plane over long distances and there can also be cosmic strings (associated with galactic spiral arms?) in the galactic plane, which would have almost intersected a cosmic string orthogonal to the plane inducing the formation of the Milky Way.

10.4 Anomalies related to galactic dynamics

Wes Johnson sent also two links related to the long range correlation between the dynamics of quasars and galaxies. The first result was about correlations of quasar spins in billion light-year scale. Second result was about coherence between the galactic spin and motions of surrounding galaxies at least up to 6 Mly. The explanation of both findings is in terms of cosmic strings thickened to flux tubes, which are the basic element in the TGD based model for the formation of quasars and galaxies. Third anomaly relates to “too” fast spinning galaxies.

10.4.1 Correlated galactic spins in billion light-year scale

The first link is to a popular article “*Alignment of quasar polarizations with large-scale structures*” (see `http://tinyurl.com/rcoam7g`) telling about alignment of quasar polarization with large scale structure in scale of Gly, which is a really huge scale. This suggests that the quasar spin axes are aligned with a linear structure connecting the quasars.

The correlations between spin directions of quasars over distances of billion light-years have been observed. These correlations have been observed earlier over much shorter distances for quasars/galaxies along the well-known linear structures. This suggests that the linear structures are much longer than previously thought.

This is what I have been preaching for decades. There would exist a fractal tensor network of cosmic string/monopole flux tubes over entire cosmos having local flux tube tangles as nodes. Networks inside networks inside.... The flux tubes would carry dark matter in TGD sense making possible quantum coherence in arbitrarily long length scales.

1. TGD predicts a fractal hierarchy of flux tubes formed from cosmic strings: 4-D surfaces in $M^4 \times CP_2$ having 2-D strings world sheet as M^4 projection.
2. Galaxies reside along linear structures which would correspond to what I call cosmic strings: galaxies would be tangles along these strings thickened locally to monopole flux tubes: part of their magnetic energy would have transformed partially to matter and formed the visible part of galaxy. Volume energy would correspond to length scale dependent cosmological constant. They would explain also flat velocity spectra associated with spiral galaxies. There would be no dark matter halo.

   Cosmic strings and their monopole flux tube portions would be remnant from cosmic string dominated period, which transformed to GRT type cosmology via an inflation type period as cosmic strings thickened to flux tubes. These strings containing the galaxies as tangles would form a network correlating the dynamics of individual galaxies and making possible correlations and synchrony even over distances of about 1 billion ly.
3. The correlations between spin directions of galaxies is what has been been could be inherited from past when the galaxies along strings were much closer to each other. Angular momentum conservation would take care that correlation are preserved.

4. Macroscopic quantum coherence even in cosmological scales is however possible by hierarchy of Planck constants explaining dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter. We could be seeing quantum coherence of dark matter inducing ordinary coherence of matter in cosmic scales.

Remark: I have asked whether all self-organization phenomena involving energy feed (needed to increase h_{eff} responsible for quantal long range correlations at dark level) could be induced by dark matter at magnetic flux tubes [L102]. A further interesting question is whether self-organization is dissipation in reversed time direction so that also it would be due to second law but in generalized sense required by ZEO.

10.4.2 Mysterious coherence in several-megaparsec scales between galaxy rotation and neighbor motion

Second link was to article "*Mysterious Coherence in Several-megaparsec Scales between Galaxy Rotation and Neighbor Motion*" by Lee *et al* (see `http://tinyurl.com/sbmcn6g`). The article states that there is a "mysterious" coherence between the rotational direction of galaxy and the average motion of its nearest neighbours within 6 MPc, possibly even up to 11 MPc. This coherence cannot result from collisions with nearby galaxies like coherence below 1 MPc and is proposed to originate from the collective motion of a structure containing the galaxies affecting the directions of angular momenta of galaxies: the coherence would be induced from that of the collective motion.

In TGD framework the natural identification for the collective structure would be as a long monopole flux tube containing the galaxies or at least a subset of them as tangles. There could be of course several monopole flux tubes in the sample studied. It was indeed found that the coherence was especially strong when neighbors of the galaxy at center were restricted to red galaxies. Red galaxies could correspond to the same flux tube. Alternatively, the collective motion affects them less than other galaxies as the article suggests.

10.4.3 Galaxies spinning "too" fast

The anomalous findings relating to cosmology and astronomy are proliferating I am grateful for Wes Johnson for a flow of links. This particular link (see `http://tinyurl.com/qv2vpw3`) gives pictures provided by NASA about spiral galaxies spinning "too" fast. The problem is that centrifugal acceleration destabilizes the system spinning too fast. This suggests that the structure of galaxy is not what our models involving ordinary matter and dark matter halo are somehow wrong. TGD suggests an improved view allowing to understand also "too" fast spinning rates.

Suppose that galaxies are tangles along monopole cosmic string such that string has thickened to flux tube. Monopole cosmic string would be rotating. These monopole tangles would serve as TGD counterparts for the magnetic field of galaxy which has no Maxwellian counterpart. No currents are needed for their maintenance.

1. Monopole flux tube has closed cross section, which is non-contractible 2-surface, pinch is impossible. In other words, the conservation of monopole flux prevents its splitting so that centrifugal acceleration cannot break the flux tube even at the highest spinning velocities. Only radial deformation increasing the size is possible.
2. Ordinary matter - generated as the magnetic energy of the flux tubes has transformed to ordinary matter in process analogous to inflation - in turn is gravitationally bound with the flux tube so that the galaxy manages to keep also the ordinary matter.

10.4.4 Galaxy, which existed 1 billion years after Big Bang

Galaxy GN-z11 (see `http://tinyurl.com/tg7sscu`) existed 1 billion years after the Big Bang and gave rise to stars with a rate much faster than Milky Way. There should have been any stars giving rise to the galaxies by the usual mechanism of gravitational condensation.

TGD explanation is simple. Galaxies formed as tangles to long cosmic string, which thickened and liberated part of its magnetic energy to ordinary matter, which formed the stars of the galaxy as local tangles inside tangle. The formation of stars was faster because local cosmological constant was larger and the rate for the transformation of magnetic energy to ordinary matter was higher. The periods of star formation should correspond to the phase transitions decreasing the local cosmological constant.

Also in younger galaxies the star formation is highest near the galactic blackhole, even at distances smaller than 3 ly, where it should not happen at all. The mechanism would be the same. For the flux tubes extending farther from galactic center the local cosmogical constant is smaller and the rate for the formation of stars is slower.

10.4.5 Support for TGD view about galactic dark matter

Cosmology an also other fields of physics with one exception - particle physics - produces fascinating results on daily basis. It is really a pity that particle physicists living in the jail of their reductionistic world view cannot pay any attention to these discoveries and continue moaning that there is no data so that it impossible to go beyond standard model. Bad philosophy can kill entire field of science. Having replaced Planck length scale reductionism by fractality I can enjoy swimming in the flood of anomalies.

One of the surprises was a popular article about a detection of dark matter lumps [E19] (`http://tinyurl.com/vjvhyud`) by Hubble telescope. The discovery is based on gravitational lense effect. The popular article tells about light coming distant quasars - distance is about 10 million light years. At the path of light coming to Earth there is foreground galaxy - distance is about 2 million light years. They are reported to give rise to four separate images of the galaxy by lense effect.

I am however wondering why one observes four images of each quasar by foreground galaxy. My naïve expectation would be a ring if dark matter halo gives rise to the lensing. If so the finding would represent an anomaly. It is also stated that the number of images depends on how many different dark matter particles there exists. I must admit that I do not understand.

What says TGD?

1. If galaxies are associated with long cosmic strings as tangles as in TGD Universe, flat velocity spectrum is automatically predicted without any other assumptions and velocity spectrum determines string tension [L83, L91]. (`http://tgdtheory.fi/public_html/articles/meco.pdf` and `http://tgdtheory.fi/public_html/articles/galaxystars.pdf`).
2. Long cosmic string would give rise to two separate images in lensing effect rather than ring as halo would do. Two long foreground cosmic strings with different directions - say being nearly orthogonal - would give rise to four images.
3. The two cosmic strings could be assigned with fusion of two galaxies associated with separate cosmic strings. One can consider the possibility that visible galaxies are formed as two cosmic strings collide: this would give rise to instability initiating the thickening of the 2-D M^4 projection of cosmic string and formation of tangles associated with both cosmic strings. Magnetic energy would be liberated and transform to ordinary matter giving rise to the visible matter of galaxy. For instance, could the 4 spiral arms of Milky way could relate to the second cosmic string in the plane of Milky way tangled around the second cosmic string orthogonal to the plane of Milky Way?

   One can consider also a situation in which there is no foreground galaxy but just two cosmic strings and this might provide a test for TGD view.

10.5 Cosmic spinning filaments that are too long

The inspiration for writing this article came from a highly interesting popular article (`https://cutt.ly/inMODTT`) providing new information about the cosmic filaments (thanks to Jebin Larosh for the link). The popular article tells about the article published in Nature [E31] (`https://cutt.ly/HnMOGcP`) and telling about the work of a team led by Noam Libeskind.

10.5.1 Findings

What has been studied is a long filament with length of order 10^8 ly characterizing the sizes of large cosmic voids. The filament consists of galaxies and the surprising finding is that besides moving along the filament, the galaxies associated with the filaments spin around the filament axis.

This finding suggests a network of filaments of length of order 10^8 ly and thickness of order 10^6 ly intersecting at nodes formed by large galaxy clusters. The larger the masses at the ends of the filament are, the larger the spin is.

How angular momentum is generated is the problem. The problem is quite general and is shared by both Newtonian and General Relativistic Universes. The natural assumption is that angular momentum vanishes in the original situation. Angular momentum conservation requires a generation of compensating angular momentum. This should happen in the case of all rotating structures. Already the case of galaxies is problematic but if the length scale of the structure is 10^8 ly, the situation becomes really difficult.

Gravitationally bound states have as a rule angular momentum preventing gravitational collapse but how the angular momentum is generated in a process believed to be a concentration of a homogeneous matter density to astrophysical objects? The basic problem is that the Newtonian description relies on scalar potential so that the field lines of the Newtonian gravitational field are never closed. It is difficult to imagine mechanisms for the generation of angular momentum by rotation. In the GRT based description gravi-magnetic fields, which are rotational, emerge but they are extremely weak. The proposal is that tidal forces could generate angular momentum but the generation of angular momentum remains poorly understood.

10.5.2 TGD view about the angular momentum generation

Could one understand the recent finding, and more generally, the generation of angular momentum, in the TGD framework? What raises hope is that in the TGD framework Kähler magnetic fields, whose flux tubes can be regarded as space-time quanta, are key players of dynamics in all scales besides gravitation.

Cosmic strings as carriers of dark matter and energy

The basic difference between GRT and TGD are cosmic strings and flux tubes resulting from their thickening. Cosmic strings are preferred extremals which are space-time surfaces with 2-D string world sheet as M^4 projection and complex surface of CP_2 as CP_2 projection.

1. The presence of the long filaments is one of the many pieces of support for the fractal web of cosmic strings thickened to flux tubes predicted by TGD. The scale is the scale of large voids 10^8 ly forming a kind of honeycomb like structure. The density of matter would be fractal in the TGD Universe [L83, L91] (`http://tgdtheory.fi/public_html/articles/meco.pdf` and `http://tgdtheory.fi/public_html/articles/galaxystars.pdf`).

2. Long cosmic string has a gravitational potential proportional to $1/\rho$, ρ the transverse distance. This predicts a flat velocity spectrum for the stars rotating around the galaxy. No dark matter halo is needed. The model contains only a single parameter, string tension, and also this can be understood in terms of the energy density of the cosmic string. The motion along the string is essentially free motion which allows to distinguish the model from the halo model. In fact, the article [E31] reports linear motion along the filament.

   Amusingly, the same day that I learned about the spinning filaments, I learned about a new evidence for the absence of the galactic halo from a popular article (`https://cutt.ly/MnMOI7F` telling about the article by Shen *et al* [E25] (`https://cutt.ly/HnMOPNA`).

Compensating angular moment as angular momentum of dark matter at cosmic string

Consider now the problem of how the compensating angular momentum is generated as visible matter starts to rotate.

In the TGD framework the picture is just the opposite.

1. The basic assumption of the Newtonian and GRT based models for the generation of angular momentum is that all astrophysical objects are formed by a condensation of matter along perturbations of the mass density. The flow of mass occurs from long scales to short scales.

2. Cosmic strings are the basic objects present already in primordial cosmology [K99, K63, K31]. Long cosmic strings form tangles along them in a local thickening, which gives rise to flux tubes [L83, L91, L103]. This involves the decay of dark energy and matter at cosmic string to

ordinary matter around them as the string tension is reduced in a phase transition decreasing the coefficient of the volume term present in the action besides Kähler action as predicted by twistor lift of TGD [L65, L85]. This parameter corresponds to length scale dependent cosmological constant Λ.

Λ depends on p-adic length scale $L_p \propto \sqrt{p}$, $p \simeq 2^k$ and satisfies $\Lambda(k) \propto 1/L^2(k)^2$. $\Lambda(k)$ approaches zero in long p-adic length scales characterizing the transversal size of flux tubes. This solves the cosmological constant problem. The thickness $d \sim L(k)$ of the flux tube, which is rather small, determines the string tension. To $L(k)$ there is associated a long p-adic length scale which is of order size of observed cosmology if $d \sim L(k)$ is of order of 10^{-4} meters, which happens to be the size of a large neuron.

3. The phase transitions reducing Λ reduce string tension are analogous to the decay of the inflaton field vacuum energy to ordinary matter. Now inflaton field vacuum energy is replaced with the dark energy and matter associated with the thickening cosmic string. Each phase transition is accompanied by an accelerated expansion. The period known as inflation in stanaard cosmology is the first phase transition of this kind. The recent accelerated expansion would correspond to a particular period of this kind and will eventually slow down.

What could happen in the decay of the energy of a flux tube tangle of a cosmic string to visible matter?

1. The visible matter resulting in the decay of the cosmic string must start to rotate around the cosmic string since otherwise it would fall back to the cosmic string like matter into a blackhole. The cosmic string must somehow generate a spin compensating the angular momentum of the visible matter.
2. One should understand angular momentum conservation. Generation of visible matter with angular momentum is possible only if the dark cosmic string is helical or becomes (increasingly) helical in the phase transitions. The angular momentum would be accompanied by the longitudinal motion along the string: this motion has been observed for the filaments [E31] .

   The helical structure could be present from the beginning or be generated during the decay of energy of the cosmic string leading to the local thickenings to flux tube giving rise to galaxies as tangles along a long cosmic string. Also the dark matter and energy at the cosmic string already have angular momentum so that the dark matter that transforms to visible matter would inherit this angular momentum.

   The reported correlation between the masses at the ends of the filament and the spin of the filament [E31] could be understood if the masses at the ends are formed from the dark energy and mass of the filament having angular momentum. The amount of spin and mass at the ends would be the larger, the longer the decay process has lasted.
3. The identification of the galaxies as tangles along long cosmic strings explains the flatness of the galactic velocity spectrum. Galaxy rotates and also now the angular momentum conservation is the problem. The simplest solution is that the cosmic string portions between the tangles generate the angular momentum opposite to that of the visible matter.

   This would happen not only for the portions of cosmic string between galaxies but also those between stars in the galactic tangle. Stars would be flux tube spaghettis and the angular momentum of the star would be compensated by the angular momentum associated with the helical cosmic string continuing outside the star and connecting it to other stars.

The illustration of the popular article brings in mind a DNA double strand and inspires a consideration of an alternative, perhaps unnecessarily complex, model.

1. Suppose one has a double helix of cosmic strings, call them Alice and Bob. Two stellar objects can form a gravitationally stable state only if relative rotation is present. This would be true also for a cosmic double strand to prevent gravitational collapse in 2-D sense.
2. Alice could remain a cosmic string and thus dark so that we would not see it. Bob would thicken to a flux tube and produce ordinary matter as galaxies as ordinary matter realized tangles along it. The matter would inherit the angular momentum the dark matter and energy producing it already has. The string tension of Bob would be reduced in this process. Of course, both Alice and Bob could have tangles along them. The experiments however support the view that spin direction is the same along the filament.

3. If the helical pair of cosmic strings is actually a closed loop in which the second strand is a piece of the same string, the motion of matter along strands is automatically in opposite directions and spins are opposite. The rotational motion as a stabilizer of a gravitationally bound state is transformed to a helical motion. The problem is however why only the other strand decays to ordinary matter (in the case of ordinary DNA there is an analogous problem due to the passivity of the second strand).

Is quantum gravitation cosmic scales involved?

There is an interesting connection to atomic physics suggesting that quantum effects are associated with gravitationally bound dark matter even in astrophysical scales.

1. The basic problem was that the electron should radiate its energy and fall into the atomic nucleus. The Bohr model of the atom solved the problem and non-radiating stationary states prevented the infrared catastrophe. Also in the gravitational case something similar is expected to happen for gravitational interaction.
2. The Bohr model of solar system [K96, K10], originally introduced by Nottale [E9], relies on the notion of gravitational Planck constant $hbar_{gr} = GMm/\beta_0$ predicts angular momentum quantization [L82, L141].
3. Angular momentum quantization as multiples of $\hbar_{gr}$ could occur also for the matter rotating around the cosmic string. In the case of the filament, the mass M could be replaced with the mass of the cosmic string (or possibly several of parallel cosmic strings) and m could correspond to the mass of a galaxy rotating around it. The velocity parameter $\beta_0 = v_0/c$ has a spectrum of values [L141] proposed to come as inverse integers.

10.6 A solution of two galactic anomalies in the TGD framework

Two anomalies related to the physics of galaxies are discussed. The first strange finding is that the initial mass function of galaxies depends on distance from the observer [E29]. The newest anomaly of cold dark matter models is that the stars of the satellite galaxies of bigger galaxies tend to rotate around the host galaxy in planar orbits rather than along random orbits as halo models predict.

10.6.1 Can the initial mass function of galaxies really depend on distance from the observer?

In learned about new very interesting findings related to distant galaxies from a popular article "*New discovery about distant galaxies: Stars are heavier than we thought*" (see `https://cutt.ly/UJdEG2G`. The article tells of the work done by astrophysicists in Niels Bohr Institute, Denmark by A. Sneppen et al.

The article "*Implications of a Temperature-dependent Initial Mass Function. I. Photometric Template Fitting*" [E29] provides a technical description of the work (`https://cutt.ly/SJdEZik`). The abstract of the article gives an overall view of the findings.

> *A universal stellar initial mass function (IMF) should not be expected from theoretical models of star formation, but little conclusive observational evidence for a variable IMF has been uncovered. In this paper, a parameterization of the IMF is introduced into photometric template fitting of the COSMOS2015 catalog. The resulting best-fit templates suggest systematic variations in the IMF, with most galaxies exhibiting top-heavier stellar populations than in the Milky Way. At fixed redshift, only a small range of IMFs are found, with the typical IMF becoming progressively top-heavier with increasing redshift. Additionally, subpopulations of ULIRGs, quiescent and star-forming galaxies are compared with predictions of stellar population feedback and show clear qualitative similarities to the evolution of dust temperatures.*

Here is how I understand the basic notions and reported findings appearing in the article.

1. Initial mass function IMF used in the modelling of the galaxies is the key notion. IMF would be the initial distribution of stellar masses as galaxy started to evolve. The ages of galaxies between 10-13.6 billion years so that they formed very early. It would be very natural to assume that IMF is universal and same for all galaxies, and this has been indeed done. The candidate for a universal IMF has been determined from the data related to Milky Way and its satellites. There are however several candidates for the galactic IMF.

2. The finding of the group is that IMF is not universal and tends to concentrate towards higher masses for distant and therefore younger galaxies. The proposed IMF is parametrized by using a temperature like parameter T_{IMF}, interpretable as the temperature when the galaxy was formed.

   Here I however encounter a problem in my attempts to understand. I find it difficult to comprehend why T_{IMF}, a parameter that should characterize a galaxy, should depend on the distance of this galaxy from us. This looks nonsensical. Perhaps IMF is not what "initial mass function" suggests. What does one mean with "initial"? Or maybe some very interesting new physics related to the notion of time and aging of the stars is lurking there!

3. High mass stars have a short lifetime and end up to Supernovae unless the star formation creates new ones. Because stellar mass is dominated by low-mass stars, the inferred stellar masses and star formation rates (SFRs) are highly sensitive to the ratio of high-mass to low-mass stars in the IMF. The inferred extinction, metallicity, and other properties depend on the assumed IMF.

   In the standard model, star formation is sensitive to the pressure-gravitation balance. The IMF should be sensitive to all variables that can affect it. Article mentions central gravitational potential, existing stellar mass, star formation history, supernova rate, cosmic-ray density and galactic magnetic fields, metallicity, dust density and composition, AGN activity, and the environment and merger history.

   All of these are known to vary both between different galaxies at fixed redshift and across different redshifts. According to the authors, it should be expected that the IMF is not universal but rather differs between galaxies and between different epochs for the same galaxy. In particular, the IMF should depend upon the gas temperature of star-forming clouds, with higher-temperature regions producing higher average stellar masses. Because observations of dust even at moderate redshifts find an increase in temperature toward higher redshifts.

4. Authors notice that already in the case of the Milky Way there are several candidates for IMB and that typical stellar mass and star formation rate (SFR) are highly sensitive to IMF. There are also significant degeneracies between the IMF and extinction, metallicity, star formation history, and the age of the stellar population, which makes it very difficult to determine the entire shape of IMF.

5. The group performs a fit to a temperature dependent family of IMFs having initial temperature T_{IMF} as a parameter. What is nice is that for a given redshift, this is found to give only a few candidates for the IMF. The very distant galaxies would be top-heavier (stellar mass would be concentrated towards higher masses) and the fraction of heavier stars would be higher.

The proposal of the authors can be criticized. There is no doubt that the dependence of IMF on the galaxy is a fact but its dependence on the distance of the galaxy from us is in a glaring conflict with the standard view about time evolution, in particular with the basic assumption of the standard ontology stating that our geometric past is fixed.

Initial mass function (IMF) would be the initial distribution of stellar masses as the galaxy started to evolve about 10-13.6 billion years ago. It would be very natural to assume that the IMF is universal and the same for all galaxies, and this has indeed been done. The candidate for a universal IMF has been determined from the data related to the Milky Way and its satellites. There are several candidates for the galactic IMF. It has been however found that the IMF depends on the distance of the galaxy from Earth and that the IMFs tend to concentrate on larger stellar masses. The dependence of MF on this distance is in conflict with the standard view about time assuming that the geometric past is fixed.

Zero energy ontology (ZEO) [L105, L142, L158] [K125] defines the ontology behind TGD based quantum measurement theory and solves the basic paradox of quantum measurement theory.

Second key element is the predicted hierarchy of effective Planck constants [L63] labeling phase of ordinary matter behaving like dark matter.

ZEO suggests a solution to the paradox created by the findings. TGD Universe is quantum coherent also in astrophysical scales and "big" state function reductions (BSFRs) reversing the arrow of time opposite to that for the environment occur for stars making them blackholes. This is the case also in GRT for Kerr-Newman rotating blackholes. Also quasars as white holes transform in BSFR to galactic blackholes with an arrow of time opposite to that for a distant environment. ZEO implies that the geometric past and thus the IMF of the galaxy changes in the sequence of BSFRs. A simple argument based on the fact that massive stars are shorter-lived shows that the IMF for large distances from Earth indeed is concentrated on larger stellar masses.

10.6.2 The satellite plane anomaly of the cold dark matter model

The anomalies of the halo models of galactic matter have been steadily accumulating during years. For instance, it has been found that satellite galaxies of larger galaxies tend to move in planes [E35] whereas the ΛCDM predicts that the orbits are more or less random. Quite generally, ΛCDM fails on short scales.

The TGD based solution of the satellite galaxy problem relies on the TGD view about galactic dark matter: dark energy and dark matter reside at long cosmic strings, which can form tangles at which the flux tubes thicken and liberate energy forming the ordinary galactic matter. The orbits of the stars around the cosmic string are helical orbits in a plane orthogonal to the string and, as a special case, planar orbits. The velocity curve is flat without further assumptions. The preferred planes could correspond to planar minimal surfaces with 3-D E^3 projection.

10.6.3 TGD based explanation for the dependence of IMF on distance

What could be the TGD based interpretation of the strange findings? Could the cosmic string model for the formation of galaxies and stars [L83, L91, L149] predict the time evolution of the galactic mass distribution by assuming a universal IMF? The paradoxical finding challenges the standard view about time: could zero energy ontology (ZEO) [L105, L142, L158] implying radical revision of this notion, be involved in an essential manner?

Cosmic string model for the formation of astrophysical objects

Consider first the cosmic string model for the formation of galaxies, stars, planets and and also smaller objects [?]

1. Cosmic strings would be the fundamental objects. Their string tension is determined by CP_2 length scale determining their energy density identifiable as dark energy and Kähler magnetic energy. Also ordinary and dark particles in the TGD sense can contribute to the density of energy. Galaxies are assumed to be tangles of a long cosmic string at which the cosmic string has thickened to a monopole flux tube with reduced string tension. The flat velocity spectrum of stars rotating around the cosmic string is flat and the value of the velocity is dictated by the string tension. Therefore galactic dark matter as a halo is replaced with the energy density of the long cosmic string containing galaxies as its tangles: this explains the linear structure formed by galaxies.
2. The energy of the cosmic strings would have been liberated as ordinary matter: this is completely analogous to the formation of ordinary matter in the decay of the inflaton field in inflation models. The seeds of stars can be identified as sub-tangles of galactic flux tubes analogous to spaghettis. This hierarchy of tangles inside tangeles inside... tangles continues to short length scales, even biomolecules, atomic nuclei, and hadrons would be this kind of tangles. The already existing ordinary matter could condense around these seeds.

   The conservative guess is that this analog of inflation was significant only during the very early stages of star formation when no stars existed yet and only the transformation of dark energy to ordinary matter could give rise to stars.

   The flux tube tangle would thicken and generate stellar objects as subtangles. The farther the star is, the younger the galaxy is. Massive stars as supernovas die soon and the mass function shifts to lighter stellar masses.

3. New massive stars are not formed after the galactic cosmic string tangle and galactic blackhole-like entity reaches a maximal size: one could say that the galaxy dies. After this star formation could happen as a condensation process around tangles serving as seeds as in the standard model and would give rise to stars, planets, and even smaller objects. The development of the flux tube containing the tangles would determine galactic evolution.

4. Note that a quasar identified as a galactic blackhole-like object would be there from the beginning and feed mass to its environment. In the spirit of ZEO, I have proposed that it is the TGD analog of white hole and a time reversed version of a blackhole-like object. Instead of sucking matter inside it it would spew matter outside, essentially energy of cosmic string, out which gives rise to the galactic matter.

   BSFR means death in a universal sense and in a well-defined sense, a blackhole is a dead object. Could blackhole be a time reversal of a white hole as quasar. BSFR changes the arrow of time and the radiation produced by blackhole would travel to the geometric past: nothing would come out from the perspective of the observer in the future! This what ordinary blackholes indeed look like. Could blackhole-like entities have an arrow of time, which is opposite to that of the environment? As a matter of fact, this would not be new! Also in GRT, Kerr-Newman solutions representing rotating blackholes have an arrow of time opposite to that of a distant environment [B32]. I have discussed Kerr-Newman blackholes in the appendix of [L44].

   Both galactic blackholes and stellar blackholes would be dead and time reversed quasars and "live" in a reversed time direction. Also ordinary blackholes would "live" in the opposite direction of time.

The interpretation of IMF and T_{IMF} in the TGD framework

What could be the interpretation of the IMF in the TGD framework? Does the parameter T_{IMF} appear naturally? Since the formation of galaxies and stars would be a process analogous to inflation, it would seem that the gravitational condensation around seeds defined by the flux tube tangles dominates except in very early times. Hence it would seem that the interpretation in terms of IMF which depends on T_{IMF} must make sense in the TGD framework. This is not possible without a new view about time provided by zero energy ontology (ZEO).

1. Zero energy ontology (ZEO) [L105, L142, L158] suggests a radical interpretation for the dependence of IMF on the distance of the galaxy from us. In ZEO, the stars of the galaxy evolve by state function reductions (SFRs) occurring in stellar and even longer scales. This is due to the hierarchy of effective Planck constants predicted by number theoretical vision of TGD involving the notion of M^8-H duality [L114, L115]) and adelic physics [L63]. ZEO predicts that both "big" and "small" SFRs (BSFRs and SSFRs) are possible.

2. In the BSFR, the arrow of geometric time changes and BSFRS can change even in astrophysical scales. This could explain the observation of stars which are older than the Universe [L91]. A given star would make BSFRs and in this manner evolve forth and back in the geometric time and become physically older but the center of mass time coordinate for the causal diamond (CD) of the star would not shift to the geometric future so that aging as it is usually understood would not take place.

   The size L of the CD is expected to increase in the process and could define as its inverse a parameter analogous to $T_{IMF}=\hbar_{eff}/L$.

3. The stellar BSFRs could explain the nonsensical looking dependence of the IMF on the distance of the galaxy from us. These stars of these very old galaxies would experienced would have made a large number of BSFRs. By universal evolution [L63] they would be at a high evolutionary stage and can be said to be represent old stars, stars older than the Universe. Star would have transformed to a blackhole and back to a white hole serving as a seed for the formation of a new star. The massive stars would have disappeared as supernovas and the mass distribution of these stars defining the IMF would shift towards lighter masses. Also the temperature would decrease for these stars determining IMF, which would imply the paradoxical looking decrease of T_{IMF} with the increasing cosmic distance.

10.6.4 TGD based explanation of the satellite plane anomaly of the cold dark matter model

The satellite galaxies of larger galaxies tend to move in a plane around the host as described in the review article [E35] whereas the ΛCDM predicts that the orbits are more or less random. The article gives illustrations showing the concentration around the planes for the Milky Way, Andromeda, and Centaurian. The plane of satellites is approximately orthogonal to the plane of the host galaxy in all cases.

Quite generally, ΛCDM fails on short scales. The success in long scales is understandable in the TGD framework since the approximation of the mass density of cosmic strings by a continuous mass density is good in long scales.

Why planar orbits are preferred?

TGD predicts [L83, L91, L149] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles inside themselves. The model finds support from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E49]).

The TGD based model predicts the formation of planes in which objects in various scales move. The prediction is fractal: this applies to planets around stars, stars around galaxies, satellite galaxies around larger galaxies,....

This model explains the satellite plane anomaly and also the earlier anomalies if the galaxies are associated with the long "cosmic strings" predicted by TGD [K31]. They create a strong gravitational potential giving rise to a radial force in the plane orthogonal to the cosmic string. The motion along the string is free whereas the planar motion is rotation. The velocity spectrum is flat as required by the flatness of the galactic velocity spectrum. In the simplest model cosmic string is the carrier of galactic dark matter and dark energy. No dark matter halo and no exotic dark matter particles are needed.

Helical orbits are the most general orbits. If a concentration of matter occurs to a plane, it tends to catch objects moving freely in the direction of string to its vertical gravitational field and planar sheets such planetary systems, spiral galaxies, and the planar systems formed by satellite galaxies can form.

The first guess is that the satellite galaxies move in the plane of the host galaxy. The plane is however approximately orthogonal to the plane of the host in the 3 cases illustrated in [E35].

1. I have proposed that the intersections of nearly orthogonal cosmic strings could induce the thickening to flux tubes and transformation of the dark energy of flux tubes to ordinary matter starting to rotate in the planes defined by the intersecting cosmic string.
2. These intersections are unavoidable for strings like objects in 4-D space-time and would occur at discrete points. In the collision of cosmic strings, these points would define the nucleus of the host galaxy, say the Milky Way. The satellite galaxies would be assignable to the plane defined by the second colliding cosmic string, which would take the role of stars in the plane of the host galaxy.

   The colling cosmic strings would be in a very asymmetric position. Why this asymmetry? Could the satellites correspond to circular pieces of cosmic string generated in the collision by reconnections (note the analogy with reconnections of magnetic flux tubes of solar wind occurring during auroras) and generating the matter of the satellite.

   Why only the second cosmic string would have satellites around it? For two separate cosmic strings it is difficult to understand why reconnection would form loops. This process is natural for the two antiparallel strands of a closed U-shaped loop. Cosmic strings indeed form loops.

This model involves two strings. One can also consider a single cosmic string.

1. Cosmic strings are closed in a large enough scale, and the model for quantum biology encourages to consider U-shaped cosmic strings for which the parallel string portions carry opposite

magnetic fluxes and can naturally reconnect. The flux tube could self-reconnect and generate loops, possibly assignable to the satellite galaxies. The reconnection process would be fundamental in TGD inspired quantum biology (see for instance [L165]).

2. In the reconnection of the strands carrying opposite magnetic flux would form a section S orthogonal to the long part L of the U-shaped string. Could one assign the host galaxy with L and the satellite galaxies to S? L and S would define nearly orthogonal planes and the satellite galaxies could form around loops created from L by a repeated reconnection and they would rotate around the host in the plane defined by S.

Evidence for the failure of the dark halo model has been steadily accumulating during years. The popular article "New Discovery Indicates an Alternative Gravity Theory" published in SciTechDaily (`https://cutt.ly/dBVUBUn`) tells of the most recent discovery challenging the halo model. The dwarf galaxies of one of Earth's closest galaxy clusters do not behave as the halo model predicts.

Elena Asencio, a Ph.D. student at the University of Bonn was the lead author of the article *"The distribution and morphologies of Fornax Cluster dwarf galaxies suggest they lack dark matter* published in Monthly Notices of the Royal Astronomical Society [E13] (`https://cutt.ly/wNPRLI5`).

The following gives the abstract of the article in shortened form.

Due to their low surface brightness, dwarf galaxies are particularly susceptible to tidal forces. The expected degree of disturbance depends on the assumed gravity law and whether they have a dominant dark halo. This makes dwarf galaxies useful for testing different gravity models.

1. Tidal susceptibility η (half-mass radius divided by theoretical tidal radius) is the basic notion. Below a certain critical value η_{destr}, tidal forces destroy the dwarf galaxy.

2. The properties of dwarf galaxies in the Fornax Cluster were compared with those predicted by the Lambda cold dark matter (ΛCDM) standard model of cosmology and Milgromian dynamics (MOND). A test particle simulation of the Fornax system was constructed. The Markov Chain Monte Carlo (MCMC) method was used to fit this to the FDS distribution of η, the fraction of dwarfs that visually appear disturbed as a function of η, and the distribution of projected separation from the cluster centre.

3. It was possible to constrain the η value at which dwarfs should get destroyed by tides. Accounting for an r'-band surface brightness limit of 27.8 magnitudes per square arcsec, the required stability threshold is $\eta_{destr} = 0.25 + 0.07 - 0.03$ in ΛCDM. This value is in tension with previous N-body dwarf galaxy simulations, which indicate that $\eta_{destr} \sim 1$.

4. The MOND N-body simulations indicated $\eta_{destr} = 1.70 \pm 0.30$, which agreed well with the MCMC analysis of the FDS. The conclusion was that the observed deformations of dwarf galaxies in the Fornax Cluster and the lack of low surface brightness dwarfs towards its centre are incompatible with ΛCDM expectations but well consistent with MOND. In accordance with findings, the observed half mass radii tend to be larger in MOND than in ΛCDM dynamics.

The dwarfs are more sensitive to the effects of the tidal forces in the MOND dynamics than in ΛCDM dynamics because the dark matter halo surrounding the dwarf galaxy and acting like a mattress, would shield it from the tidal forces. The observed tidal forces are too large to be consistent with the presence of the dark matter halo.

In the TGD framework [L83, L91, L149], the dark matter halo is replaced with a long cosmic string whose energy density giving rise to dark energy explains also the flat velocity spectrum of galaxies. There is no shielding.

Is there something that could define galactic planes?

One can wonder whether there is something, which serves as a seed for the concentration of stars around a selected plane, perhaps associated with the boundary of a cell of the honeycomb structure. The collision of two cosmic strings would naturally define two planes of this kind. In the case of a single U-shaped closed string, which looks a more promising option, there is no obvious identification of the plane orthogonal to this object.

1. In the TGD Universe, space-time is a 4-surface in $H = M^4 \times CP_2$ and also membrane like entities are predicted as 4-D minimal surfaces of H having lower-D singularities analogous to the frames of a soap film minimal surface property (and simultaneous extermality with respect to Kähler action) fail but the field equations for the entire action involving volume term and Kähler action are satisfied at the singularities.

2. One can also consider 3-D singularities, which form a tessellation of H^3 at a given moment of cosmic time a and assign it with the honeycomb of large voids. The frame would be a tessellation. The quantization of cosmic redshifts in a given direction, discussed from the TGD viewpoint in [K99], could be seen as evidence for cosmic tessellations having astrophysical objects at their nodes.

   The boundaries of the large cosmic voids form a honeycomb structure and could correspond to a tessellation of H^3. The long U-shaped cosmic strings would be associated with the boundaries of the cells of the honeycomb and perhaps even form a 2-D lattice like structure.

   TGD suggests [L83, L91, L149] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles inside themselves. The model finds support from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E49]).

3. The objects $M^1 \times X^2 \times S^1$, where M^1 is time axis, X^2 is a piece of plane of E^2, and S^1 is a geodesic sphere of CP_2, define very simple minimal surfaces carrying no induced Kähler field. The objects X^2
   $timesS^1$ could accompany the boundaries of the honeycomb cells. Universe could be populated by these membrane-like objects. Cell membrane is one important example.

4. Planar or approximately planar objects orthogonal to the cosmic string could tend to gather the matter flowing along helical orbits along the cosmic string. These planes would accompany planetary, galactic, etc... planes and the honeycomb structure could be also seen as a fractal analog of a multicellular structure.

5. Warped planes represent slightly more complex minimal surfaces with 3-D M^4 projection (a thin metal foil or sheet of paper gets warped) for which the plane is deformed but still flat minimal surface. I am not sure whether the "warping" [E5] (`https://cutt.ly/dHoeZKw`) of the outer regions of galactic planes, which has received attention recently (`https://cutt.ly/pHorgcD` and) but has been detected already 1956, is really really warping that is vertical deformation, which depends only single coordinate varying along a straight line (a 2-D plane wave of membrane).

10.7 Can the initial stellar mass distribution of galaxy really depend on its distance from Earth?

In learned about new very interesting findings related to distant galaxies from a popular article "*New discovery about distant galaxies: Stars are heavier than we thought*" (see `https://cutt.ly/UJdEG2G`. The article tells of the work done by astrophysicists in Niels Bohr Institute, Denmark by A. Sneppen et al.

The article "*Implications of a Temperature-dependent Initial Mass Function. I. Photometric Template Fitting*" [E29] provides a technical description of the work (`https://cutt.ly/SJdEZik`). The abstract of the article gives an overall view of the findings.

> *A universal stellar initial mass function (IMF) should not be expected from theoretical models of star formation, but little conclusive observational evidence for a variable IMF has been uncovered. In this paper, a parameterization of the IMF is introduced into photometric template fitting of the COSMOS2015 catalog. The resulting best-fit templates suggest systematic variations in the IMF, with most galaxies exhibiting top-heavier stellar populations than in the Milky Way. At fixed redshift, only a small range of IMFs are found, with the typical IMF becoming progressively top-heavier with increasing redshift.*

Additionally, subpopulations of ULIRGs, quiescent and star-forming galaxies are compared with predictions of stellar population feedback and show clear qualitative similarities to the evolution of dust temperatures.

Here is how I understand the basic notions and reported findings appearing in the article.

1. Initial mass function IMF used in the modelling of the galaxies is the key notion. IMF would be the initial distribution of stellar masses as galaxy started to evolve. The ages of galaxies between 10-13.6 billion years so that they formed very early. It would be very natural to assume that IMF is universal and same for all galaxies, and this has been indeed done. The candidate for a universal IMF has been determined from the data related to Milky Way and its satellites. There are however several candidates for the galactic IMF.

2. The finding of the group is that IMF is not universal and tends to concentrate towards higher masses for distant and therefore younger galaxies. The proposed IMF is parametrized by using a temperature like parameter T_{IMF}, interpretable as the temperature when the galaxy was formed.

   Here I however encounter a problem in my attempts to understand. I find it difficult to comprehend why T_{IMF}, a parameter that should characterize a galaxy, should depend on the distance of this galaxy from us. This looks nonsensical. Perhaps IMF is not what "initial mass function" suggests. What does one mean with "initial"? Or maybe some very interesting new physics related to the notion of time and aging of the stars is lurking there!

3. High mass stars have a short lifetime and end up to Supernovae unless the star formation creates new ones. Because stellar mass is dominated by low-mass stars, the inferred stellar masses and star formation rates (SFRs) are highly sensitive to the ratio of high-mass to low-mass stars in the IMF. The inferred extinction, metallicity, and other properties depend on the assumed IMF.

   In the standard model, star formation is sensitive to the pressure-gravitation balance. The IMF should be sensitive to all variables that can affect it. Article mentions central gravitational potential, existing stellar mass, star formation history, supernova rate, cosmic-ray density and galactic magnetic fields, metallicity, dust density and composition, AGN activity, and the environment and merger history.

   All of these are known to vary both between different galaxies at fixed redshift and across different redshifts. According to the authors, it should be expected that the IMF is not universal but rather differs between galaxies and between different epochs for the same galaxy. In particular, the IMF should depend upon the gas temperature of star-forming clouds, with higher-temperature regions producing higher average stellar masses. Because observations of dust even at moderate redshifts find an increase in temperature toward higher redshifts.

4. Authors notice that already in the case of the Milky Way there are several candidates for IMB and that typical stellar mass and star formation rate (SFR) are highly sensitive to IMF. There are also significant degeneracies between the IMF and extinction, metallicity, star formation history, and the age of the stellar population, which makes it very difficult to determine the entire shape of IMF.

5. The group performs a fit to a temperature dependent family of IMFs having initial temperature T_{IMF} as a parameter. What is nice is that for a given redshift, this is found to give only a few candidates for the IMF. The very distant galaxies would be top-heavier (stellar mass would be concentrated towards higher masses) and the fraction of heavier stars would be higher.

The proposal of the authors can be criticized. There is no doubt that the dependence of IMF on the galaxy is a fact but its dependence on the distance of the galaxy from us is in a glaring conflict with the standard view about time evolution, in particular with the basic assumption of the standard ontology stating that our geometric past is fixed.

Initial mass function (IMF) would be the initial distribution of stellar masses as the galaxy started to evolve about 10-13.6 billion years ago. It would be very natural to assume that the IMF is universal and the same for all galaxies, and this has indeed been done. The candidate for a universal IMF has been determined from the data related to the Milky Way and its satellites. There are several candidates for the galactic IMF. It has been however found that the IMF depends on the distance of the galaxy from Earth and that the IMFs tend to concentrate on larger stellar masses. The dependence of MF on this distance is in conflict with the standard view about time assuming that the geometric past is fixed.

Zero energy ontology (ZEO) [L105, L142, L158] [K125] defines the ontology behind TGD based quantum measurement theory and solves the basic paradox of quantum measurement theory. Second key element is the predicted hierarchy of effective Planck constants [L63] labeling phase of ordinary matter behaving like dark matter.

ZEO suggests a solution to the paradox created by the findings. TGD Universe is quantum coherent also in astrophysical scales and "big" state function reductions (BSFRs) reversing the arrow of time opposite to that for the environment occur for stars making them blackholes. This is the case also in GRT for Kerr-Newman rotating blackholes. Also quasars as white holes transform in BSFR to galactic blackholes with an arrow of time opposite to that for a distant environment. ZEO implies that the geometric past and thus the IMF of the galaxy changes in the sequence of BSFRs. A simple argument based on the fact that massive stars are shorter-lived shows that the IMF for large distances from Earth indeed is concentrated on larger stellar masses.

10.7.1 TGD based explanation for the dependence of IMF on distance

What could be the TGD based interpretation of the strange findings? Could the cosmic string model for the formation of galaxies and stars [L83, L91, L149] predict the time evolution of the galactic mass distribution by assuming a universal IMF? The paradoxical finding challenges the standard view about time: could zero energy ontology (ZEO) [L105, L142, L158] implying radical revision of this notion, be involved in an essential manner?

Cosmic string model for the formation of astrophysical objects

Consider first the cosmic string model for the formation of galaxies, stars, planets and and also smaller objects [?]

1. Cosmic strings would be the fundamental objects. Their string tension is determined by CP_2 length scale determining their energy density identifiable as dark energy and Kähler magnetic energy. Also ordinary and dark particles in the TGD sense can contribute to the density of energy. Galaxies are assumed to be tangles of a long cosmic string at which the cosmic string has thickened to a monopole flux tube with reduced string tension. The flat velocity spectrum of stars rotating around the cosmic string is flat and the value of the velocity is dictated by the string tension. Therefore galactic dark matter as a halo is replaced with the energy density of the long cosmic string containing galaxies as its tangles: this explains the linear structure formed by galaxies.

2. The energy of the cosmic strings would have been liberated as ordinary matter: this is completely analogous to the formation of ordinary matter in the decay of the inflaton field in inflation models. The seeds of stars can be identified as sub-tangles of galactic flux tubes analogous to spaghettis. This hierarchy of tangles inside tangeles inside... tangles continues to short length scales, even biomolecules, atomic nuclei, and hadrons would be this kind of tangles. The already existing ordinary matter could condense around these seeds.

   The conservative guess is that this analog of inflation was significant only during the very early stages of star formation when no stars existed yet and only the transformation of dark energy to ordinary matter could give rise to stars.

   The flux tube tangle would thicken and generate stellar objects as subtangles. The farther the star is, the younger the galaxy is. Massive stars as supernovas die soon and the mass function shifts to lighter stellar masses.

3. New massive stars are not formed after the galactic cosmic string tangle and galactic blackhole-like entity reaches a maximal size: one could say that the galaxy dies. After this star formation could happen as a condensation process around tangles serving as seeds as in the standard model and would give rise to stars, planets, and even smaller objects. The development of the flux tube containing the tangles would determine galactic evolution.

4. Note that a quasar identified as a galactic blackhole-like object would be there from the beginning and feed mass to its environment. In the spirit of ZEO, I have proposed that it is

the TGD analog of white hole and a time reversed version of a blackhole-like object. Instead of sucking matter inside it it would spew matter outside, essentially energy of cosmic string, out which gives rise to the galactic matter.

BSFR means death in a universal sense and in a well-defined sense, a blackhole is a dead object. Could blackhole be a time reversal of a white hole as quasar. BSFR changes the arrow of time and the radiation produced by blackhole would travel to the geometric past: nothing would come out from the perspective of the observer in the future! This what ordinary blackholes indeed look like. Could blackhole-like entities have an arrow of time, which is opposite to that of the environment? As a matter of fact, this would not be new! Also in GRT, Kerr-Newman solutions representing rotating blackholes have an arrow of time opposite to that of a distant environment [B32]. I have discussed Kerr-Newman blackholes in the appendix of [L44].

Both galactic blackholes and stellar blackholes would be dead and time reversed quasars and "live" in a reversed time direction. Also ordinary blackholes would live in the opposite direction of time.

The interpretation of IMF and T_{IMF} in the TGD framework

What could be the interpretation of the IMF in the TGD framework? Does the parameter T_{IMF} appear naturally? Since the formation of galaxies and stars would be a process analogous to inflation, it would seem that the gravitational condensation around seeds defined by the flux tube tangles dominates except in very early times. Hence it would seem that the interpretation in terms of IMF which depends on T_{IMF} must make sense in the TGD framework. This is not possible without a new view about time provided by zero energy ontology (ZEO).

1. Zero energy ontology (ZEO) [L105, L142, L158] suggests a radical interpretation for the dependence of IMF on the distance of the galaxy from us. In ZEO, the stars of the galaxy evolve by state function reductions (SFRs) occurring in stellar and even longer scales. This is due to the hierarchy of effective Planck constants predicted by number theoretical vision of TGD involving the notion of M^8-H duality [L114, L115]) and adelic physics [L63]. ZEO predicts that both "big" and "small" SFRs (BSFRs and SSFRs) are possible.
2. In the BSFR, the arrow of geometric time changes and BSFRS can change even in astrophysical scales. This could explain the observation of stars which are older than the Universe [L91]. A given star would make BSFRs and in this manner evolve forth and back in the geometric time and become physically older but the center of mass time coordinate for the causal diamond (CD) of the star would not shift to the geometric future so that aging as it is usually understood would not take place.

   The size L of the CD is expected to increase in the process and could define as its inverse a parameter analogous to $T_{IMF} = \hbar_{eff}/L$.
3. The stellar BSFRs could explain the nonsensical looking dependence of the IMF on the distance of the galaxy from us. These stars of these very old galaxies would experienced would have made a large number of BSFRs. By universal evolution [L63] they would be at a high evolutionary stage and can be said to be repret old stars, stars older than the Universe. Star would have transformed to a blackhole and back to a white hole serving as a seed for the formation of a new star. The massive stars would have disappeared as supernovas and the mass distribution of these stars defining the IMF would shift towards lighter masses. Also the temperature would decrease for these stars determining IMF, which would imply the paradoxical looking decrease of T_{IMF} with the increasing cosmic distance.

The newest anomaly of the cold dark matter model (ΛCDM) is discussed popular article "Space Has Invisible Walls Created by Mysterious 'Symmetrons,' Scientists Propose" (`https://cutt.ly/mHorkqG`). It has been found that satellite galaxies of larger galaxies tend to move in planes whereas the ΛCDM predicts that the orbits are more or less random. Quite generally, ΛCDM fails in short scales. The proposed model is involves traditional kind of new physics: a new exotic particle and symmetry breaking producing galactic plane domain walls.

TGD predicts [L83, L91, L149] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles insidde themselves. The model finds supports from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E49]).

The TGD based model predicts the formation of planes in which objects in various scales move. The prediction is fractal: this applies to planets around stars, stars around galaxies, satellite galaxies arond larger galaxies,....

This model explains the newest anomaly and also the earlier anomalies if the galaxies are associated with the long "cosmic strings" predicted by TGD [K31]. They create a strong gravitational potential giving rise to a radial force in the plane orthogonal to the cosmic string. The motion along the string is free whereas the planar motion is rotation. The velocity spectrum is flat as required by the flatness of the galactic velocity spectrum. In the simplest model cosmic string is the carrier of galactic dark matter and dark energy. No dark matter halo and no exotic dark matter particles are needed.

Helical orbits are the most general orbits. If a concentration of matter occurs to a plane, it tends to catch objects moving freely in the direction of string to its vertical gravitational field and planar sheets such planetary systems, spiral galaxies, and the planar systems formed by satellite galaxies can form.

One can of course wonder whether there is something which serves as a seed for the concentration of stars around particular plane. In TGD, space-time is a 4-surface in $H = M^4 \times CP_2$ and also membrane like entities are predicted as 4-D minimal surfaces in H. For instance, objects $M^1 \times X^2 \times S^1$ are predicted, where M^1 is time axis, X^2 is a piece of plane of E^2, and S^1 is a geodesic sphere of $CP_2. Universecouldbepopulatedbythesemembrane-likeobjects.Cellmembraneisoneimportantexample.Theseplanarorap$

Warped planes represent slightly more complex solutions (a thin metal foil or sheet of paper gets warped) for which the plane is deformed but still flat minimal surface. I am not sure whether the "warping" (`https://cutt.ly/dHoeZKw`) of the outer regions of galactic planes, which has received attention recently (`https://cutt.ly/pHorgcD` and) but has been detected already 1956, is really really warping that is vertical deformation, which depends only single coordinate varying along a straight line (a 2-D plane wave of membrane).

10.8 Local super-cluster Laniakea as flux tube structure

In the following I try to concretize the ideas about monopole flux tube network as a basic structure behind formation of astrophysical structures by discussing the supercluster Laniakea in this framework (the idea came from the question of Wes Johnson about how I understand Laniakea in TGD framework). There are two excellent videos about Laniakea (see `https://www.youtube.com/watch?v=rENyyRwxpHo` and `http://tinyurl.com/ufvw6v5`).

Consider first the structure of Laniakea.

1. Wikipedia contains a nice article about Laniakea (see `http://tinyurl.com/zfphldm`). Laniakea is a local supercluster containing also Milky Way so that it is own home supercluster. Local supercluster is defined as a basin of a local flow of galaxies directed to the center of the super-cluster.

   There is a video giving view about the structure and dynamics of Laniakea is warmly recommended (see `https://vimeo.com/104910552`). Laniakea contains about 10^5 galaxies, decomposes to four smaller super-cluster like entities and contains about 500 galaxy clusters.

2. The general picture supports the idea about fractal spaghetti formed by monopole flux tube or several of them. The presence of four smaller super-cluster type entities suggests quadrupole field as a rough starting point as one tries to gues the analog as field line topology. The first very naïve guess is that the tangle defining the supercluster represents roughly the topology of quadrupole magnetic field in the first approximation: there would be pair of dipoles. One cannot of course fix the number of cosmic strings.

   The simplest starting point hypothesis is that there is just single closed cosmic string forming a structure analogous to that of quadrupole magnetic field. Reconnection can split smaller closed cosmic string from a closed cosmic string and this could correspond to a decay of galaxy to smaller galaxies. Therefore single cosmic string is certainly an approximation.

Remark: Recall that cosmic strings are closed and one can have for instance helical structures: say two closed cosmic strings analogous to DNA double strands or single closed single having strands as pieces of it.

Remark: Also non-monopole flux tubes are involved and the proposal is that gravitational interactions are mediated along these flux tubes emanating radially from the source. The flux for them is vanishing and there is no current needed to create the field. These flux tubes are not topologically stable against splitting.

3. Cosmic strings are assumed to form a fractal hierarchy and that in TGD inspired biology cosmic strings thickened to monopole flux tubes are behind various linear biomolecules organized around them as ordinary matter. This leads to ask whether DNA double strand and the organization of DNA double strands to chromosomes might be more general phenomenon. Chromosomes consist of 4 strands, which allows to ask whether something similar happens even at the level of superclusters and that the topology of quadrupole field is involved.

   Interestingly, also Milky Way consists of four arms assignable spiral density waves for ordinary matter so that it is not clear whether the arms can be assigned with four poles of quadrupole. Fermi spheres are a peculiarity Milky Way possibly possibly related to a quadrupole structure of monopole flux tube topology suggesting two cosmic strings meeting at the nucleus of galaxy. There is evidence that Milky Way could be seen as being formed in a kind of cosmic collision. I have asked whether this is due to a cosmic highway accident at crossroad at which two cosmic string are pass by very near to each other is in question. This could make sense if tangle as a quadrupole corresponds to two dipoles.

Consider next the dynamics of Laniakea. Reader can build his/her own views with the help of the beautiful videos (see `https://www.youtube.com/watch?v=rENyyRwxpHo` and `http://tinyurl.com/ufvw6v5`) demonstrating the velocity flow of visible parts of galaxies, which would be associated with tangles moving along cosmic strings.

1. Wikipedia mentions that Laniakea is not gravitationally bound. Also this suggests that the galaxies associated with it are tangles of one or more cosmic strings. The dynamics would correspond to s motion in gravitational field with constraint forcing the galaxy to move along the cosmic string.

2. The motion of galactic tangles and that of ordinary matter formed from it along cosmic string is free in absence of external forces: this distinguishes TGD from halo model having a spherical symmetry. This would mean rather lose binding but strong correlation produced by the cosmic string. Most galaxy motions are directed inward towards Great Attractor: this would have explanation in terms of gravitational attraction. A good guess is that motion are along flux tube/cosmic string.

Part II

P-ADIC LENGTH SCALE HYPOTHESIS AND DARK MATTER HIERARCHY: CONDENSED MATTER PHYSICS

Chapter 11

Dark Nuclear Physics and Condensed Matter

11.1 Introduction

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether electro-weak charges of elementary particles are screened in electro-weak length scale or not. The TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale.

The large value of $\hbar$ in dark matter phase implies that Compton lengths and -times are scaled up. In particular, the sizes of nucleons and nuclei become of order atom size so that dark nuclear physics would have direct relevance for condensed matter physics. It becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore.

In its original form this chapter was an attempt to concretize and develop ideas related to dark matter by using some experimental inputs with emphasis on the predicted interaction between the new nuclear physics and condensed matter. As the vision about dark matter became more coherent and the nuclear string model developed in its recent form, it became necessary to update the chapter and throw away the obsolete material. I have also divided the material to two chapters such that second chapter focuses to dark weak and color forces and their implications. I dare hope that the recent representation is more focused than the earlier one.

11.1.1 Dark Rules

I have done a considerable amount of trials and errors in order to identify the basic rules allowing to understand what it means to be dark matter is and what happens in the phase transition to dark matter. It is good to try to summarize the basic rules of p-adic and dark physics allowing to avoid obvious contradictions.

Could basic quantum TGD imply the hierarchy of Planck constants?

The implications of the hierarchy of Planck constants depend on whether one assumes it as an independent additional postulate or as a consequence of basic quantum TGD. The first option originally motivated by physical anomalies would allow both singular coverings and factor spaces. The latter option, which emerged five years after the basic idea, would allow only singular coverings. They would provide only a convenient tool to describe the fact that the correspondence between canonical momentum densities and time derivatives of the embedding space coordinates at the ends of space-time sheets is not one-to-one. As a matter fact, this observation forced the idea about quantum physics as classical physics in the "world of classical worlds" for two decades ago. The quantization of Planck constant as integer multiples of its standard value would be an effective phenomenon for this option holding true at the sheets of the covering. These options lead to different predictions and one can in principle test whether either of them is correct.

The notion of field body

The notion of "field body" implied by topological field quantization is essential piece of classical TGD. It seems possible to assign to physical systems field identities- that is separate magnetic and electric field bodies identifiable as flux quanta. This is not possible in Maxwell's electrodynamics. The first naive guess was that one can speak of separate em, Z^0, W, gluonic, and gravitonic field bodies, each characterized by its own p-adic prime. The tight constraints coming from the fact that the induced gauge fields are expressible in terms of CP_2 coordinates and their derivatives implies however strong correlations between classical gauge fields. For instance, the vanishing of classical Kähler field for vacuum extremals implies that em and Z^0 fields are proportional to each other. The non-vanishing of induced Kähler field in turn implies non-vanishing classical color fields. This gives rise at least to two basic types of field bodies predicting a lot of new physics even in macroscopic length scales. For instance, electric and magnetic flux tubes must have at their ends quarks and antiquarks serving as sources of classical color fields unless one believes that vacuum charge densities serve as sources of these fields. In the similar way neutrinos and antineutrinos are needed to create classical Z^0 fields associated with almost vacuum extremal flux tubes. These fields could be interpreted also as vacuum polarization effects and one could distinguish them from fields created by genuine sources. For instance, the unavoidable classical color fields associated with the flux tubes of electromagnetic field body which is not vacuum extremal would represent vacuum polarization in macroscopic scale.

What is interesting that the conceptual separation of interactions to various types would have a direct correlate at the level of space-time topology. From a different perspective inspired by the general vision that many-sheeted space-time provides symbolic representations of quantum physics, the very fact that we make this conceptual separation of fundamental interactions could reflect the topological separation at space-time level.

The p-adic mass calculations for quarks encourage to think that the p-adic length scale characterizing the mass of particle is associated with its electromagnetic body and in the case of neutrinos with its Z^0 body. Z^0 body can contribute also to the mass of charged particles but the contribution would be small. It is also possible that these field bodies are purely magnetic for color and weak interactions. Color flux tubes would have exotic fermion and anti-fermion at their ends and define colored variants of pions. This would apply not only in the case of nuclear strings but also to molecules and larger structures so that scaled variants of elementary particles and standard model would appear in all length scales as indeed implied by the fact that classical electro-weak and color fields are unavoidable in TGD framework.

One can also go further and distinguish between magnetic field body of free particle for which flux quanta start and return to the particle and "relative field" bodies associated with pairs of particles. Very complex structures emerge and should be essential for the understanding the space-time correlates of various interactions. In a well-defined sense they would define space-time correlate for the conceptual analysis of the interactions into separate parts. In order to minimize confusion it should be emphasized that the notion of field body used in this chapter relates to those space-time correlates of interactions, which are more or less *static* and related to the formation of *bound states.*

What dark variant of elementary particle means

It is not at all clear what the notion of dark variant of elementary particle or of larger structures could mean.

1. *Are only field bodies dark?*

One variety of dark particle is obtained by making some of the field bodies dark by increasing the value of Planck constant. This hypothesis could be replaced with the stronger assumption that elementary particles are maximally quantum critical systems so that they are same irrespective of the value of the Planck constant. Elementary particles would be represented by partonic 2-surfaces, which belong to the universal orbifold singularities remaining invariant by all groups

$G_a \times G_b$ for a given choice of quantization axes. If $G_a \times G_b$ is assumed to leave invariant the choice of the quantization axes, it must be of the form $Z_{n_a} \times Z_{n_b} \subset SO(3) \times SU(3)$. Partonic 2-surface would belong to $M^2 \times CP_2/U(1) \times U(1)$, where M^2 is spanned by the quantization axis of angular momentum and the time axis defining the rest system.

A different way to say this is that the CP_2 type extremal representing particle would suffer multiple topological condensation on its field bodies so that there would be no separate "particle space-time sheet".

Darkness would be restricted to particle interactions. The value of the Planck constant would be assigned to a particular interaction between systems rather than system itself. This conforms with the original finding that gravitational Planck constant satisfies $\hbar = GM_1M_2/v_0$, $v_0 \simeq 2^{-11}$. Since each interaction can give rise to a hierarchy dark phases, a rich variety of partially dark phases is predicted. The standard assumption that dark matter is visible only via gravitational interactions would mean that gravitational field body would not be dark for this particular dark matter.

Complex combinations of dark field bodies become possible and the dream is that one could understand various phases of matter in terms of these combinations. All phase transitions, including the familiar liquid-gas and solid-liquid phase transitions, could have a unified description in terms of dark phase transition for an appropriate field body. At mathematical level Jones inclusions would provide this description.

The book metaphor for the interactions at space-time level is very useful in this framework. Elementary particles correspond to ordinary value of Planck constant analogous to the ordinary sheets of a book and the field bodies mediating their interactions are the same space-time sheet or at dark sheets of the book.

2. Can also elementary particles be dark?

Also dark elementary particles themselves rather than only the flux quanta could correspond to dark space-time sheet defining multiple coverings of $H/G_a \times G_b$. This would mean giving up the maximal quantum criticality hypothesis in the case of elementary particles. These sheets would be exact copies of each other. If single sheet of the covering contains topologically condensed space-time sheet, also other sheets contain its exact copy.

The question is whether these copies of space-time sheet defining classical identical systems can carry different fermionic quantum numbers or only identical fermionic quantum numbers so that the dark particle would be exotic many-fermion system allowing an apparent violation of statistics (N fermions in the same state).

Even if one allows varying number of fermions in the same state with respect to a basic copy of sheet, one ends up with the notion of N-atom in which nuclei would be ordinary but electrons would reside at the sheets of the covering. The question is whether symbolic representations essential for understanding of living matter could emerge already at molecular level via the formation of N-atoms.

What happens in charge fractionization?

The hierarchy of Planck constants suggests strongly charge fractionization. What happens for binding energies is however not obvious. The first guess is that one just replaces $\hbar$ with its scaled value in the standard formulas. One can however ask whether the resulting expression applies to single sheet of covering or to the sum of binding energies associated with the sheets of covering. In the case of factor space analogous problem is not encountered.

If the coverings follow from basic quantum TGD one can deduce unique rules for what happens. These rules can be assumed also in the more general case. Since the sheets of the singular covering co-incide at the partonic 2-surfaces associated with ends of CD the time evolution and also "evolution" in space-like direction means instability of in the sense that partonic 2-surface decomposes to $r = \hbar/\hbar_0 = n_a n_b$ sheets. This implies fractionization of all total quantum numbers such as energy and momentum. From this one can also deduce what happens to various binding energies. For instance, the total (!) cyclotron energy is indeed multiplied by factor and the total(!) binding energy of dark hydrogen atom is what the naive scaling of $\hbar$ would give. The reason is that the mass of particle is fractionized: $m \rightarrow m/n_a n_b$. Therefore the original guesses would be correct. In particular, the expression of the total gravitational binding energy essential for the original Bohr model of planetary orbits is consistent with the new more precise rules.

Criterion for the transition to dark phase

The naive criterion $\alpha Q_1 Q_2 > 1$ (or its generalization) for the transition to dark matter phase relates always to the interaction between two systems and the interpretation is that when the field strength characterizing the interaction becomes too strong, the interaction is mediated by dark space-time sheets which define $n = n(G_a) \times n(G_b)$-fold covering of $M^4 \times CP_2/G_a \times G_b$. The sharing of flux between different space-time sheets reduces the field strength associated with single sheet below the critical value.

For the option in which singular coverings follow from basic quantum TGD this criterion or its appropriate generalization has very concrete interpretation. At the ends of CD the partonic 2-surface is unstable against decay to n_a sheets when some of the quantum numbers of the partonic 2-surface are too large. A similar decay to n_b sheets would happen also when one moves in space-like direction.

One can ask whether this instability could have something to do with N-vertices of generalized Feynman diagrams in which decay of a partonic 2-surfaces to N-1 surfaces takes place. For instance, could it be that 3-vertex- possibly the only fundamental vertex, correspond to this process and could higher vertices have an interpretation in terms of the hierarchy of Planck constants? This would mean analogy with Jones inclusions for which $n \geq 3$ holds true. The assumption that exact fractionization of quantum numbers takes place is not consistent with the identification in terms of Feynman diagrams. Also the huge values of $n_a n_b$ disfavor this identification unless one restricts it to $n_a n_b = 2$.

There are considerations suggesting that in the vertices of generalized Feynman diagrams a re-distribution of the sheets of the coverings can take place in such a way that the total number of sheets is conserved. The leakage of between different sectors of WCW would in turn mean analogs of self-energy vertices in which n_a and n_b are replaced with their factors or with integers containing them as factors.

Mersenne hypothesis

The generalization of the embedding space means a book like structure for which the pages are products of singular coverings or factor spaces of CD (causal diamond defined as intersection of future and past directed light-cones) and of CP_2 [K43]. This predicts that Planck constants are rationals and that given value of Planck constant corresponds to an infinite number of different pages of the Big Book, which might be seen as a drawback. If only singular covering spaces are allowed the values of Planck constant are products of integers and given value of Planck constant corresponds to a finite number of pages given by the number of decompositions of the integer to two different integers.

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = \hbar/\hbar_0$. For the most general option the values of $\hbar$ are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a, b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

One can however ask whether a more precise characterization of preferred Mersennes could exist and whether there could exists a stronger correlation between hierarchies of p-adic length scales and Planck constants. Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k-1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ are expected to be physically highly interesting and up to $k = 127$ indeed correspond to elementary particles. The number theoretical miracle is that all the four scaled up electron Compton lengths with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm). The question has been whether these define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$. The proposal that this is the case and that these physics are in a well-defined sense induced by the dark scaled up variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$.

What induction means is that dark variant of exotic nuclear physics induces exotic physics with ordinary value of Planck constant in the new scale in a resonant manner: dark gauge bosons transform to their ordinary variants with the same Compton length. This transformation is natural since in length scales below the Compton length the gauge bosons behave as massless and free particles. As a consequence, lighter variants of weak bosons emerge and QCD confinement scale becomes longer.

This proposal will be referred to as Mersenne hypothesis. It leads to strong predictions about EEG [K41] since it predicts a spectrum of preferred Josephson frequencies for a given value of membrane potential and also assigns to a given value of $\hbar$ a fixed size scale having interpretation as the size scale of the body part or magnetic body. Also a vision about evolution of life emerges. Mersenne hypothesis is especially interesting as far as new physics in condensed matter length scales is considered: this includes exotic scaled up variants of the ordinary nuclear physics and their dark variants. Even dark nucleons are possible and this gives justification for the model of dark nucleons predicting the counterparts of DNA, RNA, tRNA, and amino-acids as well as realization of vertebrate genetic code [K118].

These exotic nuclear physics with ordinary value of Planck constant could correspond to ground states that are almost vacuum extremals corresponding to homologically trivial geodesic sphere of CP_2 near criticality to a phase transition changing Planck constant. Ordinary nuclear physics would correspond to homologically non-trivial geodesic sphere and far from vacuum extremal property. For vacuum extremals of this kind classical Z^0 field proportional to electromagnetic field is present and this modifies dramatically the view about cell membrane as Josephson junction. The model for cell membrane as almost vacuum extremal indeed led to a quantitative breakthrough in TGD inspired model of EEG and is therefore something to be taken seriously. The safest option concerning empirical facts is that the copies of electro-weak and color physics with ordinary value of Planck constant are possible only for almost vacuum extremals - that is at criticality against phase transition changing Planck constant.

11.1.2 Some Implications

As already noticed, the detailed implications of the hierarchy of Planck constants depend on whether one brings in the hierarchy of singular coverings and factor spaces of the embedding space as an independent postulate or whether one assumes that singular coverings emerge as an effective description from basic quantum TGD

Dark variants of nuclear physics

One can imagine endless variety of dark variants of ordinary nuclei and every piece of data is well-come in attempts to avoid a complete inflation of speculative ideas. The book metaphor for the extended embedding space is useful in the attempts to imagine various exotic phases of matter. For the minimal option atomic nuclei would be ordinary whereas field bodies could be dark and analogous to n-sheeted Riemann surfaces. One can imagine that the nuclei are at the "standard" page of the book and color bonds at different page with different p-adic length scale or having different Planck constant $\hbar$. This would give two hierarchies of nuclei with increasing size.

Color magnetic body of the structure would become a key element in understanding the nuclear binding energies, giant dipole resonances, and nuclear decays. Also other field bodies are in a key role and there seems to be a field body for every basic interaction (classical gauge fields are induced from spinor connection and only four independent field variables are involved so that this is indeed required).

Nothing prevents from generalizing the nuclear string picture so that color bonds could bind also atoms to molecules and molecules to larger structures analogous to nuclei. Even hydrogen bond might be interpreted in this manner. Molecular physics could be seen as a scaled up variant of nuclear physics in a well-defined sense. The exotic features would relate to the hierarchy of various field bodies, including color bonds, electric and weak bonds. These field bodies would play key role also in biology and replaced molecular randomness with coherence in much longer length scale.

In the attempt to make this vision quantitative the starting point is nuclear string model [L4] and the model of cold fusion based on it forcing also to conclude the scaled variants of electro-weak bosons are involved. The model of cold fusion requires the presence of a variant electro-weak interactions for which weak bosons are effectively massless below the atomic length scale.

$k = 113$ p-adically scaled up variant of ordinary weak physics which is dark and corresponds to $\hbar = r\hbar_0$, $r = 2^{k_d}$, $k_d = 14 = 127 - 113$ is an option consistent with Mersenne hypothesis and gives weak bosons in electron length scale. Another possibility is defined by $k = 113$ and $k_d = 24 = 113 - 89 = 151 - 127$ and corresponds to the p-adic length scale $k = 137$ defining atomic length scale. This would give rise to weak bosons with masses in keV scale and these would be certainly relevant for the physics of condensed matter.

Anomalies of water could be understood if one assumes that color bonds can become dark with suitable values of $r = 2^{k_d}$ and if super-nuclei formed by connecting different nuclei by the color bonds are possible. Tetrahedral and icosahedral water clusters could be seen as magic super-nuclei in this framework. Color bonds could connect either proton nuclei or water molecules.

The model for partially dark condensed matter deriving from exotic nuclear physics and exotic weak interactions could allow to understand the low compressibility of the condensed matter as being due to the repulsive weak force between exotic quarks, explains large parity breaking effects in living matter (chiral selection), and suggests a profound modification of the notion of chemical bond having most important implications for bio-chemistry and understanding of bio-chemical evolution.

Could the notion of dark atom make sense?

One can also imagine several variants of dark atom. Book metaphor suggest one variant of dark atom.

1. Nuclei and electrons could be ordinary but classical electromagnetic interactions are mediated via dark space-time sheet "along different page of the book". The value of Planck constant would be scaled so that one would obtain a hierarchy of scaled variants of hydrogen atom. The findings of [D58] could find an explanation in terms of a reduced Planck constant if singular factor spaces are assumed to be possible. An alternative explanation is based on the notion of quantum-hydrogen atom obtained as q-deformation of the ordinary hydrogen atom.
2. A more exotic variant if atom is obtained by assuming ordinary nuclei but dark, not totally quantum critical, electrons. Dark space-time surface is analogous to n-sheeted Riemann surface and if one assumes that each sheet could carry electron, one ends up with the notion of N-atom. This variant of dark atom is more or less equivalent with that following from the option for which the singular coverings of embedding space are effective manner to describe the many-valuedness of the time derivatives of the embedding space coordinates as functions of canonical momentum densities.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

11.2 A Generalization Of The Notion Of Embedding Space As ARealization Of The Hierarchy Of Planck Constants

11.2.1 Hierarchy Of Planck Constants And The Generalization Of The Notion Of Embedding Space

In the following the recent view about structure of embedding space forced by the quantization of Planck constant is summarized. The question is whether it might be possible in some sense to replace H or its Cartesian factors by their necessarily singular multiple coverings and factor spaces. One can consider two options: either M^4 or the causal diamond CD. The latter one is the more plausible option from the point of view of WCW geometry.

The evolution of physical ideas about hierarchy of Planck constants

The evolution of the physical ideas related to the hierarchy of Planck constants and dark matter as a hierarchy of phases of matter with non-standard value of Planck constants was much faster than the evolution of mathematical ideas and quite a number of applications have been developed during last five years.

1. The starting point was the proposal of Nottale [E9] that the orbits of the 4 inner planets correspond to Bohr orbits with Planck constant $\hbar_{gr} = GMm/v_0$ and outer planets with Planck constant $\hbar_{gr} = 5GMm/v_0$, $v_0/c \simeq 2^{-11}$. The basic proposal [K96] was that ordinary matter condenses around dark matter which is a phase of matter characterized by a non-standard value of Planck constant whose value is gigantic for the space-time sheets mediating gravitational interaction. The interpretation of these space-time sheets could be as magnetic flux quanta or as massless extremals assignable to gravitons.
2. Ordinary particles possibly residing at these space-time sheet have enormous value of Compton length meaning that the density of matter at these space-time sheets must be very slowly varying. The string tension of string like objects implies effective negative pressure characterizing dark energy so that the interpretation in terms of dark energy might make sense [K99]. TGD predicted a one-parameter family of Robertson-Walker cosmologies with critical or overcritical mass density and the "pressure" associated with these cosmologies is negative.
3. The quantization of Planck constant does not make sense unless one modifies the view about standard space-time is. Particles with different Planck constant must belong to different worlds in the sense local interactions of particles with different values of $\hbar$ are not possible. This inspires the idea about the book like structure of the embedding space obtained by gluing almost copies of H together along common "back" and partially labeled by different values of Planck constant.
4. Darkness is a relative notion in this framework and due to the fact that particles at different pages of the book like structure cannot appear in the same vertex of the generalized Feynman diagram. The phase transitions in which partonic 2-surface X^2 during its travel along X_l^3 leaks to another page of book are however possible and change Planck constant. Particle (say photon -) exchanges of this kind allow particles at different pages to interact. The interactions are strongly constrained by charge fractionization and are essentially phase transitions involving many particles. Classical interactions are also possible. It might be that we are actually observing dark matter via classical fields all the time and perhaps have even photographed it [K114].
5. The realization that non-standard values of Planck constant give rise to charge and spin fractionization and anyonization led to the precise identification of the prerequisites of anyonic phase [K81]. If the partonic 2-surface, which can have even astrophysical size, surrounds the tip of CD, the matter at the surface is anyonic and particles are confined at this surface. Dark matter could be confined inside this kind of light-like 3-surfaces around which ordinary matter condenses. If the radii of the basic pieces of these nearly spherical anyonic surfaces - glued to a connected structure by flux tubes mediating gravitational interaction - are given by Bohr rules, the findings of Nottale [E9] can be understood. Dark matter would resemble to a high degree matter in black holes replaced in TGD framework by light-like partonic 2-surfaces with a minimum size of order Schwartschild radius r_S of order scaled up Planck length $l_{Pl} = \sqrt{\hbar_{gr}G} = GM$. Black hole entropy is inversely proportional to $\hbar$ and predicted to be of order unity so that dramatic modification of the picture about black holes is implied.
6. Perhaps the most fascinating applications are in biology. The anomalous behavior ionic currents through cell membrane (low dissipation, quantal character, no change when the membrane is replaced with artificial one) has a natural explanation in terms of dark supra currents. This leads to a vision about how dark matter and phase transitions changing the value of Planck constant could relate to the basic functions of cell, functioning of DNA and amino-acids, and to the mysteries of bio-catalysis. This leads also a model for EEG interpreted as a communication and control tool of magnetic body containing dark matter and using biological body as motor instrument and sensory receptor. One especially amazing outcome is the emergence of genetic code of vertebrates from the model of dark nuclei as nuclear strings [L4, K114], [L4].

The most general option for the generalized embedding space

Simple physical arguments pose constraints on the choice of the most general form of the embedding space.

1. The fundamental group of the space for which one constructs a non-singular covering space or factor space should be non-trivial. This is certainly not possible for M^4, CD, CP_2, or H. One can however construct singular covering spaces. The fixing of the quantization axes implies a selection of the sub-space $H_4 = M^2 \times S^2 \subset M^4 \times CP_2$, where S^2 is geodesic sphere of CP_2. $\hat{M}^4 = M^4 \backslash M^2$ and $\hat{CP}_2 = CP_2 \backslash S^2$ have fundamental group Z since the codimension of the excluded sub-manifold is equal to two and homotopically the situation is like that for a punctured plane. The exclusion of these sub-manifolds defined by the choice of quantization axes could naturally give rise to the desired situation.

2. CP_2 allows two geodesic spheres which left invariant by $U(2$ *resp.* $SO(3)$. The first one is homologically non-trivial. For homologically non-trivial geodesic sphere $H_4 = M^2 \times S^2$ represents a straight cosmic string which is non-vacuum extremal of Kähler action (not necessarily preferred extremal). One can argue that the many-valuedness of $\hbar$ is un-acceptable for non-vacuum extremals so that only homologically trivial geodesic sphere S^2 would be acceptable. One could go even further. If the extremals in $M^2 \times CP_2$ can be preferred non-vacuum extremals, the singular coverings of M^4 are not possible. Therefore only the singular coverings and factor spaces of CP_2 over the homologically trivial geodesic sphere S^2 would be possible. This however looks a non-physical outcome.

   (a) The situation changes if the extremals of type $M^2 \times Y^2$, Y^2 a holomorphic surface of CP_3, fail to be hyperquaternionic. The tangent space M^2 represents hypercomplex sub-space and the product of the Kähler-Dirac gamma matrices associated with the tangent spaces of Y^2 should belong to M^2 algebra. This need not be the case in general.

   (b) The situation changes also if one reinterprets the gluing procedure by introducing scaled up coordinates for M^4 so that metric is continuous at $M^2 \times CP_2$ but CDs with different size have different sizes differing by the ratio of Planck constants and would thus have only piece of lower or upper boundary in common.

3. For the more general option one would have four different options corresponding to the Cartesian products of singular coverings and factor spaces. These options can be denoted by $C-C$, $C-F$, $F-C$, and $F-F$, where C (F) signifies for covering (factor space) and first (second) letter signifies for CD (CP_2) and correspond to the spaces $(\hat{CD} \hat{\times} G_a) \times (\hat{CP}_2 \hat{\times} G_b)$, $(\hat{CD} \hat{\times} G_a) \times \hat{CP}_2/G_b$, $\hat{CD}/G_a \times (\hat{CP}_2 \hat{\times} G_b)$, and $\hat{CD}/G_a \times \hat{CP}_2/G_b$.

4. The groups G_i could correspond to cyclic groups Z_n. One can also consider an extension by replacing M^2 and S^2 with its orbit under more general group G (say tetrahedral, octahedral, or icosahedral group). One expects that the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds M^2 or S^2. This would replace the singular manifold with a set of its rotated copies in the case that the subgroups have genuinely 3-dimensional action (the subgroups which corresponds to exceptional groups in the ADE correspondence). For instance, in the case of M^2 the quantization axes for angular momentum would be replaced by the set of quantization axes going through the vertices of tetrahedron, octahedron, or icosahedron. This would bring non-commutative homotopy groups into the picture in a natural manner.

About the phase transitions changing Planck constant

There are several non-trivial questions related to the details of the gluing procedure and phase transition as motion of partonic 2-surface from one sector of the embedding space to another one.

1. How the gluing of copies of embedding space at $M^2 \times CP_2$ takes place? It would seem that the covariant metric of CD factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of CD metric can make sense. On the other hand, one can always scale the M^4 coordinates so that the metric is continuous but the sizes of CDs with different Planck constants differ by the ratio of the Planck constants.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in M^4 degrees of freedom. This is not the case. Light-likeness in $M^2 \times S^2$ makes sense only for surfaces $X^1 \times D^2 \subset M^2 \times S^2$, where X^1 is light-like geodesic. The requirement that the partonic 2-surface X^2 moving from one sector of H to another one is light-like at $M^2 \times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of M^2 as M^2 projection. Hence no sudden change of the size X^2 occurs.

3. A natural question is whether the phase transition changing the value of Planck constant can occur purely classically or whether it is analogous to quantum tunnelling. Classical non-vacuum extremals of Chern-Simons action have two-dimensional CP_2 projection to homologically non-trivial geodesic sphere S^2_I. The deformation of the entire S^2_I to homologically trivial geodesic sphere S^2_{II} is not possible so that only combinations of partonic 2-surfaces with vanishing total homology charge (Kähler magnetic charge) can in principle move from sector to another one, and this process involves fusion of these 2-surfaces such that CP_2 projection becomes single homologically trivial 2-surface. A piece of a non-trivial geodesic sphere S^2_I of CP_2 can be deformed to that of S^2_{II} using 2-dimensional homotopy flattening the piece of S^2 to curve. If this homotopy cannot be chosen to be light-like, the phase transitions changing Planck constant take place only via quantum tunnelling. Obviously the notions of light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

How one could fix the spectrum of Planck constants?

The question how the observed Planck constant relates to the integers n_a and n_b defining the covering and factors spaces, is far from trivial and I have considered several options. The basic physical inputs are the condition that scaling of Planck constant must correspond to the scaling of the metric of CD (that is Compton lengths) on one hand and the scaling of the gauge coupling strength $g^2/4\pi\hbar$ on the other hand.

1. One can assign to Planck constant to both CD and CP_2 by assuming that it appears in the commutation relations of corresponding symmetry algebras. Algebraist would argue that Planck constants $\hbar(CD)$ and $\hbar(CP_2)$ must define a homomorphism respecting multiplication and division (when possible) by G_i. This requires $r(X) = \hbar(X)\hbar_0 = n$ for covering and $r(X) = 1/n$ for factor space or vice versa.

2. If one assumes that $\hbar^2(X)$, $X = M^4$, CP_2 corresponds to the scaling of the covariant metric tensor g_{ij} and performs an over-all scaling of H-metric allowed by the Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains the scaling of M^4 covariant metric by $r^2 \equiv \hbar^2/\hbar_0^2 = \hbar^2(M^4)/\hbar^2(CP_2)$ whereas CP_2 metric is not scaled at all.

3. The condition that $\hbar$ scales as n_a is guaranteed if one has $\hbar(CD) = n_a\hbar_0$. This does not fix the dependence of $\hbar(CP_2)$ on n_b and one could have $\hbar(CP_2) = n_b\hbar_0$ or $\hbar(CP_2) = \hbar_0/n_b$. The intuitive picture is that n_b- fold covering gives in good approximation rise to $n_a n_b$ sheets and multiplies YM action action by $n_a n_b$ which is equivalent with the $\hbar = n_a n_b \hbar_0$ if one effectively compresses the covering to $CD \times CP_2$. One would have $\hbar(CP_2) = \hbar_0/n_b$ and $\hbar = n_a n_b \hbar_0$. Note that the descriptions using ordinary Planck constant and coverings and scaled Planck constant but contracting the covering would be alternative descriptions.

   This gives the following formulas $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$ in various cases.

	$C-C$	$F-C$	$C-F$	$F-F$
r	$n_a n_b$	$\frac{n_a}{n_b}$	$\frac{n_b}{n_a}$	$\frac{1}{n_a n_b}$

Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} was proposed to define favored as values of n_a in living matter [K41].

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1 + i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ (the number theoretical miracle is that all the four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm) define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$ and that these physics are induced by dark variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$, and the resulting picture finds support from the ensuing models for biological evolution and for EEG [K41]. This hypothesis - to be referred to as Mersenne hypothesis - replaces the rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant.

How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anti-commutation relations of various superconformal algebras. Only the ratio of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the embedding space sector with given values of Planck constants are proportional to the corresponding Planck. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

11.3 General Ideas About Dark Matter

In the sequel general ideas about the role of dark matter in condensed matter physics are described.

11.3.1 How The Scaling Of $\hbar$ Affects Physics And How To Detect Dark Matter?

It is relatively easy to deduce the basic implications of the scaling of $\hbar$.

1. If the rate for the process is non-vanishing classically, it is not affected in the lowest order. For instance, scattering cross sections for say electron-electron scattering and e^+e^- annihilation are not affected in the lowest order since the increase of Compton length compensates for the reduction of α_{em}. Photon-photon scattering cross section, which vanishes classically and is proportional to $\alpha_{em}^4\hbar^2/E^2$, scales down as $1/\hbar^2$.

2. Higher order corrections coming as powers of the gauge coupling strength α are reduced since $\alpha = g^2/4\pi\hbar$ is reduced. Since one has $\hbar_s/\hbar = \alpha Q_1Q_2/v_0$, αQ_1Q_2 is effectively replaced with a universal coupling strength v_0. In the case of QCD the paradoxical sounding implication is that α_s would become very small.

11.3.2 General View About Dark Matter Hierarchy And Interactions Between Relatively Dark Matters

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constants and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different G_b phases could not appear in the same vertex since the partons in question would correspond to vacuum extremals. Hence the phase transition changing the particles to each other analogous could not be described by a vertex and would be analogous to a de-coherence.

   The phase transition could occur at the incoming or outgoing particle lines. At space-time level the phase transition would mean essentially a leakage between different sectors of embedding space and means that partonic 2-surface at leakage point has CP_2 projection reducing to the orbifold point invariant under G or alternatively, its $M^4_\pm$ projection corresponds to the tip of $M^4_\pm$. Relative darkness would certainly mean different groups G_a and G_b. Note that $\hbar(M^4)$ *resp.* $\hbar(CP_2)$ can be same for different groups G_a *resp.* G_b and that only the ratio of $\hbar(M^4)/\hbar(M^4)$ appears in the Kähler action.

2. One can represent a criticism against the idea that relatively dark matters cannot appear at the same interaction vertex. The point is that the construction of S-matrix for transitions transforming partonic 2-surfaces in different number fields involves only the rational (algebraic) points in the intersection of the 2-surfaces in question. This idea applies also to the case in which particles correspond to different values of Planck constant. What is only needed that all the common points correspond to the orbifold point in M^4 or CP_2 degrees of freedom and are thus intermediate between two sectors of embedding space. In this picture phase transitions would occur through vertices and S-matrix would characterize their probabilities. It seems that this option is the correct one.

If the matrix elements for real-real transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [K28], then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Note however that one could understand the weakness of the quantal interactions between relatively dark matters solely from the fact that the CP_2 type extremals providing space-time correlates for particle propagators must in this case go through an intermediate state with at most point-like CP_2 projection.

What does one mean with dark variants of elementary particle?

It is not at all clear what one means with the dark variant of elementary particle. In this respect p-adic mass calculations provide a valuable hint. According to the p-adic mass calculations [K71], $k = 113$ characterizes electromagnetic size of u and d quarks, of nucleons, and nuclei. $k = 107$ characterizes the QCD size of hadrons. This is somewhat paradoxical situation since one would expect that quark space-time sheets would be smaller than hadronic space-time sheets.

The simplest resolution of the problem suggested by the basic characteristics of electro-weak symmetry breaking is that $k = 113$ characterizes the size of the electro-magnetic field body of the quark and that the prime characterizing p-adic mass scale labels the em field body of the particle. One can assign mass also the Z^0 body but this would be much smaller as the small scale of neutrino masses suggests. This size scale correspond to a length scale of order 10 μm, which conforms with the expectation that classical Z^0 force is important in biological length scales. The size of Z^0 body of neutrino could relate directly to the chirality selection in living matter. An interesting question is whether the Z^0 field bodies of also other elementary fermions are of this size.

If this picture is correct then dark variant of elementary particle would differ from ordinary only in the sense that its field body would be dark. This conforms with the general working hypothesis is that only field bodies can be dark.

Are particles characterized by different p-adic primes relatively dark?

Each particle is characterized by a collection of p-adic primes corresponding to the partonic 2-surfaces associate with the particle like 3-surface. Number theoretical vision supports the notion of multi-p p-adicity and the idea that elementary particles correspond to infinite primes, integers, or perhaps even rationals [?, K105]. To infinite primes, integers, and rationals it is possible to associate a finite rational $q = m/n$ by a homomorphism. This would suggest generalization of p-adicity with q-adicity (q-adic topology does not correspond to number field) but this does not seem to be a promising idea.

The crucial observation is that one can decompose the infinite prime, call it P, to finite and infinite parts and distinguish between bosonic and fermionic finite primes of which infinite prime can be said to consist of [K121, K105, K72]. The interpretation is that bosonic and fermionic finite primes in the *infinite* part of P code for p-adic topologies of light-like partonic 3-surfaces associated with a given *real* space-time sheet whereas the primes in the *finite* part of P code for p-adic light-like partonic 3-surfaces.

This raises two options.

1. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by the exchange of particles characterized by divisors of m or n since in this case partonic 2-surface with same p-adic or effective p-adic topology can be found. This is the only possible interaction between them.
2. The number theoretic vision about the construction of S-matrix however allows to construct S-matrix also in the case that partons belong to different number fields and one ends up with a very elegant description involving only finite number of points of partonic 2-surfaces belonging to their intersection consisting of rational (algebraic points of embedding space), which by algebraic universality could apply also to diagonal transitions. Also now the interactions mediated between propagators connecting partons with different effective p-adic topologies might be very slow so that this would give rise to relative darkness.

Hierarchy of infinite primes and dark matter hierarchy

In previous consideration only the simplest infinite primes at the lowest level of hierarchy were considered. Simple infinite primes allow a symmetry changing the sign of the finite part of infinite prime. A possible interpretation in terms of phase conjugation. One can consider also more complex infinite primes at this level and a possible interpretation in terms of bound states of several particles. One can also consider infinite integers and rationals: the interpretation would be as many particle states. Rationals might correspond to states containing particles and antiparticles. At the higher levels of the hierarchy infinite primes of previous take the role of finite primes at the previous level and physically these states correspond to higher level bound states of the particles of the previous level.

Thus TGD predicts an entire hierarchy of dark matters such that the many particle states at previous level become particles at the next level. This hierarchy would provide a concrete physical identification for the hierarchy of infinite primes identifiable in terms of a repeated second quantization of an arithmetic super-symmetric QFT [K105] including both free many-particle states and their bound states. The finite primes about which infinite prime is in a well defined sense a composite of would correspond to the particles in the state forming a unit of dark matter. Particles belonging to different levels of this hierarchy would obviously correspond to different levels of dark matter hierarchy but their interactions must reduce to the fundamental partonic vertices.

11.3.3 How Dark Matter And Visible Matter Interact?

The hypothesis that the value of $\hbar$ is dynamical, quantized and becomes large at the verge of a transition to a non-perturbative phase in the ordinary sense of the word has fascinating implications. In particular, dark matter, would correspond to a large value of $\hbar$ and could be responsible for the properties of the living matter. In order to test the idea experimentally, a more concrete model for the interaction of ordinary matter and dark matter must be developed and here of course experimental input and the consistency with the earlier quantum model of living matter is of considerable help.

How dark photons transform to ordinary photons?

The transitions of dark atoms naturally correspond to coherent transitions of the entire dark electron BE condensate and thus generate N_{cr} dark photons and behave thus like laser beams.

Dark photons do not interact directly with the visible matter. An open question is whether even ordinary laser beams could be identified as beams of dark photons: the multiple covering property at the level of embedding space and the fact that MEs are possible in all sectors suggests that this is not the case. Note that the transition from dark to ordinary photons implies the scaling of wave length and thus also of coherence length by a factor n_b/n_a.

Dark $\leftrightarrow$ visible transition should have also a space-time correlate. The so called topological light rays or MEs ("massless extremals") represent a crucial deviation of TGD from Maxwell's ED and have all the properties characterizing macroscopic classical coherence. Therefore MEs are excellent candidates for the space-time correlate of BE condensate of dark photons.

MEs carry in general a superposition of harmonics of some basic frequency determined by the length of ME. A natural expectation is that the frequency of classical field corresponds to the generalized de Broglie frequency of dark photon and is thus $\hbar/\hbar_s$ times lower than for ordinary photons. In completely analogous manner de Broglie wave length is scaled up by $k = \hbar_s/\hbar$. Classically the decay of dark photons to visible photons would mean that an oscillation with frequency f inside topological light ray transforms to an oscillation of frequency f/k such that the intensity of the oscillation is scaled up by a factor k. Furthermore, the ME in question could naturally decompose into $1 < N_{cr} \leq 137$ ordinary photons in the case that dark atoms are in question. Of course also MEs could decay to lower level MEs and this has an interpretation in terms of hierarchy of dark matters to be discussed next.

About the criterion for the transition increasing the value of Planck constant

An attractive assumption is that the transition to dark matter phase occurs when the interaction strength satisfies the criticality condition $Q_1Q_2\alpha \simeq 1$. A special case corresponds to self interaction with $Q_1 = Q_2$. This condition applies only to gauge interactions so that particles can be characterized by gauge charges. A more general characterization would be that transition occurs when perturbation theory ceases to converge. The criterion cannot be applied to phenomenological QFT description of strong force in terms of, say, pion exchange.

Some examples are in order to test this view.

1. Transition from perturbative phase in QCD to hadronic phase is the most obvious application. The identification of valence quarks and gluons as dark matter would predict for them QCD size ($k = 107$ space-time sheet) of about electron Compton length. This does not change the QCD cross sections in the lowest order perturbation theory but makes them excellent predictions. It also provides completely new view about how color force determines the nuclear strong force indeed manifesting itself as long ranged harmonic oscillator potential, the long range of which becomes manifest in the case of neutron halos of size of 2.5×10^{-14} m [C133]. One can also understand tetraneutron in this framework. This criterion applies also in QCD plasma and explains the formation of liquid like color glass condensate detected in RHIC [C124]. A possible interpretation for QCD size would be as a length of the cylindrical magnetic walls defining the magnetic body associated with u and d type valence quarks, nucleons, and nuclei.

2. QCD size of quark must be distinguished from the electromagnetic size of quark associated with $k = 113$ space-time sheets of u and d quarks and assignable to the height of the magnetic body and defining the length scale of flux tubes feeding quark charges to $k = 113$ space-time sheets.

3. In the case of atomic nuclei the criterion would naturally apply to the electromagnetic interaction energy of two nucleon clusters inside nucleus or to self energy ($Q^2\alpha_{em} = 1$). Quite generally, the size of the electromagnetic $k = 113$ space-time sheet would increase by a $n_F = 2^k \prod_s F_s$, where F_s are different Fermat primes (the known ones being $3, 5, 17, 257, 2^{16} + 1$), in the transition to large $\hbar$ phase. Especially interesting values of n_F seem to be of form $n_F = 2^{k11}$ and possibly also $n_F = 2^{k11} \prod_s F_s$. Similar criterion would apply in the plasma phase. Note that many free energy anomalies involve the formation of cold plasma [K113].

   The criterion would give in the case of single nucleus and plasma $Z \geq 12$ if the charges are within single space-time sheet. This is consistent with cold fusion involving Palladium nuclei [C48]. Since u and d quarks have $k = 113$, they both and thus both neutrons and protons could make a transition to large $\hbar$ phase. This is consistent with the selection rules of cold fusion since the production of ^3He involves a phase transition pnp$_d$ $\rightarrow$ pnp and the contraction of p_d to p is made un-probable by the Coulomb wall whereas the transition nnp$_d$ $\rightarrow$nnp producing tritium does not suffer from this restriction.

Strong and weak physics of nuclei would not be affected in the phase transition. Electromagnetic perturbative physics of nuclei would not be affected in the process in the lowest order in $\hbar$ (classical approximation) but the height of the Coulomb wall would be reduced by a factor $1/n_F$ by the increase in the electromagnetic size of the nucleus. Also Pd nuclei could make the transition and Pd nuclei could catalyze the transition in the case the deuterium nuclei.

11.3.4 Could One Demonstrate The Existence Of Large Planck Constant Photons Using Ordinary Camera Or Even Bare Eyes?

If ordinary light sources generate also dark photons with same energy but with scaled up wavelength, this might have effects detectable with camera and even with bare eyes. In the following I consider in a rather light-hearted and speculative spirit two possible effects of this kind appearing in both visual perception and in photos. For crackpotters I want to make clear that I love to play with ideas to see whether they work or not, and that I am ready to accept some convincing mundane explanation of these effects and I would be happy to hear about this kind of explanations. I was not able to find any such explanation from Wikipedia using words like camera, digital camera, lense, aberrations [D3].

Why light from an intense light source seems to decompose into rays?

If one also assumes that ordinary radiation fields decompose in TGD Universe into topological light rays ("massless extremals", MEs) even stronger predictions follow. If Planck constant equals to $\hbar = q \times \hbar_0$, $q = n_a/n_b$, MEs should possess Z_{n_a} as an exact discrete symmetry group acting as rotations along the direction of propagation for the induced gauge fields inside ME.

The structure of MEs should somewhat realize this symmetry and one possibility is that MEs has a wheel like structure decomposing into radial spokes with angular distance $\Delta\phi = 2\pi/n_a$ related by the symmetries in question. This brings strongly in mind phenomenon which everyone can observe anytime: the light from a bright source decomposes into radial rays as if one were seeing the profile of the light rays emitted in a plane orthogonal to the line connecting eye and the light source. The effect is especially strong if eyes are stirred. It would seem that focusing makes the effect stronger.

Could this apparent decomposition to light rays reflect directly the structure of dark MEs and could one deduce the value of n_a by just counting the number of rays in camera picture, where the phenomenon turned to be also visible? Note that the size of these wheel like MEs would be macroscopic and diffractive effects do not seem to be involved. The simplest assumption is that most of photons giving rise to the wheel like appearance are transformed to ordinary photons before their detection.

The discussions about this led to a little experimentation with camera at the summer cottage of my friend Samppa Pentikäinen, quite a magician in technical affairs. When I mentioned the decomposition of light from an intense light source to rays at the level of visual percept and wondered whether the same occurs also in camera, Samppa decided to take photos with a digital camera directed to Sun. The effect occurred also in this case and might correspond to decomposition to MEs with various values of n_a but with same quantization axis so that the effect is not smoothed out.

What was interesting was the presence of some stronger almost vertical "rays" located symmetrically near the vertical axis of the camera. In old-fashioned cameras the shutter mechanism determining the exposure time is based on the opening of the first shutter followed by closing a second shutter after the exposure time so that every point of sensor receives input for equally long time. The area of the region determining input is bounded by a vertical line. If macroscopic MEs are involved, the contribution of vertical rays is either nothing or all unlike that of other rays and this might somehow explain why their contribution is enhanced. The shutter mechanism is unnecessary in digital cameras since the time for the reset of sensors is what matters. Something in the geometry of the camera or in the reset mechanism must select vertical direction in a preferred position. For instance, the outer "aperture" of the camera had the geometry of a flattened square.

Anomalous diffraction of dark photons

Second prediction is the possibility of diffractive effects in length scales where they should not occur. A good example is the diffraction of light coming from a small aperture of radius d. The diffraction pattern is determined by the Bessel function

$$J_1(x) \ , \ x = kdsin(\theta) \ , \ k = 2\pi/\lambda .$$

There is a strong light spot in the center and light rings around whose radii increase in size as the distance of the screen from the aperture increases. Dark rings correspond to the zeros of $J_1(x)$ at $x = x_n$ and the following scaling law for the nodes holds true

$$sin(\theta_n) = x_n \frac{\lambda}{2\pi d} per.$$

For very small wavelengths the central spot is almost point-like and contains most light intensity.

If photons of visible light correspond to large Planck constant $\hbar = q \times \hbar_0$ transformed to ordinary photons in the detector (say camera film or eye), their wavelength is scaled by q, and one has

$$sin(\theta_n) \rightarrow q \times sin(\theta_n)$$

The size of the diffraction pattern for visible light is scaled up by q.

This effect might make it possible to detect dark photons with energies of visible photons and possibly present in the ordinary light.

1. What is needed is an intense light source and Sun is an excellent candidate in this respect. Dark photon beam is also needed and n dark photons with a given visible wavelength λ could result when dark photon with $\hbar = n \times q \times \hbar_0$ decays to n dark photons with same wavelength but smaller Planck constant $\hbar = q \times \hbar_0$. If this beam enters the camera or eye one has a beam of n dark photons which forms a diffraction pattern producing camera picture in the de-coherence to ordinary photons.

2. In the case of an aperture with a geometry of a circular hole, the first dark ring for ordinary visible photons would be at $sin(\theta) \simeq (\pi/36)\lambda/d$. For a distance of $r = 2$ cm between the sensor plane ("film") and effective circular hole this would mean radius of $R \simeq rsin(\theta) \simeq 1.7$ micrometers for micron wave length. The actual size of spots is of order $R \simeq 1$ mm so that the value of q would be around 1000: $q = 2^{10}$ and $q = 2^{11}$ belong to the favored values for q.

3. One can imagine also an alternative situation. If photons responsible for the spot arrive along single ME, the transversal thickness R of ME is smaller than the radius of hole, say of of order of wavelength, ME itself effectively defines the hole with radius R and the value of $sin(\theta_n)$ does not depend on the value of d for $d > R$. Even ordinary photons arriving along MEs of this kind could give rise to an anomalous diffraction pattern. Note that the transversal thickness of ME need not be fixed however. It however seems that MEs are now macroscopic.

4. A similar effect results as one looks at an intense light source: bright spots appear in the visual field as one closes the eyes. If there is some more mundane explanation (I do not doubt this!), it must apply in both cases and explain also why the spots have precisely defined color rather than being white.

5. The only mention about effects of diffractive aberration effects are colored rings around say disk like objects analogous to colors around shadow of say disk like object. The radii of these diffraction rings in this case scale like wavelengths and distance from the object.

6. Wikipedia contains an article from which one learns that the effect in question is known as lens flares [D11]. The article states that flares typically manifest as several starbursts, circles, and rings across the picture and result in internal reflection and scattering from material inhomogenuities in lens (such as multiple surfaces). The shape of the flares also depends on the shape of aperture. These features conform at least qualitatively with what one would expect from a diffraction if Planck constant is large enough for photons with energy of visible photon.

The article [D18] defines flares in more restrictive manner: lense flares result when *non-image* forming light enters the lens and subsequently hits the camera's film or digital sensor and produces typically polygonal shape with sides which depend on the shape of lense diaphgram. The identification as a flare applies also to the apparent decomposition to rays and this dependence indeed fits with the observations.

The experimentation of Samppa using digital camera demonstrated the appearance of colored spots in the pictures. If I have understood correctly, the sensors defining the pixels of the picture are in the focal plane and the diffraction for large Planck constant might explain the phenomenon. Since I did not have the idea about diffractive mechanism in mind, I did not check whether fainter colored rings might surround the bright spot.

1. In any case, the readily testable prediction is that zooming to bright light source by reducing the size of the aperture should increase the size and number of the colored spots. As a matter fact, experimentation demonstrated that focusing brought in large number of these spots but we did not check whether the size was increased.
2. Standard explanation predicts that the bright spots are present also with weaker illumination but with so weak intensity that they are not detected by eye. The positions of spots should also depend only on the illumination and camera. The explanation in terms of beams of large Planck constant photons predicts this if the flux of dark photons from any light source is constant.

11.3.5 Dark Matter And Exotic Color And Electro-Weak Interactions

The presence of classical electro-weak and color gauge fields in all length scales is an unavoidable prediction of TGD and the interpretation in terms of p-adic and dark matter hierarchies is also more or less unavoidable. The new element in the interpretation is based on the observation that the quark and antiquarks at the ends of flux tubes serving as sources of classical color gauge fields could be seen as a vacuum polarization effect. In the same manner neutrino pairs at the ends of flux tubes serving as sources of classical Z^0 fields could be seem as a vacuum polarization effect.

One of the many open questions is whether also p-adic hierarchy defines a hierarchy of confinement scales for color interactions and screening scales for weak interactions or whether only the hierarchy of Planck constants gives rise to this kind of hierarchy. It would look strange if all flux tubes of macroscopic size scale would always correspond to a large value of $\hbar$ and therefore singular covering and fractionized quantum numbers. Also the proposed dark rules involving hierarchy of Mersenne rules would support the view that both hierarchies are present and there is an interaction between them in the sense that phase transitions between dark and thus scaled up counterpart of p-adic length scale and non-dark scaled up p-adic length scale can take place. The proposed stability criteria certainly allow this.

Do p-adic and dark matter hierarchies provide a correct interpretation of long ranged classical electro-weak gauge fields?

For two decades one of the basic interpretational challenges of TGD has been to understand how the un-avoidable presence of long range classical electro-weak gauge fields can be consistent with the small parity breaking effects in atomic and nuclear length scales. Also classical color gauge fields are predicted, and I have proposed that color qualia correspond to increments of color quantum numbers [K47] . The proposed model for screening cannot banish the unpleasant feeling that the screening cannot be complete enough to eliminate large parity breaking effects in atomic length scales so that one one must keep mind open for alternatives.

p-Adic length scale hypothesis suggests the possibility that both electro-weak gauge bosons and gluons can appear as effectively massless particles in several length scales and there indeed exists evidence that neutrinos appear in several scaled variants [C118] (for TGD based model see [K61]).

This inspires the working hypothesis that long range classical electro-weak gauge and gluon fields are correlates for light or massless p-adically scaled up and dark electro-weak gauge bosons and gluons. Thus both p-adic and dark hierarchies would be involved. For the p-adic hierarchy the masses would be scaled up whereas for the dark hierarchy masses would be same. The essentially new element in the interpretation would be that these fields assignable to flux quanta could be seen as vacuum polarization effects in even macroscopic length scales. This vision would definitely mean new physics effects but the interpretation would be consistent with quantum field theoretic intuition.

1. In this kind of scenario ordinary quarks and leptons could be essentially identical with their standard counterparts with electro-weak charges screened in electro-weak length scale so that the problems related to the smallness of atomic parity breaking would be trivially resolved. The weak form of electric-magnetic duality allows to identify the screening mechanism as analog of confinement mechanism for weak isospin

2. In condensed matter blobs of size larger than neutrino Compton length (about 5 μm if $k = 169$ determines the p-adic length scale of condensed matter neutrinos) the situation could be different. Also the presence of dark matter phases with sizes and neutrino Compton lengths corresponding to the length scales defined as p-adically scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$, $k = 151, 157, 163, 167$ in the range 10 nm-2.5 μm are suggested by the number theoretic considerations (these values of k correspond to so called Gaussian Mersennes [K56]). Only a fraction of the condensed matter consisting of regions of size $L_e(k)$ need to be in the dark phase.

3. Dark quarks and leptons would have masses essentially identical to their standard model counterparts. Only the electro-weak boson masses which are determined by a different mechanism than the dominating contribution to fermion masses [K61, K61] would be small or vanishing. Below the dark or p-adic length scale in question gauge bosons would behave like massless quanta.

4. The large parity breaking effects in living matter would be due to the presence of dark nuclei and leptons. Later the idea that super-fluidity corresponds to Z^0 super-conductivity will be discussed it might be that also super-fluid phase corresponds to dark neutron phase.

The basic prediction of TGD based model of dark matter as a phase with a large value of Planck constant is the scaling up of various quantal length and time scales. Mersenne hypothesis allows a wide range of scales so that very rich structures are possible.

Dark photon many particle states behave like laser beams decaying to ordinary photons by de-coherence meaning a transformation of dark photons to ordinary ones. Also dark electro-weak bosons and gluons would be massless or have small masses determined by the p-adic length scale in question. The decay products of dark electro-weak gauge bosons would be ordinary electro-weak bosons decaying rapidly via virtual electro-weak gauge boson states to ordinary leptons. Topological light rays ("massless extremals") for which all classical gauge fields are massless are natural space-time correlates for the dark boson laser beams. Obviously this means that the basic difference between the chemistries of living and non-living matter would be the absence of electro-weak symmetry breaking in living matter (which does not mean that elementary fermions would be massless).

Criterion for the presence of exotic electro-weak bosons and gluons

Classical gauge fields directly are space-time correlates of quantum states. The gauge fields associated with massless extremals ("topological light rays") decompose to free part and a part having non-vanishing divergence giving rise to a light-like Abelian gauge current. Free part would correspond to Bose-Einstein condensates and current would define a coherent state of dark photons.

The dimension D of the CP_2 projection of the space-time sheet serves as a criterion for the presence of long ranged classical electro-weak and gluon fields. D also classifies the (possibly asymptotic) solutions of field equations [K14].

1. For $D = 2$ induced gauge fields are Abelian and induced Kähler form vanishes for vacuum extremals: in this case classical em and Z^0 fields are proportional to each other. The non-vanishing Kähler field implies that induced gluon fields are non-vanishing in general. This raises the question whether long ranged color fields and by quantum classical correspondence also long ranged QCD accompany non-vacuum extremals in all length scales. This makes one wonder whether color confinement is possible at all and whether scaled down variants of QCD appear in all length scales.

The possibility to add constants to color Hamiltonians appearing in the expression of the classical color gauge fields allows to have vanishing color charges in the case of an arbitrary space-time sheet. The requirement that color quantum numbers of the generator vanish allows to add the constant only to the Hamiltonians of color hyper charge and isospin so that for $D = 2$ extremals color charges can be made vanishing. This might allow to understand how color confinement is consistent with long ranged induced Kähler field.

2. For $D \geq 3$ all classical long ranged electro-weak fields and non-Abelian color fields are present. This condition is satisfied when electric and magnetic fields are not orthogonal and the instanton density $A \wedge J$ for induced Kähler form is non-vanishing. The rather strong conclusion is that in length scales in which exotic electro-weak bosons are not present, one has $D = 2$ and gauge fields are Abelian and correspond trivially to fixed points of renormalization group realized as a hydrodynamic flow at space-time sheets [L82].

Quantum classical correspondence suggests the existence of electro-weak gauge bosons with mass scale determined by the size of the space-time sheets carrying classical long range electro-weak fields. This would mean the existence of new kind of gauge bosons.

The obvious objection is that the existence of these gauge bosons would be reflected in the decay widths of intermediate gauge bosons. The remedy of the problem is based on the notion of space-time democracy suggested strongly by the fact that the interactions between space-time sheets possessing different p-adic topologies proceed with very slow rates simply because the number of common rational (algebraic) points of partonic 2-surfaces appearing in the vertex is small.

For light exotic electro-weak bosons also the corresponding leptons and quarks would possess a large weak space-time sheet but lack the ordinary weak partonic 2-surface so that there would be no direct coupling to electro-weak gauge bosons. These space-time sheets are dark in weak sense but need not have a large value of $\hbar$. This picture implies the notion of partial darkness since any space-time sheets with different ordinary of Gaussian primes are dark with respect to each other.

Do Gaussian Mersennes define a hierarchy of dark electro-weak physics?

Gaussian Mersennes are defined as Gaussian primes of form $g_n = (1+i)^n - 1$, where n must be prime. They have norm squared $g\overline{g} = 2^n - 1$. The list of the first Gaussian Mersennes corresponds to the following values of n.

2, 3, 5, 7, 11, 19, 29, 47, 73, 79, 113, 151, 157, 163, 167, 239, 241, 283, 353, 367, 379, 457, 997, 1367, 3041, 10141, 14699, 27529, 49207, 77291, 85237, 106693, 160423 and 203789.

The Gaussian primes $k = 113, 151, 157, 163, 167$ correspond to length scales which are of most obvious interest but in TGD framework one cannot exclude the twin prime $239, 241$ corresponds to length scales $L_e(k) \simeq 160$ km and 320 km. Also larger primes could be of relevant for bio-systems and consciousness. Also the secondary and higher length scales associated with $k < 113$ could be of importance and their are several length scales of this kind in the range of biologically interesting length scales. Physics and biology inspired considerations suggests that particular Gaussian primes correspond to a particular kind of exotic matter, possibly also to large $\hbar$ phase.

$k = 113$ corresponds to the electromagnetic length scale of u and d quarks and nuclear p-adic length scale. For dark matter these length scales are scaled up by a factor $r \sim 2^{k_d}$, with k_d fixed by Mersenne hypothesis.

On basis of biological considerations (large parity breaking in living matter) there is a temptation to assign to these length scales a scaled down copy of electro-weak physics and perhaps also of color physics. The mechanism giving rise to these states would be a phase transition transforming the ordinary $k = 89$ Mersenne of weak space-time sheets to a Gaussian Mersenne and thus increasing its size dramatically.

If given space-time sheet couples considerably only to space-time sheets characterized by same prime or Gaussian prime, the bosons of these physics do not couple directly to ordinary particles, and one avoids consistency problems due to the presence of new light particles (consider only the decay widths of intermediate gauge bosons [K66]) even in the case that the loss of asymptotic freedom is not assumed.

A question arises about the interpretation of structures of the predicted size. The strong interaction size of u and d quarks, hadrons, and nuclei is smaller than $L(k = 113) \simeq 2 \times 10^{-4}$ m for even heaviest nuclei if one accepts the formula $R \sim A^{1/3} \times 1.5 \times 10^{-15}$ m. A natural interpretation for this length scale would be as the size of the field body/magnetic body of system defined by its topologically quantized gauge fields/magnetic parts of gauge fields. The (possibly dark) p-adic length scale characterizes also the lengths of flux tubes feeding gauge fluxes from elementary particle to the space-time sheet in question. The de-localization due these flux tubes in p-adic length scale in question would determine the scale of the contribution to the mass squared of the system as predicted by p-adic thermodynamics.

11.3.6 Anti-Matter And Dark Matter

The usual view about matter anti-matter asymmetry is that during early cosmology matter-antimatter asymmetry characterized by the relative density difference of order $r = 10^{-9}$ was somehow generated and that the observed matter corresponds to what remained in the annihilation of quarks and leptons to bosons. A possible mechanism inducing the CP asymmetry is based on the CP breaking phase of CKM matrix.

The TGD based view about energy [K117, K99] forces the conclusion that all conserved quantum numbers including the conserved inertial energy have vanishing densities in cosmological length scales. Therefore fermion numbers associated with matter and antimatter must compensate each other. Therefore the standard option seems to be excluded in TGD framework.

The way out could be based on the many-sheeted space-time and the possibility of cosmic strings. One particular TGD inspired model involves a small matter-antimatter asymmetry induced by the Kähler electric fields of cosmic strings [K31]. The topological condensation of fermions and anti-fermions at space-time sheets carrying Kähler electric field of say cosmic string gives rise to a binding energy which is of different sign for fermions and anti-fermions and therefore should induce the asymmetry. The outcome of the annihilation period would be matter outside cosmic strings and antimatter inside them.

One can also imagine that in a given Kähler electric field matter develops large binding energy and antimatter large positive interaction energy which induces instability leading to the splitting of partonic 2-surfaces to dark space-time sheets implying fractionization and reduction of the energy at given sheet of the covering. Dark antimatter would interact very weakly with ordinary matter so that the non-observability of antimatter would find an elegant explanation. One can imagine also the generation of local asymmetries inside Kähler electric flux tubes leading to flux tube states with matter and antimatter condensed at the opposite ends of the flux tubes.

11.4 Dark Variants Of Nuclear Physics

The book metaphor for the extended embedding space can be utilized as a guideline as one tries to imagine various exotic phases of matter. For the minimal option atomic nuclei can be assumed to be ordinary (in the sense of nuclear string model [K31] !) and only field bodies can be dark. If only singular coverings of M^4 and CP_2 are allowed the value of Planck constant is product of two integers. Ruler and compass hypothesis restricts these integers considerably and Mersenne hypothesis provides further constraints on the model. Nuclei can be visualized as residing at the "standard" pages of the book and dark color-/weak-/em- bonds are at different pages with different p-adic length scale or having different Planck constant. This would give two hierarchies of nuclei with increasing size.

11.4.1 Constraints From The Nuclear String Model

In the case of exotic nuclei nuclear string model [L4], [L4] is a safe starting point. In this model nucleons are connected by color flux tubes having exotic light fermion and anti-fermion at their ends. Whether fermion is quark or colored excitation of lepton remains open question at this stage. The mass of the exotic fermion is much smaller than 1 MeV (p-adic temperature $T = 1/n < 1$). This model predicts large number of exotic states since color bonds, which can be regarded as colored pions, can have em charges (1, -1, 0). In particular, neutral variant of deuterium is predicted and this leads to a model of cold fusion explaining its basic selection rules. The earlier model for cold fusion discussed in [K103], which served as a constraint in the earlier speculations, is not so simple than the model of [L4], [L4].

What is important that the model requires that weak bosons for which Compton length is of order atomic size are involved. Weak bosons would behave as massless particles below the Compton and the rates for the exchanges of weak bosons would be high in the length scales considered. Weak bosons would correspond to scaled up variants of the ordinary weak bosons: scaling could be p-adic in which mass scale is reduced and weak interaction rates even above Compton length would be scaled up as $1/M_W^4$. The scaling could result also from the scaling of Planck constant in which case masses of weak bosons nor weak interaction rates in the lowest order would not be affected. If only dark scaling is involved, weak interactions would be still extremely weak above dark Compton length of weak bosons. Of course, both scalings can be imagined.

The scale of the color binding energy is $E_s = .2$ MeV for ordinary ^4He strings [K31]. $k = 151, 157, 163, 167$ define Gaussian Mersennes $G_{M,k} = (1+i)^k - 1$ and excellent candidates for biologically important p-adic length scales. There are also higher Gaussian Mersennes such as those corresponding to $k = 239, 241$ and also these seem to be interesting biologically (see [K41] where a vision about evolution and generalized EEG based on Gaussian Mersennes is described). Let us assume that these scales and also those corresponding to $k = 89, 107, 113, 127$ allow scaled variants of electroweak and color interactions with ordinary value of Planck constant. If M_{127} is scaled up to Gaussian Mersenne $M_{G,167}$, one obtains cell-nucleus sized (2.58 μm) exotic nuclei and the unit of color binding energy is still.2 eV. For p-adic length scale of order 100 μm (size of large neuron) the energy scale is still around thermal energy at room temperature.

In the case of dark color bonds it is not quite clear how the unit E_s of the color binding energy scales. If color Coulomb energy is in question, one expects $1/\hbar^2$ scaling. Rather remarkably, this scaling predicts that the unit for the energy of $A < 4$ color bond scales down to.5 eV which is the energy of hydrogen bond so that hydrogen bonds, and also other molecular bonds, might involve color bonds between proton and oxygen.

11.4.2 Constraints From The Anomalous Behavior Of Water

$H_{1.5}O$ behavior of water with respect to neutron and electron scattering is observed in atto-second time scale which corresponds to 3 Angstrom length scale, defining an excellent candidate for the size scale of exotic nuclei and Compton length of exotic weak interactions.

What happens to the invisible protons?

A possible explanation for the findings is that one fourth of protons forms neutral multi-proton states connected by possibly negatively charged color bonds of length differing sufficiently from the length of ordinary O-H bond. Although the protons are ordinary, neutron diffraction reflecting the crystal like order of water in atomic length scales would not see these poly-proton super-nuclei if they form separate closed strings.

1. For the ordinary nuclei the p-adic length scale associated with the color bonds between ^4He corresponds to M_{127}, and one can imagine exotic nuclear strings obtained by connecting two ordinary nuclei with color bonds. If second exotic nucleus is neutral (the model of cold fusion assumes that D nucleus is neutral) this could work since the Coulomb wall is absent. If the exotic nuclei have opposite em charges, the situation improves further. New super-dense phases of condensed matter would be predicted.

   If one fourth of hydrogen nuclei of water combine to form possibly neutral nuclear strings with average distance of nuclei of order $L(127)$, they are not visible in diffraction at atomic length scale because the natural length scale is shortened by a factor of order 32 but could be revealed in neutron diffraction at higher momentum exchanges. The transition between this kind of phase and ordinary nuclei would be rather dramatic event and the exchanges of exotic weak bosons with Compton lengths of order atomic size induce the formation of this kind of nuclei (this exchange is assumed in the model of cold fusion).

2. If dark color magnetic bonds are allowed, a natural distance between the building blocks of super-nuclei is given by the size scale of the color magnetic body. In nuclear string model

k_d	24	20	18
$k_{eff} = 116 + k_d$	140	136	134

Table 11.1: The integers k_{eff} characterize the effective p-adic length scales for some dark variants of color magnetic bodies for ^4He and $A < 4$ color magnetic bodies corresponding to $k \in \{127, 118\}$ and for the dark variants of $k = 116$ electromagnetic body for nuclear strings. Dark variants correspond to $k_d \in \{24 = 113 - 89 = 151 - 127, 20 = 127 - 107, 18 = 107 - 89\}$ allowed by Mersenne hypothesis.

the size scales of color magnetic bodies associated with nuclear strings consisting of ^4He and $A < 4$ nuclei color magnetic bodies correspond to $k = 127$ and $k = 118$ whereas em magnetic body corresponds to $k = 116$ [L4], [L4]. For dark variants of magnetic bodies the sizes of these magnetic bodies are scaled. There are several options to consider: consider only $k_d = 113 - 89 = 24$, $k_d = 127 - 107 = 20$ and $k_d = 107 - 89 = 18$. Note that one has $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}. **Table 11.1** below summarizes the effective dark p-adic length scales involved.

3. Consider $k_d = 24$ as an example. From **Table 11.1** the scaled up p-adic length scales of the magnetic bodies would be $L(127+24 = 151) = 10$ nm, $L(118+24 = 142) = 4.4$ Angstrom, and $L(116 + 24 = 140) = 2.2$ Angstrom. The first scale equals to the thickness of cell membrane which suggests a direct connection with biology. The latter two scales correspond to molecular length scales and it is not clear why the protons of dark nuclear strings of this kind would not be observed in electron and neutron scattering. This would leave only nuclear strings formed from ^4He nuclei into consideration.

   The crucial parameter is the unit E_s of the color binding energy. Since this parameter should correspond to color Coulombic potential it could transform like the binding energy of hydrogen atom and therefore scale as $1/\hbar^2$. This would mean that $E_s = 2.2$ MeV deduced from the deuteron binding energy would scale down to .12 eV for $r = 2^{24}$.

The transition between the dark and ordinary nuclei would be favored by the minimization of Coulomb energy and energy differences would be small because of darkness. The transitions in which ordinary proton becomes dark and fuses to super-nuclear string or vice versa could be the basic control mechanism of bio-catalysis. Metabolic energy quantum.5 eV should relate to this transition.

Magic nuclei could have fractally scaled up variants in molecular length scale and tetrahedral and icosahedral water clusters could correspond to $A = 8$ and $A = 20$ magic nuclei with color bonds connecting nucleons belonging to different dark nuclei.

About the identification of the exotic weak physics?

The model of cold fusion requires exotic weak physics with the range of weak interaction of order atomic radius.

One can consider the possibility of $k = 113$ dark weak physics with $r = 2^{24}$ ($89 \rightarrow 113$ in Mersenne hypothesis) implying that the dark weak scale corresponds to p-adic length scale $k = 137$. Weak Compton length for $k = 113$ dark weak bosons would be about 3 Angstrom. Below $L(137)$ weak bosons would behave as massless particles. Above $L(137)$ weak bosons would have the mass scale $2^{-12}m_W \sim 25$ MeV and weak rates would be scaled up by 2^{48}. Bohr radius would represent a critical transition length scale and exotic weak force could have dramatic implications for the behavior of the condensed matter in high pressures when exotic weak force would become visible. In particular, chiral selection in living matter could be understood in terms of large parity breaking implied. These physics would manifest themselves only at criticality for the phase transitions changing Planck constant and would correspond to almost vacuum extremals defining a phase different from that assignable to standard model physics.

To sum up, it would seem that the variant of ordinary nuclear physics obtained by making color bonds and weak bonds dark is the most promising approach to the $H_{1.5}O$ anomaly and cold fusion. Exotic weak bosons with Compton wave length of atomic size and the most natural assumption is that they are dark $k = 113$ weak bosons with $k_d = 24 = 113 - 89$. One variant of exotic atoms is as atoms for which electromagnetic interaction between ordinary nuclei and ordinary electrons is mediated along dark topological field quanta.

11.4.3 Exotic Chemistries And Electromagnetic Nuclear Darkness

The extremely hostile and highly un-intellectual attitude of skeptics stimulates fear in anyone possessing amygdala, and I am not an exception. Therefore it was a very pleasant surprise to receive an email telling about an article published in April 16, 2005 issue of New Scientist [D116]. The article gives a popular summary about the work of the research group of Walter Knight with Na atom clusters [D53] and of the research group of Welford Castleman with Al atom clusters [D42].

The article tells that during last two decades a growing evidence for a new kind of chemistry have been emerging. Groups of atoms seem to be able to mimic the chemical behavior of single atom. For instance, clusters of 8, 20, 40, 58 or 92 sodium atoms mimic the behavior of noble gas atoms [D53]. By using oxygen to strip away electrons one by one from clusters of Al atoms it is possible to make the cluster to mimic entire series of atoms [D42]. For aluminium cluster-ions made of 13, 23 and 37 atoms plus an extra electron are chemically inert.

One can imagine two explanations for the findings.

1. The nuclei are dark in the sense that the sizes of nuclear space-time sheets are scaled up implying the smoothing out of the nuclear charge.
2. Only electrons are dark in the sense of having scaled up Compton lengths so that the size of multi-electron bound states is not smaller than electron Compton length and electrons "see" multi-nuclear charge distribution.

If darkness and Compton length is assigned with the em field body, it becomes a property of interaction, and it seems impossible to distinguish between options 1) and 2).

What one means with dark nuclei and electrons?

Can the idea about dark nuclei and electrons be consistent with the minimalist picture in which only field bodies are dark? Doesn't the darkness of nucleus or electron mean that also multi-electron states with n electrons are possible?

The proper re-interpretation of the notion Compton length would allow a consistency with the minimalist scenario. If the p-adic prime labelling the particle actually labels its electromagnetic body as p-adic mass calculations for quark masses encourage to believe, Compton length corresponds to the size scale of the electromagnetic field body and the models discussed below would be consistent with the minimal scenario. Electrons indeed "see" the external charge distribution by their electromagnetic field body and field body also carries this distribution since CP_2 type extremals do not carry it. One could also defend this interpretation by saying that electrons is operationally only what can be observed about it through various interactions and therefore Compton length (various Compton length like parameters) must be assigned with its field body (bodies).

Also maximal quantum criticality implies that darkness is restricted to field bodies but does not exclude the possibility that elementary particle like structures can possess non-minimal quantum criticality and thus possess multi-sheeted character.

Option I: nuclei are electromagnetically dark

The general vision about nuclear dark matter suggests that the system consists of super-nuclei analogous to ordinary nuclei such that electrons are ordinary and do not screen the Coulomb potentials of atomic nuclei.

The simplest possibility is that the electromagnetic field bodies of nuclei or quarks become dark implying de-localization of nuclear charge. The valence electrons would form a kind of mini-conductor with electrons de-localized in the volume of the cluster. The electronic analog of the nuclear shell model predicts that full electron shells define stable configurations analogous to magic nuclei. The model explains the numbers of atoms in chemically inert Al and Ca clusters and generalizes the notion of valence to the level of cluster so that the cluster would behave like single super-atom.

The electromagnetic $k = 113$ space-time sheets (em field bodies) of quarks could have scaled up size $\sqrt{r}L(113) = L(113 + k_d) = 2^{k_d/2} \times 2 \times 10^{-14}$ m. One would have atomic size scale .8 Angstroms for $r = 2^{k_d}$, $k_d = 24$- an option already introduced. A suggestive interpretation is that the electric charge of nuclei or valence quarks assignable to their field bodies is de-localized quantum mechanically to atomic length scale. Electrons would in a good approximation experience quantum mechanically the nuclear charges as a constant background, jellium, whose effect is indeed modellable using harmonic oscillator potential.

One can test the proposed criterion for the phase transition to darkness. The unscreened electromagnetic interaction energy between a block of partially ionized nuclei with a net em charge Z with Z electrons would define the relevant parameter as $r \equiv Z^2\alpha$. For the total charge $Z \geq 12$ the condition $r \geq 1$ is satisfied. For a full shell with 8 electrons this condition is not satisfied.

Option II: Electrons are electro-magnetically dark

Since the energy spectrum of harmonic oscillator potential is invariant under the scaling of $\hbar$ accompanied by the opposite scaling of the oscillator frequency ω, one must consider also the em bodies of electrons are in large $\hbar$ phase (one can of course ask whether they could be observed in this phase!). The rule would be that the size of the bound states is larger than the scaled up electron Compton length.

The Compton wavelength of electrons would be scaled up by a factor r where r is product of different Fermat primes and power of 2 for ruler and compass hypothesis. For Mersenne hypothesis one would have $r = 2^{k_d}$. For $k_d = 24$ the effective p-adic scale of electron would be to about $L(151) = 10$ nm. The atomic cluster of this size would contain roughly $10^6 \times (a_0/a)^3$ atoms where a is atomic volume and $a_0 = 1$ Angstrom is the natural unit.

The shell model of nucleus is in TGD framework a phenomenological description justified by nuclear string model with string tension responsible for the oscillator potential. This leads to ask whether the electrons of jellium actually form analogs of nuclear strings with electrons connected by color bonds.

11.5 Has Dark Matter Been Observed?

In this section two examples about anomalies perhaps having interpretation in terms of quantized Planck constant are discussed. The first anomaly belongs to the realm of particle physics and hence does not quite fit the title of the chapter. Second anomaly relates to nuclear physics.

11.5.1 Optical Rotation Of A Laser Beam In A Magnetic Field

The group of G. Cantatore has reported an optical rotation of a laser beam in a magnetic field [D41]. The experimental arrangement involves a magnetic field of strength $B = 5$ Tesla. Laser beam travels 22000 times forth and back in a direction orthogonal to the magnetic field travelling 1 m during each pass through the magnet. The wavelength of the laser light is 1064 nm (the energy is 1.1654 eV). A rotation of $(3.9 \pm .5) \times 10^{-12}$ rad/pass is observed.

Faraday effect [D5] is optical rotation which occurs when photon beam propagates in a direction parallel to the magnetic field and requires parity breaking guaranteeing that the velocities of propagation for two circular polariations are different. Now however the laser beam is orthogonal to the magnetic field so that Faraday effect cannot be in question.

The proposed interpretation for the rotation would be that the component of photon having polarization parallel to the magnetic field mixes with QCD axion, one of the many candidates for dark matter. The mass of the axion would be about 1 meV. Mixing would imply a reduction of the corresponding polarization component and thus in the generic case induce a rotation of the polarization direction. Note that the laser beam could partially transform to axions, travel through a non-transparent wall, and appear again as ordinary photons.

The disturbing finding is that the rate for the rotation is by a factor 2.8×10^4 higher than predicted. This would have catastrophic astrophysical implications since stars would rapidly lose their energy via axion radiation.

What explanations one could imagine for the observations in TGD framework if one accepts the hierarchy of Planck constants?

1. The simplest model that I have been able to imagine does not assume axion like states. The optical rotation would be due to the leakage of the laser photons to dark pages of the Big Book at the ends of the magnet where the space-time sheet carrying the magnetic field becomes locally a vacuum extremal. This explanation would not mean direct seeing of dark matter but the observation of a transformation of ordinary matter to dark matter. Quite generally, this experimental approach might be much better strategy to the experimental proof of the existence of the dark matter than the usual approaches and is especially attractive in living matter.

2. TGD could also provide a justification for the axion based explanation of the optical rotation involving parity breaking. TGD predicts the existence of a hierarchy of QCD type physics based on the predicted hierarchy of scaled up variants of quarks and also those of color excited leptons. The fact that these states are not seen in the decay widths of intermediate gauge bosons can be understood if the particles in question are dark matter with non-standard value of Planck constant and hence residing at different page of the book like structure formed by the embedding space. I have discussed in detail the general model in the case of lepto-hadrons consisting of colored excitation of ordinary lepton and explaining quite an impressive bundle of anomalies [K115]. Since lepto-pion has quantum numbers of axion and similar couplings, it is natural to propose that the claimed axion like particle -if it indeed exists- is a pion like state consisting either exotic light quarks or leptons.

   The dark variants of hadron physics are suggestive in living matter. By p-adic length scale hypothesis one expects that the mass of axion-like state identifiable as a scaled variant of pion would relate by a power of $\sqrt{2}$ to pion mass. For 1 meV axion like particle, call it A, the mass ratio is $m(\pi)/m(A) = 2^{37} \times 1.004$ and indeed very near to a power of 2.

3. Rather interestingly, years later emerged evidence for an axion like particle interpreted as dark matter and having mass $m(A) = .11$ meV. The decays of this particle in the electric field of Josephson junction generate photon absorbed by Cooper pair are claimed to induce resonantly an anomalous Josephson current [D27] (`http://tinyurl.com/yck3qeyb`). If there exists several dark copies of hadron physics, it would not be surprising if the pions of these copies would behave like axions. Interpretation as scaled variant of electro-pion however yields a mass ratio nearer to a power of two: it consists of electron and positron and has mass $m(\pi_L) \simeq 2m_e$ given $m(\pi_L)(m(A) \simeq 1.08$. For ordinary pion the ratio is $m(\pi)(m(A) \simeq 1.14$.

4. The TGD inspired model would differ from the above model only in that the leakage to the dark sector would take place by a transformation of the laser photon to a pionlike state so that no parity breaking would take place. But the basic point is that vacuum extremals through which the leakage can occur, break the parity strongly by the presence of classical Z^0 fields. The idea about leakage together with the non-constancy of pion-type field appearing in the coupling to the instanton density imply that the space-time sheet representing the magnetic field is vacuum extremal -at least in some regions- and this assumption looks un-necessarily strong. Also detailed assumptions about the dependence of the basic parameters appearing in PCAC hypothesis must be made.

   What raised the hopes was the intriguing observation that the ratio of laser photon frequency to the cyclotron frequency of electron in the magnetic field considered equals to $r = 2^{11}$: this put bells ringing in the p-adically tuned mind and inspired the question whether one could have $\hbar/\hbar_0 = 2^{11}$. It must be however emphasized that this assumption about the values of $\hbar$ might be too restrictive. The assumption of cyclotron condensate of electron pairs at dark space-time sheet must be however justified and one must answer at least the question why it is needed. A possible answer would be that the leakage occurs via Bose-Einstein condensation to a coherent state of cyclotron photons. But this would mean return to the original model where laser photons leak! Obviously the model becomes too complicated for Occam and therefore I have dropped out the model.

The simplest model should start just from the finding that the linear polarization parallel to the magnetic field seems to leak with a certain rate as it traverses the magnet. The leakage of laser photons to a dark matter space-time sheet is what comes mind first in TGD context. A killer test for this explanation is to use polarization parallel to the magnetic field: in this case no optical rotation should take place.

1. The leakage should take place along the intersection of the pages of the Big Book which correspond to geodesically trivial geodesic sphere of CP_2 so that induced Kähler field vanishes and vacuum extremals or nearly vacuum extremals are in question. Leakage could occur within magnet or the ends of the magnet could involve this kind of critical membrane like region and as the photon passes through them the leakage could occur.
2. Since parity breaking takes place, the instanton density for the electromagnetic field provides a natural description of the situation. The interaction term is obtained by replacing either E in $E \cdot B$ with its quantized counterpart describing laser photons. This gives a linear coupling to photon oscillator operators completely analogous to a coupling to an external current and one can calculate the leakage rate using the standard rules.
3. The interaction term is total divergence and reduces to a 3-D Chern-Simons type term associated with the boundaries of the membrane like region or magnet in the general case and the leakage can be said to occur at the ends of the magnet for non-vacuum exremals.

One can ask whether one should use the instanton density of Kähler field rather than that of em field in the model. In this case Kähler gauge potential would couple the quantized em field via U(1) part of em charge. One would not have gauge invariance since for the induced Kähler field gauge degeneracy is replaced with spin glass degeneracy and gauge transformations of the vacuum extremals induced by symplectic transformations of CP_2 deform the space-time surface. In this case E in $E \cdot A$ would be replaced with the radiation field at the ends of the magnet. In order to have a non-vanishing leakage the instanton density within magnet must be non-vanishing meaning that CP_2 projection of the magnet's space-time sheet must be 4-D at least somewhere. For the first option it can be 2-D.

The coefficient K of the instanton term defining the action should depend on the value of Planck constant. $1/e^2$ proportionality of the ordinary Maxwell action means that the coefficient of the instanton term could be propertional to $\hbar$. The most general dependence $K = k(e^2\hbar/4\pi)/e^2 \equiv f(\alpha_{em}r)/e^2$, $r = \hbar/\hbar_0$. Since non-perturbative effect is in question $k((\alpha_{em}r) \propto 1/(\alpha_{em}r)$ is suggestive and guarantees that the leakage probability becomes small for large values of Planck constant.

This option will not be discussed further but it might have also relevance to the parity breaking in biology. In fact, I have proposed that the realization of genetic code based on nuclelotide dependent optical rotation of polarization of photons proposed by Gariaev [I11] could be based on Faraday effect or its analogy [K114].

One can consider also a generalization of this model by assuming that photon transforms to dark pion-like state in the leakage. In this case the action does not however reduce to a total divergence and the condition that the entire magnet corresponds to vacuum extremal seems to be unrealistic.

11.5.2 Do Nuclear Reaction Rates Depend On Environment?

Claus Rolfs and his group have found experimental evidence for the dependence of the rates of nuclear reactions on the condensed matter environment [C84]. For instance, the rates for the reactions ^{50}V(p, n)^{50}Cr and ^{176}Lu(p, n) are fastest in conductors. The model explaining the findings has been tested for elements covering a large portion of the periodic table.

Debye screening of nuclear charge by electrons as an explanation for the findings?

The proposed theoretical explanation [C84] is that conduction electrons screen the nuclear charge or equivalently that incoming proton gets additional acceleration in the attractive Coulomb field of electrons so that the effective collision energy increases so that reaction rates below Coulomb wall increase since the thickness of the Coulomb barrier is reduced.

The resulting Debye radius

$$R_D = 69\sqrt{\frac{T}{n_{eff}\rho_a}} \ , \tag{11.5.1}$$

where ρ_a is the density of atoms per cubic meter and T is measured in Kelvins. R_D is of order.01 Angstroms for $T = 373$ K for $n_{eff} = 1$, $a = 10^{-10}$ m. The theoretical model [C21, C140] predicts that the cross section below Coulomb barrier for $X(p,n)$ collisions is enhanced by the factor

$$f(E) \quad = \quad \frac{E}{E+U_e}exp(\frac{\pi\eta U_e}{E}) \ . \tag{11.5.2}$$

E is center of mass energy and η so called Sommerfeld parameter and

$$U_e \quad \equiv \quad U_D = 2.09\times 10^{-11}(Z(Z+1))^{1/2}\times(\frac{n_{eff}\rho_a}{T})^{1/2} \ \ eV \tag{11.5.3}$$

is the screening energy defined as the Coulomb interaction energy of electron cloud responsible for Debye screening and projectile nucleus. The idea is that at R_D nuclear charge is nearly completely screened so that the energy of projectile is $E + U_e$ at this radius which means effectively higher collision energy.

The experimental findings from the study of 52 metals support the expression for the screening factor across the periodic table.

1. The linear dependence of U_e on Z and $T^{-1/2}$ dependence on temperature conforms with the prediction. Also the predicted dependence on energy has been tested [C84].
2. The value of the effective number n_{eff} of screening electrons deduced from the experimental data is consistent with $n_{eff}(Hall)$ deduced from quantum Hall effect.

The model suggests that also the decay rates of nuclei, say beta and alpha decay rates, could be affected by electron screening. There is already preliminary evidence for the reduction of beta decay rate of ^{22}Na β decay rate in Pd [C83], metal which is utilized also in cold fusion experiments. This might have quite far reaching technological implications. For instance, the artificial reduction of half-lives of the radioactive nuclei could allow an effective treatment of radioactive wastes. An interesting question is whether screening effect could explain cold fusion [C48] and sono-fusion [C90]: I have proposed a different model for cold fusion based on large $\hbar$ in [K103].

Could quantization of Planck constant explain why Debye model works?

The basic objection against the Debye model is that the thermodynamical treatment of electrons as classical particles below the atomic radius is in conflict with the basic assumptions of atomic physics. On the other hand, it is not trivial to invent models reproducing the predictions of the Debye model so that it makes sense to ask whether the quantization of Planck constant predicted by TGD could explain why Debye model works.

TGD predicts that Planck constant is quantized in integer multiples: $\hbar = n\hbar_0$, where $\hbar_0$ is the minimal value of Planck constant identified tentatively as the ordinary Planck constant. The preferred values for the scaling factors n of $\hbar$ correspond to n-polygons constructible using ruler and compass. The values of n in question are given by $n_F = 2^k\prod_i F_{s_i}$, where the Fermat primes $F_s = 2^{2^s}+1$ appearing in the product are distinct. The lowest Fermat primes are $3, 5, 17, 257, 2^{16}+1$. In the model of living matter the especially favored values of $\hbar$ come as powers 2^{k11} [K40, K41].

It is not quite obvious that ordinary nuclear physics and atomic physics should correspond to the minimum value $\hbar_0$ of Planck constant. The predictions for the favored values of n are not affected if one has $\hbar(stand) = 2^k\hbar_0$, $k \geq 0$. The non-perturbative character of strong force suggests that the Planck constant for nuclear physics is not actually the minimal one [K103]. As a matter fact, TGD based model for nucleus implies that its "color magnetic body" has size of order electron Compton length. Also valence quarks inside hadrons have been proposed to correspond to non-minimal value of Planck constant since color confinement is definitely a non-perturbative effect. Since the lowest order classical predictions for the scattering cross sections in perturbative phase do not depend on the value of the Planck constant one can consider the testing of this issue is not trivial in the case of nuclear physics where perturbative approach does not really work.

Suppose that one has $n = n_0 = 2^{k_0} > 1$ for nuclei so that their quantum sizes are of order electron Compton length or perhaps even larger. One could even consider the possibility that both nuclei and atomic electrons correspond to $n = n_0$, and that conduction electrons can make a transition to a state with $n_1 < n_0$. This transition could actually explain how the electron conductivity is reduced to a finite value. In this state electrons would have Compton length scaled down by a factor n_0/n_1.

For instance, if one has $n_0 = 2^{11k_0}$ as suggested by the model for quantum biology [K41] and by the TGD based explanation of the claimed detection of dark matter [D41], the Compton length $L_e = 2.4 \times 10^{-12}$ m for electron would reduce in the transition $k_0 \to k_0 - 1$ to $L_e = 2^{-11} L_e \simeq 1.17$ fm, which is rather near to the proton Compton length since one has $m_p/m_e \simeq .94 \times 2^{11}$. It is not too difficult to believe that electrons in this state could behave like classical particles with respect to their interaction with nuclei and atoms so that Debye model would work.

The basic objection against this model is that anyonic atoms should allow more states that ordinary atoms since very space-time sheet can carry up to n electrons with identical quantum numbers in conventional sense. This should have been seen.

Electron screening and Trojan horse mechanism

An alternative mechanism is based on Trojan horse mechanism suggested as a basic mechanism of cold fusion [K103]. The idea is that projectile nucleus enters the region of the target nucleus along a larger space-time sheet and in this manner avoids the Coulomb wall. The nuclear reaction itself occurs conventionally. In conductors the space-time sheet of conduction electrons is a natural candidate for the larger space-time sheet.

At conduction electron space-time sheet there is a constant charged density consisting of n_{eff} electrons in the atomic volume $V = 1/n_a$. This creates harmonic oscillator potential in which incoming proton accelerates towards origin. The interaction energy at radius r is given by

$$V(r) = \alpha n_{eff} \frac{r^2}{2a^3} , \qquad (11.5.4)$$

where a is atomic radius.

The proton ends up to this space-time sheet by a thermal kick compensating the harmonic oscillator energy. This occurs below with a high probability below radius R for which the thermal energy $E = T/2$ of electron corresponds to the energy in the harmonic oscillator potential. This gives the condition

$$R = \sqrt{\frac{Ta}{n_{eff}\alpha}} a . \qquad (11.5.5)$$

This condition is exactly of the same form as the condition given by Debye model for electron screening but has a completely different physical interpretation.

Since the proton need not travel through the nuclear Coulomb potential, it effectively gains the energy

$$E_e = Z\frac{\alpha}{R} = \frac{Z\alpha^{3/2}}{a}\sqrt{\frac{n_{eff}}{Ta}} . \qquad (11.5.6)$$

which would be otherwise lost in the repulsive nuclear Coulomb potential. Note that the contribution of the thermal energy to E_e is neglected. The dependence on the parameters involved is exactly the same as in the case of Debye model. For $T = 373$ K in the ^{176}Lu experiment and $n_{eff}(Lu) = 2.2 \pm 1.2$, and $a = a_0 = .52 \times 10^{-10}$ m (Bohr radius of hydrogen as estimate for atomic radius), one has $E_e = 28.0$ keV to be compared with $U_e = 21 \pm 6$ keV of [C84] ($a = 10^{-10}$m corresponds to 1.24×10^4 eV and 1 K to 10^{-4} eV). A slightly larger atomic radius allows to achieve consistency. The value of $\hbar$ does not play any role in this model since the considerations are purely classical.

An interesting question is what the model says about the decay rates of nuclei in conductors. For instance, if the proton from the decaying nucleus can enter directly to the space-time sheet of the conduction electrons, the Coulomb wall corresponds to the Coulomb interaction energy of proton with conduction electrons at atomic radius and is equal to $\alpha n_{eff}/a$ so that the decay rate should be enhanced.

11.5.3 Refraction Of Gamma Rays From Silicon Prism?

The following considerations were inspired by to a popular article [D21] (http://tinyurl.com/ydautan4) telling about refraction of gamma rays from silicon prisms. This should not be possible and since I love anomalies I got interested. Below I discuss the discovery from the point of standard physics and TGD point of view.

What happens in refraction?

Absorption, reflection, and refraction are basic phenomena of geometric optics (see http://tinyurl.com/y7bqfu8m) [D7] describing the propagation of light in terms of light rays and neglecting interference and diffraction making it possible for light to "go around the corner". The properties of medium are described in terms of refraction index n which in general is a complex quantity. The real part of n gives the phase velocity of light in medium using vacuum velocity c as unit, which - contrary to a rather common misconception - can be also larger than c as a phase velocity which cannot be assigned to energy transfer. The imaginary part characterizes absorption. n depends in general on frequency of the incoming light and the resonant interactions of light with the atoms of medium make themselves manifest in the frequency dependence of n - in particular in absorption described by the imaginary part of n.

What happens in the boundary of two media - reflection or refraction - is characterized the refraction index boundary conditions for radiation fields at the boundary, which are essentially Maxwell's equations at the discontinuity. Snell's law tells what happens to the direction of the beam and states essentially that only the momentum component of incoming photon normal to the boundary changes in these processes since only the translational symmetry in normal direction is changed.

How refractive index is determined?

What determines the index of refraction (see http://tinyurl.com/qcdk687) [D10] ? To build a microscopic theory for n one must model what happens for the incoming beam of light in medium. One must model the scattering of light from the atoms of the medium.

In the case of condensed matter X ray diffraction is excellent example about this kind of theory. In this case the lattice structure of the condensed matter system makes the situation simple. For infinitely large medium and for an infinitely wide incoming beam the scattering amplitude is just the Fourier transform of the density of atoms for the change of the wave vector (or equivalently momentum) of photon, which must be a vector in the resiprocal lattice of the crystal lattice. Therefore the beam is split into beams in precisely defined directions. The diffracted beam has a sharp maximum in forward direction and the amplitude in this direction is essentially the number of atoms.

In less regular situation such as for water or bio-matter for which regular lattice structure typically exists only locally the peaking to forward direction, is even more pronounced, and in the first approximation the beam travels in the direction that it has after entering to the system and only the phase velocity is changed and attenuation takes place. Diffraction patterns are however present also now and allow to deduce information about the structure of medium in short length scales. For instance, Delbrueck diffraction from biological matter allowed to deduce structural information about DNA and deduce its structure.

This description contains an important implicit assumption. The width and length of the incoming photon beam must be so large that the number of atoms inside it is large enough. If this condition is not satisfied, the large scale interference effects crucial for diffraction do not take place. For very narrow beams the situation approaches to a scattering from single atom and one expects that the beam is gradually widened but that it does not make sense to speak about refraction index and that the application of Snell's law does not make sense. Incoming photons see individual atoms rather than the lattice of atoms. For this reason the prevailing wisdom has been that it does not make sense to speak about bending of gamma rays from solid state. A gamma ray photon with energy of one MeV corresponds to a wavelength λ of about 10^{-12} meters which is of same order as electron Compton length. One expects that the width and length of gamma ray beam is measured using λ as a natural unit. Even width of 100 wavelengths corresponds to 1 Angstrom which corresponds to the size scale of single atom.

Surprise

The real surprise was that gamma rays bend in prisms made from silicon! The discovery (see http://tinyurl.com/ydautan4) was made by a group of scientists working in Ludwig-Maximilians-Universität in Munich [D21, D20, D50]. The group was led by Dietrich Habs. The gamma ray energies where in the range.18-2 MeV. The bending known as refraction was very small using every day standards. The value of the refractive index which gives the ratio c/v for light velocity c to the light velocity v in silicon is $1 + 10^{-9}$ as one learns from another popular article (see http://tinyurl.com/p4zy9a6) [D20]. When compared to the predictions of the existing theory, the bending was however anomalously large. By the previous argument it should not be even possible to talk about bending.

Dietrich Habs suggests that so called Delbrueck scattering of gamma rays from virtual electron positron pairs created in the electric fields of atoms could explain (see http://tinyurl.com/ydautan4) the result. This scattering would be diffraction (scattering almost totally in forward direction as for light coming through a hole). This cannot however give rise to an effective scattering from a many-atom system unless the gamma ray beam is effectively or in real sense scaled up. The scattering would be still from single atom or even part of single atom. One could of course imagine that atoms themselves have hidden structure analogous to lattice structure but why virtual electron pairs could give rise to it?

In the following I discuss two TGD inspired proposals for how the diffraction that should not occur could occur after all?

Could gamma rays scatter from quarks?

There is another strange anomaly that I discussed for a couple of years ago christened as the incredibly shrinking proton (see http://tinyurl.com/y9aklsbk) [K67]. It was found that protons charge distribution deviates slightly from the expected one. The TGD inspired explanation was based on the observation that quarks in proton are rather light having masses of 5 and 20 MeV. These correspond to gamma ray energies. Therefore the Compton wave lengths of quarks are also rather long, much longer than the Compton length of proton itself! Parts would be larger than the whole! The explanation for this quantum mystical fact would be that the Compton length corresponds to length scale assignable to color magnetic body of quark. Could it be that the scattering gamma rays see the magnetic bodies of $3 \times 14 = 42$ valence quarks of 14 nucleons of Si nucleus. The regular structure of atomic nucleus as composite of quark magnetic would induce the diffractive pattern. If so, we could do some day nuclear physics and perhaps even study the structure of proton by studying diffraction patterns of gamma rays on nuclei!

Could part of gamma beam transform to large $\hbar$ gamma rays?

Also the hierarchy of Planck constants (see http://tinyurl.com/y7c8e6x8) [K43] comes in mind. Scaling of $\hbar$ for a fixed photon energy scales up the wavelength of gamma ray. Could some fraction of incoming gamma rays suffer a phase transition increasing their Planck constant? The scaling of Planck constant make gamma rays to behave like photons with scaled up wavelength. Also the width of the beam would be zoomed up. As a result the incoming gamma ray beam would see a group of atoms instead of single atom and for a large enough value of Planck constant one could speak of diffraction giving rise to refraction.

For years ago I considered half jokingly the possibility that hierarchy of Planck constants could imply quantum effects in much longer scales than usually [K43]. Diffraction would be a typical quantum effect involving interference. Perhaps even the spots seen sometimes in ordinary camera lense could be analogous to diffractive spots generated by diffraction of large $\hbar$ visible photons through a hole (they should usually appear in the scale of visible wavelength about few microns [K42]. Take this as a joke!

I also proposed that strong classical em fields provide the environment inducing increase of Planck constant at some space-time sheets. The proposal was that Mother Nature is theoretician friendly [K43]. As perturbation expansion in powers of $1/\hbar$ fails, Mama Nature scales up $\hbar$ to make the life of her theorizing children easier, one might say. Strong electric and magnetic fields of atomic nuclei believed by Habs to be behind the diffraction might provide the manner to generate large Planck constant phases and dark matter.

11.6 Water And New Physics

In this section the previous ideas are applied in an attempt to understand the very special properties of water.

11.6.1 The 41 Anomalies Of Water

The following list of 41 anomalies of water taken from [D104] should convince the reader about the very special nature of water. The detailed descriptions of the anomalies can be found in [D104]. As a matter fact, the number of anomalies had grown to 63 when I made my last visit to the homepage of Chaplin.

The many anomalies of water need not be all due to the presence of the dark matter. As suggested already fifteen years ago, p-adic length scale hierarchy forces to replace ordinary thermodynamics with a p-adic fractal hierarchy of thermodynamics and this means that one must speak about thermodynamics in a given length scale rather than mere thermodynamics of continuous matter.

Instead of listing just the anomalies I suggest also a possible interpretation based on the assumption that some fraction of protons (and perhaps also OH^- ions) is dark. This hypothesis is motivated by the scattering data suggesting that $H_{1.5}O$ is the proper chemical formula for water in atto-second time scale and explained by assuming that about 1/4 of protons are dark in the experimental situation. It is natural to assume that the increase of temperature or pressure reduces the dark portion. Unless the establishment of equilibrium ratio for dark and ordinary phase is very fast process, water can be regarded as a two-phase system mathematically. A continuous spectrum of metastable forms of water and ice distinguished by the ratio of the densities of ordinary and dark phase is expected. Complex phase diagrams is also a natural outcome.

Dark portion is expected to induce long range correlations affecting melting/boiling/critical points, viscosity, and heats of vaporization and fusion. Anomalous behaviors under the changes of temperature and pressure and anomalies in compressibility and thermal expansivity are expected. Specific heats and transport properties are affected by the presence of dark degrees of freedom, and the coupling of electromagnetic radiation to dark degrees of freedom influences the di-electric properties of water.

In order to systematisize the discussion I have classified the anomalous to different groups.

1. Anomalies suggesting the presence of dark phase inducing long range correlations.
   (a) Water has unusually high melting point.
   (b) Water has unusually high boiling point.
   (c) Water has unusually high critical point.
   (d) Water has unusually high surface tension and can bounce.
   (e) Water has unusually high viscosity.
   (f) Water has unusually high heat of vaporization.

   Comment: The presence of dark portion implies long range correlations and they could help to restore solid/liquid phase, raise the critical point, increase surface tension, increase viscosity and require more energy to achieve vaporization. The ability to bounce would suggest that dark portion of water -at least near the surface- is in solid phase. Dark water is in rubber-like phase also in the interior below a length scale defined by the length of dark flux tubes.

2. Anomalies related to the effect of temperature increase.
   (a) Water shrinks on melting.
   (b) Water has a high density that increases on heating (up to 3.984°C).
   (c) The number of nearest neighbors increases on melting.
   (d) The number of nearest neighbors increases with temperature.
   (e) Water shows an unusually large viscosity increase but diffusion decrease as the temperature is lowered.
   (f) At low temperatures, the self-diffusion of water increases as the density and pressure increase.

(g) Water has a low coefficient of expansion (thermal expansivity).

(h) Water's thermal expansivity reduces increasingly (becoming negative) at low temperatures.

Comment: The increase of temperature induces shrinking of the flux tubes connecting water molecules in the phase transition reducing Planck constant and brings the molecules closer to each other. This could explain shrinking on melting, the increase of the density in some temperature range above which the normal thermal expansion would win the shrinking tendency, the increase of nearest neighbors on melting and with the increase of temperature. Concerning the shrinking on melting one can however argue that the regular lattice like structure of ice is not that with minimum volume per molecule so that no new physics would be needed unless it is needed to explain why the volume per molecule is not minimum.

The unusually large viscosity increase with reduce temperature would be due to the increase of the large $\hbar$ portion inducing long range correlations. If the diffusion takes place only in the normal phase the anomalous reduction of diffusion could be due to the reduction of the density of the normal phase. Similar explanation applies to the behavior of self-diffusion.

The low value of coefficient of thermal expansion could be understood in terms of the phase transitions reducing the flux tube lengths and bringing the molecules near to each other and thus reducing the normal thermal expansion. At low enough temperatures the expansivity would become negative since this effect would overcome the normal thermal expansion.

3. Anomalies related to the effects of pressure.

(a) Pressure reduces its melting point (13.35 MPa about 133.5 times the standard atmospheric pressure) gives a melting point of -1°C)

(b) Pressure reduces the temperature of maximum density.

(c) D_2O and T_2O differ from H_2O in their physical properties much more than might be expected from their increased mass; e.g. they have increasing temperatures of maximum density (11.185°C and 13.4°C respectively).

(d) Water's viscosity decreases with pressure (at temperatures below 33°C).

Comment: The reduction of melting point, temperature of maximum density, and viscosity with pressure could be due to the reduction of the dark portion as pressure increases. Pressure would induce the phase transition reducing the value of Planck constant for the flux tubes connecting water molecules. That the situation is different for D_2O and T_2O could be understood if dark D and T are absent. The question is what happens in the transition to solid phase. The reduction of the density would conform with the idea that the portion of dark phase increases. The reduction of viscosity with pressure would would follow from the reduction of dark phase causing long range correlations.

4. Anomalies related to compressibility.

(a) Water has unusually low compressibility.

(b) The compressibility drops as temperature increases down to a minimum at about 46.5°C. Below this temperature, water is easier to compress as the temperature is lowered.
Comment: The anomalously high compressibility below 46.5°C could be understood if only the standard phase responds to pressure appreciably. In this case the effective density is smaller than the net density and make it easier to compress the water as the temperature is lowered. The increase of temperature would increase the effective density as dark matter is transformed to ordinary one and reduce the compressibility. Above 46.5°C the effect of dark matter would be overcome by the increase of compressibility due to the increase of temperature.

(c) The speed of sound increases with temperature (up to a maximum at 73°C).
Comment: The speed of sound is given by the expression

$$c^2 = \frac{\partial p}{\partial \rho} \quad .$$

Pressure p is essentially the density of thermal energy associate with the ordinary matter. When the fraction of ordinary matter increases the pressure effectively increases and this leads to the increase of c.

(d) Under high pressure water molecules move further away from each other with increasing pressure.
Comment: The behavior under increasing high pressure is in conflict with the hypothesis that pressure tends to reduce the portion of dark phase. The question is why the increase of pressure at high enough pressures would induce phase transition increasing the value of Planck constant for the flux tubes connecting the molecules? If the dark matter does not respond to pressure appreciably, the increase of the portion of dark matter might allow the minimization of energy. Does this mean that the work done by the high enough pressure to reduce the volume is larger than the energy needed to induce the tunnelling to the dark phase?

5. Anomalies related to the heat capacity.

   (a) Water has over twice the specific heat capacity of ice or steam.
   (b) The specific heat capacity (C_P and C_V) is unusually high.
   (c) Specific heat capacity C_P has a minimum.

   Comment: The anomalously high heat capacity of water could be understood in terms of dark non-translational degrees of freedom even if the dark phase is rubber-like below the length scale of the dark flux tubes. The energy pumped to the system would go to these degrees of freedom. The small heat capacity of solid phase would suggest that the freezing means also freezing of these degrees of freedom meaning the reduction of the contribution to heat capacity.

6. Anomalies related to phase transitions

   (a) Supercooled water has two phases and a second critical point at about -91°C.
   (b) Liquid water may be supercooled, in tiny droplets, down to about -70°C. It may also be produced from glassy amorphous ice between -123°C and - 149°C and may coexist with cubic ice up to -63°C.
   (c) Solid water exists in a wider variety of stable (and metastable) crystal and amorphous structures than other materials.
   (d) The heat of fusion of water with temperature exhibits a maximum at -17°C.

   Comment: The presence of both dark and ordinary phase with varying ratio of densities could help to understand the richness of the structures below freezing point. For instance, one can imagine that either the ordinary or dark phase is super-cooled and the other freezes.

7. Anomalies of solutions of water.

   (a) Solutes have varying effects on properties such as density and viscosity.
   (b) None of its solutions even approach thermodynamic ideality; even D_2O in H_2O is not ideal.
   (c) The solubilities of non-polar gases in water decrease with temperature to a minimum and then rise.

   Comment: The different interactions of solutes with the dark phase could explain these findings. For instance, the probability that the presence of solute induces a phase transition reducing the portion of the dark phase could depend on solute. The decrease of the solubilities of non-polar gases in water with temperature could be due to the fact that the solubility is at low temperatures basically due to the presence of the dark phase. At higher temperatures higher thermal energies of the solute molecules would increase the solubility.

8. Anomalies in transport properties.

   (a) NMR spin-lattice relaxation time is very short at low temperatures.
   Comment: The transfer of magnetic energy to the dark degrees of freedom could dominate the relaxation process. If synchrotron Bose-Einstein condensates are present in dark degrees of freedom this might make sense.
   (b) Hot water may freeze faster than cold water; the Mpemba effect [D12]. For instance, water sample in 100 C freezes faster than that in 35 C.
   Comment: This effect seems to be in conflict with thermodynamics and remains poorly understood. The possibility of having continuum of metastable two-phase systems

suggests a possible solution to the mystery. The freezing of the dark portion of water should occur slower than the freezing of the ordinary portion since the heat transfer rate is expected to be lower for a larger value of Planck constant. The very naïve just-for-definiteness estimate is that the transfer rate for energy to the cold system is inversely proportional to $1/\hbar$. If the formation of dark phase is a slow process as compared to the transfer of energy to the cold phase, the freezing of hot water would lead to a metastable ice consisting mostly of ordinary water molecules and takes place faster than the freezing of cold water already containing the slowly freezing dark portion.

(c) Proton and hydroxide ion mobilities are anomalously fast in an electric field.
Comment: Mobility is of form $a\tau$, where a the acceleration a in the electric field times the characteristic time τ for motion without collisions. If part of protons move along dark flux tubes this time is longer. The high mobility of OH_- ions would suggest that also these can be in dark phase.

(d) The electrical conductivity of water rises to a maximum at about 230°C and then falls.
Comment: Electrical conductivity is closely related to mobility so that the same argument applies.

(e) The thermal conductivity of water is high and rises to a maximum at about 130°C.
Comment: The anomalously high thermal conductivity could be due to the motion of heat carriers along dark flux tubes with low dissipation.

(f) Warm water vibrates longer than cold water.
Comment: This could be due to the faster transfer of vibrational energy to the dark vibrational of magnetic degrees of freedom. If the number of these degrees of freedom is higher than the number of ordinary degrees of freedom, one can understand also the anomalously high heat capacity. Vibration could continue in dark degrees of freedom in which case the effect would be apparent. If its only the ordinary water which vibrates in the original situation then equipartition of energy with dark degrees of freedom implies apparent dissipation.

9. Anomalous electromagnetic properties of water.

(a) X-ray diffraction shows an unusually detailed structure.
Comment: This would not be surprising if two phases with possibly varying ratio are present. For instance, the different X-ray diffraction patterns for water obtained by a rapid freezing from high and low temperatures could serve as a test for the proposed explanation of Mpemba effect.

(b) The dielectric constant is high and behaves anomalously with temperature.
Comment: This could relate to the interaction of photons with dark portion of water. Dielectric constant characterizes the coupling of radiation to oscillatory degrees of freedom and is sum of terms proportional to $1/(\omega^2 - \omega_i^2)$, where ω_i is resonance frequency. If the resonance frequencies ω_i scale as $1/\hbar$, dark portion gives a larger contribution at frequencies $\omega < \omega_i$. In particular the static dielectric constant increases.

(c) The refractive index of water has a maximum value at just below 0°C.
Comment: It is not quite clear whether this maximum corresponds to room pressure or appears quite generally. Let us assume the first option. In any case the dependence of the freezing temperature on pressure is very weak. The maximal interaction with the dark portion of water at freezing point combined with the above argument would predict that refractive index increases down to the freezing point. The reduction of the density at freezing point would reduce the refractive index since dynamic susceptibility is proportional to the density of atom so that a maximum would be the outcome.

These examples might serve as a motivation for an attempt to build a more detailed model for the dark portion of water. The model to be discussed was one of the first attempts to understand the implications of the idea about hierarchy of Planck constants. Since five years have passed is badly in need of updating.

11.6.2 The Model

Networks of directed hydrogen bonds $H - O - H \cdots OH_2$ with positively charged H acting as a binding unit between negatively charged O (donor) and OH_2 (acceptor) bonds explaining clustering of water molecules can be used to explain qualitatively many of the anomalies at least qualitatively [D104].

The anomaly giving evidence for anomalous nuclear physics is that the physical properties D_2O and T_2O differ much more from H_2O than one might expect on basis of increased masses of water molecules. This suggests that dark protons could be responsible for the anomalies. That heavy water in large concentrations acts as a poison is consistent with the view that the macroscopic quantum phase of dark protons is responsible for the special biological role of water.

What proton darkness could mean?

In the experimental situation one fourth of protons of water are not seen in neither electron nor neutron scattering in atto-second time scale which translates 3 Angstrom wavelength scale suggesting that in both cases diffraction scattering is in question. This of course does not mean that the fraction of dark protons is always 1/4 and it is indeed natural to assume that it is reduced at higher temperatures. Both nuclear strong interactions and magnetic scattering contribute to the diffraction which is sensitive to the intra-atomic distances. The minimal conclusion is that the protons form a separate phase with inter-proton distance sufficiently different from that between water molecules and are not seen in neutron and electron diffraction in the atto-second time scale at which protons of water molecule are visible. The stronger conclusion is that they are dark with respect to nuclear strong interactions.

The previous considerations inspired by the model of nuclei as nuclear strings suggests possible explanations.

1. Hydrogen atoms form analogs of nuclear strings connected by color bonds.
2. Nuclear protons form super-nuclei connected by dark color bonds or belong to such super-nuclei (possibly consisting of ^4He nuclei). If color bonds are negatively charged, closed nuclear strings of this kind are neutral and not visible in electron scattering: this assumption is however un-necessarily strong for invisibility in diffractive scattering in atto-second time scale. Only the field bodies of proton carrying weak and color fields could be dark and electromagnetic field body has ordinary value of Planck constant so that dark protons could give rise to ordinary hydrogen atoms.

Could also the color flux tubes connecting quarks inside dark protons be dark?

The first option is that only the color flux tubes connecting protons are dark and of length of atomic size scale. The second possibility is that also the color flux tubes connecting quarks are dark and have length of order atomic size scale. Dark nucleons could be visualized as strings formed from three quarks of order atom size scale connected by color flux tubes. The generalization of the nuclear string model leads to a model of dark nucleon discussed in detail [L4, K51, K118], [L4]. Dark nucleons would in turn form dark nuclei as string like objects.

The amazing finding is that the states of nucleon assumed to be neutral (for definiteness) are in one-one-correspondence with DNA, RNA, mRNA, tRNA and amino-acids and that a physically natural pairing of DNA codons and amino-acids exists and consistent with vertebrate genetic code. Same applies also to nucleons having the charge of proton. The nuclear strings formed from either dark neutrons or dark protons could in principle realize genetic code. This realization would be more fundamental than the usual chemical realization and would force to modify profoundly the ideas about prebiotic evolution. The prebiotic evolution could be evolution of water and the recent evolution could involve genetic engineering based on virtual world experimentation with the dark variant variant of the genetic apparatus. The minimum requirement would be the transcription of at dark DNA defined by nuclear strings to ordinary DNA. Dark nuclear strings could be able to diffuse without difficulties through cell membranes and the transcription of the dark genes to ordinary ones followed by gluing and pasting to genome could make possible the genetic engineering at the level of germ cells.

Another natural hypothesis is that the magnetic bodies assignable to the nuclear strings are responsible for water memory [K51] and that the mechanism of water memory relies on the mimicry of biologically active molecules by dark proton strings. The frequencies involved with water memory are low and nothing to do with molecular energy levels. This is consistent with the identification as cyclotron frequencies so that it would be enough to mimic only the cyclotron spectrum. The mechanism would be similar to that of entrainment of brain to external frequencies and based on the variation of the thickness of magnetic flux tubes or sheets inducing the change of magnetic field and cyclotron frequency. One could perhaps say that magnetic bodies of dark genes as living creatures with some amount of intelligence and ability to planned actions. The evolution of cells up to the neurons of cortex could be accompanied by the evolution of the magnetic bodies of dark nuclear strings realized as the emergence of higher values of Planck constant.

Concerning the mechanism of the debated homeopathic effect itself the situation remains unclear. Homeopathic remedy is obtained by a repeated dilution and succussion of the solution containing the molecules causing the symptoms of the disease [K51]. If the cyclotron frequencies of the magnetic body alone are responsible for the biological effect, one can wonder why the homeopathic remedy does not have the same undesired effects as the original molecule. A more reasonable hypothesis is that the cyclotron frequency spectrums serves only as a signature of the molecule and the homeopathic remedy only activates the immune system of the organism by cheating it to believe that the undesired molecules are present. The immune system is known to be subject to very fast genetic evolution, and dark nuclear strings forming representations of biologically active molecules and dark genome could be actively involved with this evolution.

What inspires to take these speculations more than as a poor quality entertainment is that the recent findings of the group led by HIV Nobelist Montagnier related to water memory provide support for the hypothesis that a nonstandard realization of genetic code indeed exists [I15]. These findings will be discussed later in this section.

Model for super-nuclei formed from dark protons

Dark protons could form super nuclei with nucleons connected by dark color bonds with $\hbar = r\hbar_0$ with $r = 2^{k_d}$, $k_d = 151 - 127 = 24$. The large distance between protons would eliminate isospin dependent strong force so that multi-proton states are indeed possible. The interpretation would be that nuclear p-adic length scale is zoomed up to $L(113+24 = 137) \sim .78$ Angstroms. Dark color bonds could also connect different nuclei. The earlier hypothesis $r = 2^{11k}$ encourages to consider also $k_d = 22$, which is also one of the favored dark scalings allowed by Mersenne hypothesis $(22 = 18 + 4 = 107 - 89 + 167 - 163)$ giving p-adic scale .39 Angstroms.

The predictions of the model for bond energy depend on the transformation properties of E_s under the scaling of $\hbar$.

1. For small perturbations harmonic oscillator approximation $V \propto kR^2/2 \propto \alpha R^2/2$ makes sense and is invariant under the scalings $\alpha_s \to \alpha_s/r$ and $R \to \sqrt{r}R$ -at least if the scalings are not too large. Bonds with different values of Planck constant have nearly identical energies, which would be indeed consistent with the idea about criticality against the change of Planck constant.

   One can arrive the same conclusion follows also in different manner. The parameter ω corresponds to a quantity of form $\omega = v/L$, where L is a characteristic length scale and v a characteristic velocity. The scaling law of homeopathy [K51] would suggest the dependence $v = c/\sqrt{r}$ and $L \propto \sqrt{r}L$ giving predicting that energy is invariant.

   The result also conforms with the idea that classical perturbative theory does not involve Planck constant. This behavior does not however allow to identify hydrogen as color bonds since the resulting bond energies would be in MeV range.

2. The interpretation of E_s as color Coulombic potential energy α_s/R would suggest that E_s behaves under scaling like the binding energy of hydrogen atom ($1/r^2$ scaling). This interpretation implies non-perturbative effects since in semiclassical approximation energy should not depend on r. Color force is non-perturbative so that one can defend this assumption.

   (a) For $k_d = 24$ E_s would be about.12 eV and considerably lower than the nominal energy of the hydrogen bond.

   (b) For $k_d = 22$ one would obtain energy .48 eV. This energy is same as the universal metabolic energy quantum so that the basic metabolic processes might involve transitions dark-ordinary transition for protons. This would however suggest that the length of color bond is same as that of hydrogen bond so that the protons in question would not be invisible in diffraction in atto-second time scale. The interpretation of color bonds between atoms as hydrogen bonds is much more attractive. Of course, for large values of Planck the invariance of oscillator spectrum implies very large force constant so that the color bond would become very rigid.

These two interpretations are not contradictory if one interprets the non-perturbative contribution to the color binding energy as an additional constant contribution to the harmonic oscillator Hamiltonian which does not contribute the spectrum of excitations energies but only to the ground state energy.

The notion of flux tube state

An approach based more heavily on first principles that the above order of magnitude estimates is inspired by two steps of progress several years after these speculations.

1. Weak form of electric-magnetic duality

The weak form of electric magnetic duality led to an identification of a concrete mechanism of electroweak screening based on the pairing of homological Kähler magnetic monopoles formed by fermion wormhole throats with oppositely magnetically charged wormhole throats carrying quantum numbers of neutrino pair and screening the weak isospin and leaving only electromagnetic charge.

1. The size scale of the Kähler magnetic flux tubes connecting the magnetic monopoles would be of order intermediate gauge boson Compton length. For dark variants of elementary fermions it would be scaled up by $\sqrt{\hbar/\hbar_0}$. The new weak physics involving long range weak fields would be associated with magnetic flux tube like structures. Same conclusion applies also to new QCD type physics since also color confinement would be accompanied Kähler magnetic confinement. This allows to pose very strong restrictions on the models. For instance, it is quite possible that the notion of neutrino atom does not make sense expect if one can assume that the dark quarks feed their weak Z^0 gauge fluxes through a spherically symmetric flux collection of radial flux tubes allowing Coulombic Z^0 gauge potential as an approximate representation inside the radius defined by the length of the flux tubes.
2. It is important to notice that the screening leaves the vectorial coupling to classical Z^0 field proportional to $sin^2(\theta_W)Q_{em}$. This could have non-trivial physical implications perhaps allowing to kill the model.
   (a) For space-time surfaces near vacuum extremals the classical Z^0 fields are strong due to the condition that the induced Kähler field is very weak. More explicitly, from the equations for classical induced gauge fields in terms of Kähler form and classical Z^0 field [L3], [L3]

   $$\gamma = 3J - \frac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = sin^2(\theta_W) \tag{11.6.1}$$

   it follows that for the vacuum extremals the part of the classical electro-weak force proportional to the electromagnetic charge vanishes for $p = 0$ so that only the left-handed couplings to the weak gauge bosons remain. The vanishing of induced Kähler form gives

   $$Z^0 = -\frac{2}{p}\gamma \ . \tag{11.6.2}$$

   The condition implies very large effective coupling to the classical electromagnetic field since electromagnetic charge is effectively replaced with

   $$Q_{em,eff} = Q_{em} - \frac{2}{p}(I_L^3 - pQ_{em}) \ . \tag{11.6.3}$$

   (b) The proposed model for cell membrane as a Josephson junction relies on almost vacuum extremals and dark nuclei in the sense that the weak space-time sheet associated with the nuclei of biological important ions (at least) are dark [K88]. It is is assumed that quarks are dark in the length scale considered so that also their weak isospin remains unscreened. In the case of nuclei this means that there is contribution from the vectorial part of weak isospin given by $(Z-N)/4$ proportional to the difference of proton number and neutron number. The dominating contribution comes from Q_{em} term for heavier nuclei. It is essential that weak space-time sheets of electrons are assumed to be ordinary.

(c) One can ask whether the nuclei could be ordinary nuclei. If so, one must still assume that the electrons of the nuclei do not couple to the classical fields assignable to the cell membrane space-time sheet since without this assumption the coupling to Z^0 field would be proportional to the total em charge of the ion rather than nuclear em charge. It is difficult to justify this assumption. In any case, for this option I_L^3 contribution would be totally absent. This affects the effective couplings of biologically important ions to the membrane potential somewhat and modifies the nice quantitative predictions of the model of photoreceptors predicting correctly the frequencies of visible light with maximal response.

2. The notion of flux tube state

The TGD inspired explanation for the finding that the measurement of Lamb shift for muonic hydrogen atom gives proton radius which is 4 per cent smaller than that deducible from ordinary hydrogen atom led to the notion of flux tube state in which muon or electric is confined inside flux tube [K66]. In non-relativistic approximation based on Schrödinger equation, the model leads to wave functions expressible in terms of Airy and "Bairy" functions and WKB approximation allows to deduce an estimate for the energy eigenvalue spectrum. This model works as such also as a model for flux tubes states in which also classical electroweakandcolor fields are involved. Color holonomy is quite generally Abelian for classical color fields and for 2-D CP_2 projection electroweak fields are also Abelian so that the model is expected to be mathematically reasonably simple even when induced spinors are assumed.

The concept of flux tube state is very general and allow to model at least some chemical bonds. In particular, valence bonds might allow description as flux tube states of valence electrons. Hydrogen bonds are responsible for the clustering of water molecules and an obvious question is whether these bonds could be modeled as dark flux tube states of valence electrons. The model is testable since one can predict the energy spectrum of excited states for given thickness of the flux tube and the value of electric flux through it. Also the flux tube states of say electrons assignable to the magnetic flux tubes assumed to connect DNA nucleotides and lipids of cell membrane in the model of DNA as topological quantum computer [K4] could be relevant.

Two kinds of bonds are predicted

Duppose that dark bonds are associated with the electro-magnetic field body. If classical Z^0 field vanishes, em field is proportional to Kähler field as are also the components of the classical color field. The bonds involving classical color gauge fields could have quark and antiquark at the opposite ends of the flux tube as the source of the color gauge field. This is indeed assumed in the model of DNA as topological quantum computer [K4].

If one wants vanishing or very weak color gauge fields, one must allow almost vacuum extremals. This implies that classical Z^0 force is strong and the situation assumed to prevail for the cell membrane would hold also for hydrogen bonds. For almost vacuum extremals the ratio of electric and Z^0 fluxes is so small- of order 1/50 for the small value of Weinberg angle $p = .0295$ (rather than $p \simeq .23$) if appearing as the parameter of the model. The molecule can serve as the source of classical Z^0 and electromagnetic fields in two ways.

1. The almost vacuum flux tubes could have many neutrino state and its conjugate at the opposite ends of the flux tube acting as the source of the classical Z^0 field. This kind of flux tubes would traverse through the cell membrane.
2. The molecule would be accompanied by two kinds of flux tubes. Some of them would be almost vacuum extremals carrying an electric flux much smaller than elementary charge e. Some of them would be accompanied by very weak Z^0 field and electromagnetic field plus color gauge fields generated by the above mechanism. These flux tubes would connect cell membrane and genome.

Two kinds of hydrogen bonds

There is experimental evidence for two different hydrogen bonds. Li and Ross represent experimental evidence for two kinds of hydrogen bonds in ice in an article published in Nature 1993 [D101]. The ratio of the force constants K associated with the bonds is 1: 2.

The proposed scaling law $\omega \to \omega/r$ predicts $\omega \propto 1/r$ so that $k_d \to k_d + 1$ would explain the reduction of the force constant by factor 1/2. The presence of two kinds of bonds could be also seen as a reflection of quantum criticality against change of Planck constant.

Can one understand the finding in terms of dark color bonds?

1. The model is consistent with the identification of the two bonds in terms different values of Planck constant. The proposed scaling law for ω predicts $\omega \propto 1/r$ so that $k_d \to k_d + 1$ would explain the reduction of the force constant by factor 1/2. above described general model for which bond energy contains perturbative harmonic oscillator contribution and non-perturbative Coulombic contribution.

2. The identification of hydrogen bond as dark color bond is however questionable. If bond energy contains a color binding energy scaling as $1/r^2$ contributing only constant shift to the harmonic oscillator Hamiltonian, the behavior of the force constant is consistent with the model. If one assumes that the harmonic oscillator spectrum remains invariant under large scalings of $\hbar$, the force constant becomes extremely strong and the color bond would be by a factor r^2 more rigid than hydrogen bond if one takes seriously the proposed estimates for the value of r. The alternative interpretation would be in terms of almost vacuum extremal property reducing the force constant to a very small value already from the beginning.

The possibility to divide the bonds to two kinds of bonds in an arbitrary manner brings in a large ground state degeneracy given by $D = 16!/(8!)^2$ unless additional symmetries are assumed and give for the system spin glass like character and explain large number of different amorphous phases for ice [D104]. This degeneracy would also make possible information storage and provide water with memory.

Hydrogen bonds as color bonds between nuclei?

The original hypothesis was that there are two kinds of hydrogen bonds: dark and “ordinary”. The finding that the estimate for the energy of dark nuclear color bond with $k_d = 22$ equals to the energy of typical hydrogen bond raises the question whether all hydrogen bonds are associated with color bonds between nuclei. Color bond would bind the proton to electronegative nucleus and this would lead to the formation of hydrogen bond at the level of valence electrons as hydrogen donates its electron to the electronegative atom. The electronic contribution would explain the variation of the bond energy.

If hydrogen bonds connect H-atom to O-atom to acceptor nucleus, if E_s for p-O bond is same as for p-n color bond, and if color bonds are dark with $k_d = 22$, the bond energy $E_s = .5$ eV. Besides this one must assume that the oscillator energy is very small and comparable to the energy of hydrogen bond - this could be due to almost vacuum extremal property.

Dark -possibly (almost unavoidably) colored or weakly charged- bonds could serve as a prerequisite for the formation of electronic parts of hydrogen bonds and could be associated also with other molecular bonds so that dark nuclear physics might be essential part of molecular physics. Dark color bonds could be also charged which brings in additional exotic effects. The long range order of hydrogen bonded liquids could due to the ordinary hydrogen bonds. An interesting question is whether nuclear color bonds could be responsible for the long range order of all liquids. If so dark nuclear physics would be also crucial for the understanding of the condensed matter.

In the case of water the presence of dark color bonds between dark protons would bring in additional long range order in length scale of order 10 Angstrom characteristic for DNA transversal scale: also hydrogen bonds play a crucial role in DNA double strand. Two kinds of bond networks could allow to understand why water is so different from other molecular liquids containing also hydrogen atoms and the long range order of water molecule clusters would reflect basically the long range order of two kinds of dark nuclei.

Recall that the model for dark nucleons predicts that nucleon states can be grouped to states in one-one correspondence with DNA, RNA, tRNA, and amino-acids and that the degeneracies of the vertebrate genetic code are predicted correctly. This led to suggestion that genetic code is realized already at the level of dark nuclei consisting of sequences of neutrons [L4, K118], [L4] . Neutrons were assumed in order to achieve stability and could be replaced with protons.

Tedrahedral and icosahedral clusters of water molecules and dark color bonds

Water molecules form both tetrahedral and icosahedral clusters. ^4He corresponds to tetrahedral symmetry so that tetrahedral cluster could be the condensed matter counterpart of ^4He. It the nuclear string model nuclear strings consist of maximum number of ^4He nuclei themselves closed strings in shorter length scale.

The p-adic length scales associated with ^4He nuclei and nuclear string are $k = 116$ and $k = 127$ The color bond between ^4He units has $E_s = .2$ MeV and $r = 2^{22}$ would give by scaling $E_s = .05$ eV which is the already familiar energy associated with cell membrane potential at the threshold for the nerve pulse generation. The binding energy associated with a string formed by n tetrahedral clusters would be n^2E_s. This observation raises the question whether the neural firing is accompanied by the re-organization of strings formed by the tetrahedral clusters and possibly responsible for a representation of information and water memory.

The icosahedral model [D104] for water clusters assumes that 20 tetrahedral clusters, each of them containing 14 molecules, combine to form icosahedral clusters containing 280 water molecules. Concerning the explanation of anomalies, the key observation is that icosahedral clusters have a smaller volume per water molecule than tetrahedral clusters but cannot form a lattice structure.

The number 20 for the dark magic dark nuclei forming the icosahedron is also a magic number and a possible interpretation for tetrahedral and icosahedral water clusters would be as magic super-nuclei and the prediction would be that binding energy behaves as n^2E_s rather than being just the sum of the binding energies of hydrogen bonds (nE_s).

It is interesting to compare this model with the model for hexagonal ice which assumes four hydrogen bonds per water molecule: for two of them the molecule acts as a donor and for two of them as an acceptor. Each water molecule in the vertices of a tetrahedron containing 14 hydrogen atoms has a hydrogen bond to a water molecule in the interior, each of which have 3 hydrogen bonds to molecules at the middle points of the edges of the tetrahedron. This makes 16 hydrogen bonds altogether. If all of them are of first type with bonding energy $E_s = .5$ eV and if the bond network is connected one would obtain total bond energy equal to $n^2E_s = 258 \times .5$ eV rather than only $nE_s = 16 \times .5$ eV. Bonds of second type would have no role in the model.

Tedrahedral and icosahedral clusters and dark electrons

An interesting question is whether one could interpret tetrahedral and icosahedral symmetries in terms of symmetries of the singular coverings or factor spaces of CD. This does not seem to be the case.

1. One cannot understand discrete molecular symmetries for factor space-space option since the symmetry related points of CD would correspond to one and same space-time point.

2. For the option allowing only singular coverings of $CD \times CP_2$ interpreted in terms of many-valuedness of the time derivatives of the embedding space coordinates as functions of canonical momentum densities this interpretation is not possible.

3. One can also consider the possibility that the singular coverings are over $(CD/G_a)\times(CP_2/G_b)$ rather than $CD\times CP_2$. This would predict Planck constant to be of form $r = n_an_b$, with $n_a = 3$ for tetrahedral clusters and $n_a = 5$ for icosahedral clusters. n_a and n_b would correspond to the orders of maximal cyclic subgroups of the corresponding symmetry groups. There would be a deviation from the simplest proposal for preferred Planck constants. This option would require space-time surfaces to have exact discrete symmetries and this does not look plausible.

Note that synaptic contacts contain clathrin molecules which are truncated icosahedrons and form lattice structures and are speculated to be involved with quantum computation like activities possibly performed by microtubules. Many viruses have the shape of icosahedron.

It should be noticed that single nucleotide in DNA double strands corresponds to a twist of $2\pi/10$ per single DNA triplet so that 10 DNA strands corresponding to length $L(151) = 10$ nm (cell membrane thickness) correspond to $3 \times 2\pi$ twist. This could be perhaps interpreted as evidence for group C_{10} perhaps making possible quantum computation at the level of DNA.

11.6.3 Further Comments On 41 Anomalies

Some clarifying general comments -now in more standard conceptual framework- about the anomalies are in order. Quite generally, it seems that it is the presence of new degrees of freedom, the presence of icosahedral clusters, and possibly also macroscopic quantum coherence of dark matter, which are responsible for the peculiar properties of water.

The hydrogen bonds assigned to tetrahedral and icosahedral clusters should be same so that if the hydrogen bonds are assignable to dark protons this is the case for all clusters. Perhaps the number of dark protons and -perhaps equivalently- hydrogen bonds per volume is what distinguishes between these clusters and that the disappearance of dark protons leads to the disappearance of hydrogen bonds. Since it is quite possible that no new physics of proposed kind is involved, the following the explanation of anomalies uses only the notions of icosahedral and tetrahedral clusters and dark protons are mentioned only in passing.

1. Anomalies relating to the presence of icosahedral clusters

Icosahedral water clusters have a better packing ratio than tetrahedral lattice and thus correspond to a larger density. They also minimize energy but cannot cannot form a lattice [D104].

1. This explains the unusually high melting point, boiling point, critical point, surface tension, viscosity, heat of vaporization, shrinking on melting, high density increasing on heating, increase of the number of nearest neighbors in melting and with temperature. It is also possible to understand why X-ray diffraction shows an unusually detailed structure.

   The presence of icosahedral clusters allows to understand why liquid water can be super-cooled, and why the distances of water molecules increase under high pressure. The spin glass degeneracy implied by dark and ordinary hydrogen bonds could explain why ice has many glassy amorphous phases. The two phases of super-cooled water could correspond to the binary degree of freedom brought in by two different hydrogen bonds. For the first phase both hydrogen atoms of a given water molecule would be either dark or ordinary. For the second phase the first hydrogen atom would be dark and second one ordinary.

   Since icosahedral clusters have lower energy than a piece of ice of same size, they tend to super-cool and this slows down the transition to the solid phase. The reason why hot water cools faster would be that the number of icosahedral clusters is smaller: if cooling is carried with a sufficient efficiency icosahedral clusters do not form.

2. Pressure can be visualized as a particle bombardment of water clusters tending to reduce their volume. The collisions with particles can induce local transitions of icosahedral structures to tetrahedral structures with a larger specific volume and energy. This would explain the low compressibility of water and why pressure reduces melting point and the temperature of maximum density and viscosity.

3. The increase of temperature is expected to reduce the number of icosahedral clusters so that the effect of pressure on these clusters is not so large. This explains the increase of compressibility with temperature below 46.5°C. The fact that the collapse of icosahedral clusters opposes the usual thermal expansion is consistent with the low thermal expansivity as well as the change of sign of expansivity near melting point. Since the square of sound velocity is inversely proportional to compressibility and density, also the increase of speed of sound with temperature can be understood.

2. The presence of dark degrees of freedom and spin glass degeneracy

The presence of dark degrees of freedom and the degeneracy of dark nucleus ground states could explain the high specific heat capacity of water. The reduction of dark matter degrees of freedom for ice and steam would explain why water has over twice the specific heat capacity of ice or steam. The possibility to relax by dissipating energy to the dark matter degrees of freedom would explain the short spin-lattice relaxation time. The fact that cold water has more degrees of freedom explains why warm water vibrates longer than cold water.

Also the high thermal and electric conductivity of water could be understood. The so called Grotthuss [I5] [D104] explaining OH_- and H_+ mobilities (related closely to conductivities) is based on hopping of electron of OH_- and H_+ in the network formed by hydrogen bonds and generalizes to the recent case. The reduction of conductivity with temperature would be due to the storage of the transferred energy/capture of charge carriers to the water molecule clusters.

3. Macroscopic quantum coherence

The high value of dielectric constant could derive from the fact that dark nuclei and super-nuclei are quantum coherent in a rather long length scale. For curl free electric fields potential difference must be same along space-time sheets of matter and dark matter. The synchronous quantum coherent collective motion of dark protons (and possible dark electrons) in an oscillating external electric field generates dark photon laser beams (it is not clear yet whether these dark laser beams are actually ordinary laser beams) de-cohering to ordinary photons and yield a large dynamical polarization. As the temperature is lowered the effect becomes stronger.

11.6.4 The strange properties of water as indication for the existence of dark matter in TGD sense

The motivation for this brief comment came from a popular article telling that a new phase of water has been discovered in the temperature range 50-60 °C (see `http://tinyurl.com/h4wlf6o`. Also Gerald Pollack [L24] (see `http://tinyurl.com/oyhstc2`) has introduced what he calls the fourth phase of water. For instance, in this phase water consists of hexagonal layers with effective $H_{1.5}O$ stoichiometry and the phase has high negative charge. This phase plays a key role in TGD based quantum biology. These two fourth phases of water could relate to each other if there exist a deeper mechanism explaining both these phases and various anomalies of water.

Martin Chaplin (see `http://tinyurl.com/ye77f7d`) has an extensive web page about various properties of water. The physics of water is full of anomalous features and therefore the page is a treasure trove for anyone ready to give up the reductionistic dogma. The site discusses the structure, thermodynamics, and chemistry of water. Even academically dangerous topics such as water memory and homeopathy are discussed.

One learns from this site that the physics of water involves numerous anomalies (see `http://tinyurl.com/hs77fsh`). The structural, dynamic and thermodynamic anomalies form a nested in density-temperature plane. For liquid water at atmospheric pressure of 1 bar the anomalies appear in the temperature interval 0-100 °C.

Hydrogen bonding creating a cohesion between water molecules distinguishes water from other substances. Hydrogen bonds induce the clustering of water molecules in liquid water. Hydrogen bonding is also highly relevant for the phase diagram of H_2O coding for various thermodynamical properties of water (see `http://tinyurl.com/hr77ou5`). In biochemistry hydrogen bonding is involved with hydration. Bio-molecules - say amino-acids - are classified to hydrophobic, hydrophilic, and amphiphilic ones and this characterization determines to a high extent the behavior of the molecule in liquid water environment. Protein folding represents one example of this.

Anomalies are often thought to reduce to hydrogen bonding. Whether this is the case, is not obvious to me and this is why I find water so fascinating substance.

Examples of anomalies

Some examples about anomalies are in order.

1. The high cohesion between water molecules due to hydrogen bonds gives it exceptionally high freezing and boiling points. The high latent heat of evaporation implied by hydrogen bond gives a high resistance to hydration and high evaporative cooling. Hydrogen bonds also give rise to an especially high surface tension.

   Water has unique hydration properties with respect to the basic biomolecules. Hydration leads to the formation of gels, which can reversibly undergo gel-sol phase transitions important for the physics of life. Water ionizes easily and proton transfer reactions between molecules giving rise to rich interactions in biochemistry.

2. Solid (liquid) water has anomalously low (high) density so that the difference between densities of liquid and solid states is small. In the range 0-4 °C water compresses (becomes more dense

than solid phase) when heated at constant pressure rather than expanding as other liquids. This anomaly is fundamental for life.

3. Water has anomalously high specific heat capacity $c_p = dC_p/dM$, $C_p = (dE/dT)_p$. This might be understood in terms of breaking of hydrogen bonds giving rise to new translational degrees of freedom as water molecules begin to move freely.

   The specific heat capacity c_p of liquid water at atmospheric pressure decreases in the interval 5-37 °C, and increases in the range 37-100 °C. The minimum is at physiological temperature (see `http://tinyurl.com/zfv22yz`) - hardly an accident. For other liquids c_p increases steadily in this interval. The compressibility of water depicts similar behavior distinguishing water from other liquids.

4. Mpemba effect (see `http://tinyurl.com/7h2h59p`) means that hot water freezes faster than cold water. The effect is maximal at 35 °C, which is remarkably close to the physiological temperature. Mpemba effect challenges the naïve views about what happens in freezing, and several explanations have been proposed.

The anomalies of water in TGD framework

What TGD can say about these anomalies? I have already earlier considered a model of water explaining some of the basic anomalies and it is interesting to see whether the recent understanding of TGD might allow more precise articulation of the basic ideas.

1. The TGD inspired model assumes that water consists of ordinary water plus dark water. Dark matter is identified in TGD framework as phases of ordinary matter but with effective Planck constant h_{eff}, which is integer multiple $h_{eff}/h = n$ of the ordinary Planck constant. This proposal is motivated by several experimental findings. In particular, Pollack effect leading to a generation of negatively charged exclusion zones (EZs) with effective stoichiometry of water to $H_{1.5}O$ would be due to the transfer of one-over-fourth of protons do dark protons at magnetic flux tubes.

   One must be careful in defining what "dark" means. Does dark matter include only the dark particles at flux tubes or does it include also the water molecules connected by these flux tubes? The following considerations suggest that the latter definition allowing to talk about dark water is more appropriate.

2. The dark matter at magnetic flux tubes could involve also other particles than protons (electrons and even ions) and would serve as the "boss" controlling biochemistry in TGD based view about biology. The communications between visible matter and dark particles at magnetic flux tubes would rely on dark photons with energy $E = h_{eff}f$, which can be above thermal energy for even EEG frequencies. This makes possible interaction between widely different length and time scales.

3. $h_{eff}/h = n$ phases would be generated at quantum criticality and serve as correlates for long range correlations and fluctuations at criticality. The transformation of ordinary protons to dark protons and vice versa could be essential for proton transfer reactions and even give rise to high Tc super-conductivity along dark flux tubes based on pairs of parallel flux tubes carrying the members of Cooper pairs.

4. Several values of h_{eff}/h are possible. The matter visible to us need not correspond to the minimal value of h. The hydrino atoms with scaled up binding energy spectrum claimed by Randell Mills [D58] could be understood if $h_{eff}/h = n$ for ordinary atomics equals to $n = 6$ and hydrino atoms have $n < 6$ [L42].

I am not trying to give any summary about various anomalies of water in the following but consider only the above mentioned examples from TGD point of view. Let us therefore make following assumptions (one could represent these assumptions also as questions).

1. Water consists of ordinary and dark fractions. Several values of $h_{eff}/h = n$ are possible and their fractions depend on pressure and temperature. These two fractions can be present in both solid and liquid states. The dark fraction of water - say dark proton sequences at magnetic flux tubes leading also to the notion of dark variant of genetic code inducing the ordinary chemical code [L36] - does not interact directly with ordinary water except

via classical em fields (this is important!). More generally, phases with different values of n are dark relative to each other. The quantal interactions are only via exchange of dark photons transforming to ordinary photons identified in biology as bio-photons or vice versa. The additional assumption $h_{eff} = h_{gr}$, where h_{gr} is gravitational Planck constant [K80, ?], guarantees that the cyclotron energy spectrum of dark photons is universal and corresponds to that for bio-photons (visible and UV) [K13].

The presence of dark protons implies the generation of negative electronic charge. Could repulsive Coulomb interactions become significant and lead to an expansion of water possibly relevant for the understanding of the anomalously low density of ice?

2. Hydrogen bond is thought to be essential for the understanding of the anomalies. Hydrogen bonds could correspond in TGD framework to short and rigid flux tubes. Large values of n scaling up the flux tube lengths would give rise to longer, possibly loop-like, magnetic flux tubes. Indeed, if the total magnetic energy is not changed the string tension defined as magnetic energy density is reduced like $1/n$. Flux tubes could form a dynamical network in which reconnections and phase transitions changing the value of n would make the topology of the network dynamical.

   This kind of flux tube network could give rise to TGD analog of tensor networks [L40] realizing quantum entanglement between the nodes of the network and to be central for the formation of gel phase explaining the quantum coherence of water in vivo. The generalization of the usual picture behind bio-chemistry in which one has only molecules to a flux tube network having various particles at its nodes would allow to understand the emergence of complexity in both condensed matter physics and biology [L40].

   Hydration, dehydration and gel-sol phase transition could involve a phase transition changing the value of n and transforming the hydrogen bonds to longer flux tubes and vice versa. These phase transitions would be also essential in bio-catalysis. It would seem that the natural formulation for various anomalies would be in terms of the flux tube network, whose connectivity depends on temperature and pressure.

3. Dark particles are generated at quantum criticality and quantum criticality could accompany also ordinary thermal phase transitions such as freezing of water.

4. One can imagine several models for the dark fraction of water. Since the temperature range 0-100 °C involves several anomalies, it is natural to assume that the dark fraction of water varies as function of p and T. It seems also safe to assume that the hydrogen bonding becomes maximal at freezing and the bonds identifiable as flux tubes become short. Since the anomalies are strongest around physiological temperature 37 °C, TGD inspired model of quantum biology suggests that dark fraction is highest near this temperature. One expects several fractions with different values of n depending on temperature and pressure.

5. Why water would be so special? Also other liquids could involve flux tubes but with small value of n and therefore much shorter than those in water. Hydrogen bonds in water would also have larger value of n than for other substances. Heavy water does not share the anomalies of ordinary water although the electronic chemistry is the same. The large mass of deuterium probably prevents the formation of dark deuterium. Maybe the fact that the Compton length of (also dark) deuterium is 1/2 of that for (dark) proton could be significant and prevents the formation of dark deuterium bonds?

   Hydrogen bonds are usually associated with electronegative atoms - usually F, O, and N (see `http://tinyurl.com/bntn28n`). Also hydrogen bond between hydrogen and carbon is possible when C is bound to electronegative atoms (chloroform $CHCl_3$ is one example). Note that H_2S, which is chemical analog of water, can form hydrogen with F but two H_2S molecules do not form hydrogen bonds so that H_2S based life is not possible.

Consider first a model for what could happen in the range $0 - 4$ °C under normal pressure.

1. The presence of negative electronic charge induced by the transfer of dark protons to magnetic flux tubes might explain the larger volume of ice as compared to liquid water above 4 °C. The standard explanation is in terms of hydrogen bonds leading to rigid clusters with average distance between water molecules longer than in ordinary water. If hydrogen bonds correspond to short rigid flux tubes these explanations are consistent. The positive charge of dark protons

would generate classical Coulomb fields and neutralize this negative charge non-locally as a kind of smooth background so that neutralization would take place in longer length scale and lead to a lower density.

2. What would happen at the interval $0 - 4$ °C? Do the dark protons at flux tubes assigned to hydrogen bonds transform to ordinary ones and reduce the number of hydrogen bonds and lead to a reduction of the density? Or does the average value of n assignable to the flux tubes increase and increase the average length of flux tubes? Heating would transforms short and rigid flux tubes (hydrogen bonds) to longer and loopy ones. If the magnetic energy is conserved, string tension must scale down by $1/n$ leading to the melting of flux tubes. The melted loopy flux tubes would be longer but their ends could become nearer to each other.

   Melting would thus have a counterpart at the level of magnetic body. Could the freezing of the flux tubes induce the freezing of water? Could the dynamics of ordinary water fraction of water be governed by that of the dark fraction? TGD inspired biology assumes that magnetic body carrying dark matter serves as a template for biochemistry. Could this be true also for thermodynamics?

One can try to explain the anomalies of heat capacity in this picture.

1. Specific heat capacity defined as total heat capacity per mass $c_p = (dC_p/dM)$, $C_p = (dE/dT)_p$ at constant pressure. The large value of c_p for water is thought to be due to the splitting of hydrogen bonds by energy feed so that new translational degrees of freedom are created and the energy feed goes to these.

   Could this intuition generalize? Hydrogen bonds would be replaced with flux tube pairs with members carrying opposite fluxes and carrying dark protons and connecting two water molecules. There would be two phases of matter. Lonely water molecules possibly accompanied by short flux loops and pairs of water molecules connected by flux tube pairs. Also clusters of water molecules connected by flux tubes with several pairs of flux tubes emerging from each molecule are possible. Dark matter could be identified the molecule pairs or groups connected by flux tube pairs distinguishing between water and other liquids.

2. The reconnection for a pair of flux tubes with opposite fluxes creates molecules with U-shaped flux tubes, which could rapidly contract. This would lead to two free molecules of ordinary water. These molecules would take most of the feeded energy ΔE and heat the water by ΔT. Also part of the magnetic energy of the flux tubes would be transferred to the kinetic energy of liberated molecules. This energy could be small for short flux tubes at least. If the phase transition increasing the value of n preserves the total magnetic energy, this energy would be small also for long flux tubes.

3. Suppose that the fraction of flux molecules connected by flux tube pairs - dark matter - increases with temperature. c_p is determined by the rate of reconnections of flux tube pairs effectively transforming two dark water molecule pair to ordinary ones. c_p should be reduced above 4 °C up to 37 °C. The value of the latter temperature suggests an increase of dark matter component so that the number of ordinary water molecules would decrease. The first guess is that the magnetic energy is of the order of the bond energy assignable to hydrogen bond and in the range .023-.05 eV. Note that membrane voltage eV corresponds to energy which is same order of magnitude. This interpretation is natural if the creation and annihilation of flux tube pairs is basic mechanism of biology.

   The reconnection creates more ordinary water molecule pairs and only these absorb heat. The absorbed heat is shared between the ordinary water molecules. The energy is shared by a smaller number of ordinary water molecules so that ΔT for given ΔE is higher and c_p is smaller. Note that also the fact that total mass $M = M_o + M_{dark}$ of water is larger than M_o reduces c_p.

4. Why c_p would increase above 37 °C? The most straightforward explanation is that dark matter - that is the molecules connected by flux tube pairs begins to decrease above this temperature. The amount of dark matter - the connectivity of the web formed by flux tubes - is highest at 37 °C. The splitting of the flux tube pairs to pairs of loops would explain disappearance of dark matter above 37 °C. The heat is shared between larger number of ordinary molecules and ΔT is smaller for a given ΔE so that c_p becomes larger. Also the reduction of M_{dark} has similar effect.

Consider next the anomalous behavior of compressibility.

1. The reduction of compressibility K ($\Delta V = -(dlog(V)/dp)\Delta p = -K\Delta p$), which at zero pressure limit is maximal at 45 °C should have an explanation along the same lines. Compressibility is reduced if the increase in pressure produces ordinary water molecules, whose emergence tends to increase the volume filled n by ordinary water molecules. This is the case if the fraction of dark matter decreases with increasing pressure. The reason could be splitting of the flux tube pairs to loops. This predicts that anomalies are absent for high enough pressures as they indeed are.
2. What happens in evaporation? It would seem that the density of dark matter fraction becomes so small that the flux tube connections cannot anymore create the needed cohesion and water evaporates. Note that also the connectivity of the flux tube web is reduced.

What about Mpemba effect (see `http://tinyurl.com/7h2h59p`)? Why hot water would freeze faster than cold water and why the effect would be strongest around 35 °C?

1. The amount of dark matter seems to be essential for the effect. A possible mechanism of freezing would be reduction of lengths of dark flux tube pairs by quantum phase transitions reducing the value of n. This mechanism would contract the flux tubes to hydrogen bonds very rapidly. The resulting ice would serve as seeds inducing the freezing of the ordinary portion of water. Freezing would be fastest around 35 °C.
2. The freezing of dark portion eliminates it. The condition that dark and ordinary portion of water are in kinetic equilibrium could induce the transformation of ordinary matter to dark matter. If this process is fast enough, the freezing could take place via the cycle *ordinary water* $\rightarrow$ *dark water* $\rightarrow$ *ice* and be faster than freezing near freezing point where dark matter fraction is small.

11.6.5 Genes And Water Memory

After long time I had opportunity to read a beautiful experimental article about experimental biology. Yolene Thomas, who worked with Benveniste, kindly sent the article to me. The freely loadable article is *Electromagnetic Signals Are Produced by Aqueous Nanostructures Derived from Bacterial DNA Sequences* by Luc Montagnier, Jamal Aissa, Stephane Ferris, Jean-Luc Montagnier, and Claude Lavall'e published in the journal Interdiscip. Sci. Comput. Life Sci. (2009) [I15].

Basic findings at cell level

I try to list the essential points of the article. Apologies for biologists: I am not a specialist.

1. Certain pathogenic micro-organisms are objects of the study. The bacteria Mycoplasma Pirum and E. Choli belong to the targets of the study. The motivating observation was that some procedures aimed at sterilizing biological fluids can yield under some conditions the infectious micro-organism which was present before the filtration and absent immediately after it. For instance, one filtrates a culture of human lymphocytes infected by M. Pirum, which has infected human lymphocytes to make it sterile. The filters used have 100 nm and 20 nm porosities. M. Pirum has size of 300 nm so that apparently sterile fluids results. However if this fluid is incubated with a mycoplasma negative culture of human lymphocytes, mycoplasma re-appears within 2 or 3 weeks! This sounds mysterious. Same happens as 20 nm filtration is applied to a a minor infective fraction of HIV, whose viral particles have size in the range 100-120 nm.
2. These findings motivated a study of the filtrates and it was discovered that they have a capacity to produce low frequency electromagnetic waves with frequencies in good approximation coming as the first three harmonics of kHz frequency, which by the way plays also a central role in neural synchrony. What sounds mysterious is that the effect appeared after appropriate dilutions with water: positive dilution fraction varied between 10^{-7} and 10^{-12}. The uninfected eukaryotic cells used as controls did not show the emission. These signals appeared for both M. Pirum and E. Choli but for M. Pirum a filtration using 20 nm filter canceled the effect. Hence it seems that the nano-structures in question have size between 20 and 100 nm in this case.

A resonance phenomenon depending on excitation by the electromagnetic waves is suggested as an underlying mechanism. Stochastic resonance familiar to physicists suggests itself and also I have discussed it while developing ideas about quantum brain [K89]. The proposed explanation for the necessity of the dilution could be kind of self-inhibition. Maybe a gel like phase which does not emit radiation is present in sufficiently low dilution but is destroyed in high dilutions after which emission begins. Note that the gel phase would not be present in healthy tissue. Also a destructive interference of radiation emitted by several sources can be imagined.

3. Also a cross talk between dilutions was discovered. The experiment involved two tubes. Donor tube was at a low dilution of E. Choli and "silent" (and carrying gel like phase if the above conjecture is right). Receiver tube was in high dilution (dilution fraction 10^{-9}) and "loud". Both tubes were placed in mu-metal box for 24 hours at room temperature. Both tubes were silent after his. After a further dilution made for the receiver tube it became loud again. This could be understood in terms of the formation of gel like phase in which the radiation does not take place. The effect disappeared when one interposed a sheath of mu-metal between the tubes. Emission of similar signals was observed for many other bacterial specials, all pathogenic. The transfer occurred only between identical bacterial species which suggests that the signals and possibly also frequencies are characteristic for the species and possibly code for DNA sequences characterizing the species.

4. A further surprising finding was that the signal appeared in dilution which was always the same irrespective of what was the original dilution.

Experimentation at gene level

The next step in experimentation was performed at gene level.

1. The killing of bacteria did not cancel the emission in appropriate dilutions unless the genetic material was destroyed. It turned out that the genetic material extracted from the bacteria filtered and diluted with water produced also an emission for sufficiently high dilutions.

2. The filtration step was essential for the emission also now. The filtration for 100 nm did not retain DNA which was indeed present in the filtrate. That effect occurred suggests that filtration destroyed a gel like structure inhibiting the effect. When 20 nm filtration was used the effect disappeared which suggests that the size of the structure was in the range 20-100 nm.

3. After the treatment by DNAse enzyme inducing splitting of DNA to pieces the emission was absent. The treatment of DNA solution by restriction enzyme acting on many sites of DNA did not suppress the emission suggesting that the emission is linked with rather short sequences or with rare sequences.

4. The fact that pathogenic bacteria produce the emission but not "good" bacteria suggests that effect is caused by some specific gene. It was found that single gene - adhesin responsible for the adhesion of mycoplasma to human cells- was responsible for the effect. When the cloned gene was attached to two plasmids and the E. Choli DNA was transformed with the either plasmid, the emission was produced.

Some consequences

The findings could have rather interesting consequences.

1. The refinement of the analysis could make possible diagnostics of various diseases and suggests bacterial origin of diseases like Alzheimer disease, Parkinson disease, Multiple Sclerosis and Rheumatoid Arthritis since the emission signal could serve as a signature of the gene causing the disease. The signal can be detected also from RNA viruses such as HIV, influenza virus A, and Hepatitis C virus.

2. Emission could also play key role in the mechanism of adhesion to human cells making possible the infection perhaps acting as a kind of password.

The results are rather impressive. Some strongly conditioned skeptic might have already stopped reading after encountering the word "dilution" and associating it with a word which no skeptic scientist in his right mind should not say aloud: "homeopathy" ! By reading carefully what I wrote above, it is easy to discover that the experimenters unashamedly manufactured a homeopathic remedy out of the filtrate! And the motivating finding was that although filtrate should not have contained the bacteria, they (according to authors), or at least the effects caused by them, appeared within weeks to it! This is of course impossible in the word of skeptic.

The next reaction of the skeptic is of course that this is fraud or the experimenters are miserable crackpots. Amusingly, one of the miserable crackpots is Nobelist Luc Montagnier, whose research group discovered AIDS virus.

How TGD could explain the findings?

Let us leave the raging skeptics for a moment and sketch possible explanations in TGD framework.

1. Skeptic would argue that the filtration allowed a small portion of infected cells to leak through the filter. Many-sheeted space-time suggests a science fictive variant of this explanation. During filtration part of the infected cells is "dropped" to large space-time sheets and diffused back to the original space-time sheets during the next week. This would explain why the micro-organisms were regenerated within few weeks. Same mechanism could work for ordinary molecules and explain homeopathy. This can be tested: look whether the molecules return back to the diluted solution in the case of a homeopathic remedy.
2. If no cells remain in the filtrate, something really miraculous looking events are required to make possible the regeneration of the effects serving as the presence of cells. This even in the case that DNA fragments remain in the filtrate.
    (a) The minimum option is that the presence of these structures contained only the relevant information about the infecting bacteria and this information coded in terms of frequencies was enough to induce the signatures of the infection as a kind of molecular conditioning. Experimentalists can probably immediately answer whether this can be the case.
    (b) The most radical option is that the infecting bacteria were actually regenerated as experimenters claim! The information about their DNA was in some form present and was transcribed to DNA and/or RNA, which in turn transformed to proteins. Maybe the small fragment of DNA (adhesin) and this information should have been enough to regenerate the DNA of the bacterium and bacterium itself. A test for this hypothesis is whether the mere nanoparticles left from the DNA preparation to the filtrate can induce the regeneration of infecting molecules.

The notion of magnetic body carrying dark matter quantum controlling living matter forms the basic element of TGD inspired model of quantum biology and suggests a more concrete model. The discovery of nanotubes connecting cells with distance up to 300 μ [I4] provides experimental support for the notion.

1. If the matter at given layer of the onion-like structure formed by magnetic bodies has large $\hbar$, one can argue that the layer corresponds to a higher evolutionary level than ordinary matter with longer time scale of memory and planned action. Hence it would not be surprising if the magnetic bodies were able to replicate and use ordinary molecules as kind of sensory receptors and motor organs. Perhaps the replication of magnetic bodies preceded the replication at DNA level and genetic code is realized already at this more fundamental level somehow. Perhaps the replication of magnetic bodies induces the replication of DNA as I have suggested.
2. The magnetic body of DNA could make DNA a topological quantum computer [K4]. DNA itself would represent the hardware and magnetic bodies would carry the evolving quantum computer programs realized in terms of braidings of magnetic flux tubes. The natural communication and control tool would be cyclotron radiation besides Josephson radiation associated with cell membranes acting as Josephson junctions. Cyclotron frequencies are indeed the only natural frequencies that one can assign to molecules in kHz range. There would be an entire fractal hierarchy of analogs of EEG making possible the communication with and control by magnetic bodies.

3. The values of Planck constant would define a hierarchy of magnetic bodies which corresponds to evolutionary hierarchy and the emergence of a new level would mean jump in evolution. Gel like phases could serve as a correlate for the presence of the magnetic body. The phase transitions changing the value of Planck constant and scale up or down the size of the magnetic flux tubes. They are proposed to serve as a basic control mechanism making possible to understand the properties and the dynamics of the gel phases and how biomolecules can find each other in the thick molecular soup via a phase transition reducing the length of flux tubes connecting the biomolecules in question and thus forcing them to the vicinity of each other.

Consider now how this model could explain the findings.

1. Minimal option is that the flux tubes correspond to "larger space-time sheets" and the infected cells managed to flow into the filtrate along magnetic flux tubes from the filter. This kind of transfer of DNA might be made possible by the recently discovered nanotubes already mentioned.
2. Maybe the radiation resulted as dark photons invisible for ordinary instruments transformed to ordinary photons as the gel phase assignable with the dark matter at magnetic flux tube network associated with the infected cells and corresponding DNA was destroyed in the filtration.

   This is not the only possible guess. A phase conjugate cyclotron radiation with a large value of Planck constant could also allow for the nanostructures in dilute solute to gain metabolic energy by sending negative energy quanta to a system able to receive them. Indeed the presence of ambient radiation was necessary for the emission. Maybe that for sufficiently dilute solute this mechanism allows to the nanostructures to get metabolic energy from the ambient radiation whereas for the gel phase the metabolic needs are not so demanding. In the similar manner bacteria form colonies when metabolically deprived. This sucking of energy might be also part of the mechanism of disease.
3. What could be the magnetic field inducing the kHz radiation as a synchrotron radiation?
   (a) For instance, kHz frequency and its harmonics could correspond to the cyclotron frequencies of proton in magnetic field which field strength slightly above that for Earth's magnetic field (750 Hz frequency corresponds to field strength of B_E, where $B_E = .5$ Gauss, the nominal strength of Earth's magnetic field). A possible problem is that the thickness of the flux tubes would be about cell size for Earth's magnetic field from flux quantization and even larger for dark matter with a large value of Planck constant. Of course, the flux tubes could make themselves thinner temporarily and leak through the pores.
   (b) If the flux tube is assumed to have thickness of order 20-100 nm, the magnetic field for ordinary value of $\hbar$ would be of order.1 Tesla from flux quantization and in the case of DNA the cyclotron frequencies would not depend much on the length of DNA fragment since the it carries a constant charge density. Magnetic field of order.2 Tesla would give cyclotron frequency of order kHZ from the fact that the field strength of.2 Gauss gives frequency of about .1 Hz. This correspond to a magnetic field with flux tube thickness $\sim$ 125 nm, which happens to be the upper limit for the porosity. Dark magnetic flux tubes with large $\hbar$ are however thicker and the leakage might involve a temporary phase transition to a phase with ordinary value of $\hbar$ reducing the thickness of the flux tube. Perhaps some genes (adhesin) plus corresponding magnetic bodies representing DNA in terms of cyclotron frequencies depending slightly on precise weight of the DNA sequence and thus coding it correspond to the frequency of cyclotron radiation are the sought for nano-structures.
4. While developing a model for homeopathy based on dark matter I ended up with the idea that dark matter consisting of nuclear strings of neutrons and protons with a large value of $\hbar$ and having thus a zoomed up size of nucleon could be involved. The really amazing finding was that nucleons as three quark systems allow to realize vertebrate code in terms of states formed from entangled quarks [L4], [L4] described also in this chapter! One cannot decompose codons to letters as in the case of the ordinary genetic code but codons are analogous to symbols representing entire words in Chinese. The counterparts of DNA, RNA, and amino-acids emerge and genetic code has a concrete meaning as a map between quantum states.

Without any exaggeration this connection between dark hadronic physics and biology has been one of the greatest surprises of my professional life. It suggests that dark matter in macroscopic quantum phase realizes genetic code at the level of nuclear physics and biology only provides one particular (or probably very many as I have proposed) representations of it. If one takes this seriously one can imagine that genetic information is represented by these dark nuclear strings of nanoscopic size and that there exists a mechanism translating the dark nuclei to ordinary DNA and RNA sequences and thus to biological matter. This would explain the claimed regeneration of the infected cells.

5. Genetic code at dark matter level would have far reaching implications. For instance, living matter - or rather, the magnetic bodies controlling it - could purposefully perform genetic engineering. This forces me to spit out another really dirty word, "Lamarckism" ! We have of course learned that mutations are random. The basic objection against Lamarckism is that there is no known mechanism which would transfer the mutations to germ cells. In the homeopathic Universe of TGD the mutations could be however performed first for the dark nucleon sequences. After this these sequences would diffuse to germ cells just like homeopathic remedies do, and after this are translated to DNA or RNA and attach to DNA.

The findings of both Montagnier and Gariaev suggests that also the representation of genetic code in terms of dark photons is involved. How genetic code could be represented in terms of frequencies? The TGD based model of music harmony [L22] [K87] (see `http://tinyurl.com/zg3aaj7`) relies on the idea that 12-note scale is representable as a closed non-self-intersecting curve (Hamilton's cycle) at icosahedron having 12 vertices. The harmony assignable to a given Hamilton's cycle is characterized in terms of 3-chords assignable to the 20 faces (triangles) of the icosahedron once the 12-note scale is represented as a particular Hamilton's cycle.

Remarkably, the number of amino-acids is also 20! One indeed ends up with a model in which 20+20+20=60 DNA codons are represented by 3-chords for a triplet of harmonies defined by Hamilton's cycles predicting correctly the numbers of DNAs coding for a given amino-acid for vertebrate code. One must however assume that also tetrahedral harmony is present to get 64 DNA codons rather than only 60. TActually two variants of the code are predicted and altogether one obtains the standard 20 amino-acids plus two additional ones identified as Pyl and Sec known to be realized in living matter.

In music realization DNA codons can be represented as 3 dark photons or phonons with appropriate frequency ratios. This representation could explain the findings of Montagnier and Gariaev. There is also a connection with TGD inspired theory of consciousness. Music both expresses and induces emotions. The proposal is that the representation of DNA codons in terms of triplets of sounds or dark photons defines molecular level representation of emotions. There is large number of different harmonies and they could represent different moods.

11.6.6 Burning Water And Photosynthesis

For a physicist liberated from the blind belief in reductionism, biology transforms to a single gigantic anomaly about which recent day physics cannot say much. During years I have constructed several models for these anomalies helping to develop a more detailed view about how the new physics predicted by quantum TGD could allow to understand biology and consciousness.

The basic problem is of course the absence of systematic experimentation so that it is possible to imagine many new physics scenarios. For this reason the article series of Mae-Wan Ho [D111, D109, D107, D110] in ISIS was a very pleasant surprise, and already now has helped considerably in the attempts to develop the ideas further.

The first article "Water electric" [D111] told about the formation of exclusion zones around hydrophilic surfaces, typically gels in the experiments considered [D140]. The zones were in potential of about 100 meV with respect to surroundings (same order of magnitude as membrane potential) and had thickness ranging to hundreds of micrometers (the size of a large cell): the standard physics would suggests only few molecular layers instead of millions. Sunlight induced the effect. This finding allow to develop TGD based vision about how proto cells emerged and also the model for chiral selection in living matter by combining the finding with the anomalies of water about which I had learned earlier.

The article “Can water burn?” [D107] tells about the discovery of John Kanzius - a retired broadcast engineer and inventor. Kanzius found that water literally burns if subjected to a radio frequency radiation at frequency of 13.56 MHz [D1]. The mystery is of course how so low frequency can induce burning. The article “The body does burn water” [D110] notices that plant cells burn water routinely in photosynthesis and that also animal cells burn water but the purpose is now to generate hydrogen peroxide which kills bacteria (some readers might recall from childhood how hydrogen peroxide was used to sterilize wounds!). Hence the understanding of how water burns is very relevant for the understanding of photosynthesis and even workings of the immune system.

Living matter burns water routinely

Photosynthesis burns water by decomposing water to hydrogen and oxygen and liberating oxygen. Oxygen from CO_2 in atmosphere combines with the oxygen of H_2O to form O_2 molecules whereas H from H_2O combines with carbon to form hydrocarbons serving as energy sources for animals which in turn produce CO_2. This process is fundamental for aerobic life. There is also a simpler variant of photosynthesis in which oxygen is not produced and applied by an-aerobic life forms. The article “Living with Oxygen” by Mae-Wan Ho gives a nice overall view about the role of oxygen [D108]. As a matter fact, also animals burn water but they do this to produce hydrogen peroxide H_2O_2 which kills very effectively bacteria.

Burning of water has been studied as a potential solution for how to utilize the solar energy to produce hydrogen serving as a natural fuel [D109]. The reaction $O_2 + H_2 \rightarrow 2H_2O$ occurs spontaneously and liberates energy of about 1.23 eV. The reverse process $2H_2 \rightarrow H_2O_2 + H_2$ in the presence of sunlight means burning of water, and could provide the manner to store solar energy. The basic reaction $2H_2O + 4h\nu \leftrightarrow H_2O_2 + H_2$ stores the energy of four photons. What really happens in this process is far from being completely understood. Quite generally, the mechanisms making possible extreme efficiency of bio-catalysis remain poorly understood. Here new physics might be involved. I have discussed models for photosynthesis and $ADP \leftrightarrow ATP$ process involved with the utilization of the biochemical energy already earlier [K57].

How water could burn in TGD Universe?

The new results could help to develop a more detailed model about what happens in photosynthesis. The simplest TGD inspired sketch for what might happen in the burning of water goes as follows.

1. Assume that 1/4 of water molecules are partially dark (in sense of nonstandard value of Planck constant) or at least at larger space-time sheets in atto-second scale [D104, D93, D119, D60]. This would explain the $H_{1.5}O$ formula explaining the results of neutron diffraction and electron scattering.
2. The question is what this exotic fraction of water precisely is. The models for water electret, exclusion zones and chiral selection lead to concrete ideas about this. Electrons assignable to the H atoms of (partially) dark H_2O reside at space-time sheet $k_e = 151$ (this p-adic length scale corresponds to 10 nm, the thickness of cell membrane). At least the hydrogen atom for this fraction of water molecules is exotic and findings from neutron and electron scattering suggest that both proton and electron are at non-standard space-time sheets but not necessarily at the same space-time sheet. The model for the burning requires that electron and proton are at different space-time sheets in the initial situation.
3. Suppose all four electrons are kicked to the space-time sheet of protons of the exotic hydrogen atoms labeled by k_p. This requires the energy $E_\gamma = (1-2^{-n})E_0(k_p)$ (the formula involves idealizations). At this space-time sheet protons and electrons are assumed to combine spontaneously to form two H_2 atoms. Oxygen atoms in turn are assumed to combine spontaneously to form O_2.
4. For $k_f = 148$ and $n = 3$ minimum energy needed would be $4E_\gamma = 4 \times .4 = 1.6$ eV. For $k_p = 149$ (thickness of lipid layer) and $n = 2$ one would have $4E_\gamma = 4 \times .3462 = 1.385$ eV whereas $H_2O_2 + H_2 \rightarrow 2H_2O$ liberates energy 1.23 eV. Therefore the model in which electrons are at cell membrane space-time sheet and protons at the space-time sheet assignable to single lipid layer of cell membrane suggests itself. This would also mean that the basic length scales

of cell are already present in the structure of water. Notice that there is no need to assume that Planck constant differs from its standard value.

There is no need to add, that the model is an unashamed oversimplification of the reality. It might however catch the core mechanism of photosynthesis.

Burning of salt water induced by RF radiation

Engineer John Kanzius has made a strange discovery [D1]: salt water in the test tube radiated by radio waves at harmonics of a frequency f=13.56 MHz burns. Temperatures about 1500 K, which correspond to.15 eV energy have been reported. One can irradiate also hand but nothing happens. The original discovery of Kanzius was the finding that radio waves could be used to cure cancer by destroying the cancer cells. The proposal is that this effect might provide new energy source by liberating chemical energy in an exceptionally effective manner. The power is about 200 W so that the power used could explain the effect if it is absorbed in resonance like manner by salt water.

Mae-Wan Ho's article "Can water Burn?" [D107] provides new information about burning salt water [D1], in particular reports that the experiments have been replicated. The water is irradiated using polarized radio frequency light at frequency 13.56 MHz. The energy of radio frequency quantum is $E_{rf} = .561\times10^{-7}$ eV and provides only a minor fraction $E_{rf}/E = .436\times10^{-7}$ of the needed energy which is $E = 1.23$ eV for single $2H_2O \rightarrow H_2O_2 + H_2$ event. The structure of water has been found to change, in particular something happens to O-H bonds. The Raman spectrum of the water has changed in the energy range $[0.37, 0.43]$ eV. Recall that the range of metabolic energy quanta $E(k,n) = (1-2^{-}n)E_0(k)$ varies for electron in the range $[.35, .46]$ eV in the model for the formation of exclusion zone induced by light. Therefore the photons assigned to changes in Raman spectrum might be associated with the transfer of electrons between space-time sheets.

The energies of photons involved are very small, multiples of 5.6×10^{-8} eV and their effect should be very small since it is difficult to imagine what resonant molecular transition could cause the effect. This leads to the question whether the radio wave beam could contain a considerable fraction of dark photons for which Planck constant is larger so that the energy of photons is much larger. The underlying mechanism would be phase transition of dark photons with large Planck constant to ordinary photons with shorter wavelength coupling resonantly to some molecular degrees of freedom and inducing the heating. Microwave oven of course comes in mind immediately.

As I made this proposal, I did not realize the connection with photosynthesis and actual burning of water. The recent experimental findings suggest that dark radio frequency photons transform to photons inducing splitting of water as in photosynthesis so that one should have $r = \hbar/\hbar_0 = E_{rf}/4E$. One could say that large number of radio wave photons combine to form a single bundle of photons forming a structure analogous to what mathematician calls covering space. In the burning event the dark photon would transform to ordinary photon with the same energy. This process would thus transform low energy photons to high energy protons with the ratio $r = \hbar/\hbar_0$.

Therefore the mechanism for the burning of water in the experiment of Kanzius could be a simple modification of the mechanism behind burning of water in photosynthesis.

1. Some fraction of dark radio frequency photons are dark or are transformed to dark photons in water and have energies around the energy needed to kick electrons to smaller space-time sheets .4 eV. After this they are transformed to ordinary photons and induce the above process. Their in-elastic scattering from molecules (that is Raman scattering) explains the observation of Raman scattered photons. For a fixed value of $\hbar$ the process would occur in resonant manner since only few metabolic quanta are allowed.

2. How dark radio frequency photons could be present or could be produced in water? Cyclotron radiation assignable to say electrons in magnetic field comes in mind. If the cyclotron radiation is associated with electrons it requires a magnetic field of 4.8 Gauss the cyclotron frequency is 13.56 MHz. This is roughly ten times the nominal value $B_E = .5$ Gauss of the Earth's magnetic field and 24 times the value of dark magnetic field $B_d = .4B_E = .2$ Gauss needed to explain the effects of ELF em fields on vertebrate brain. Maybe dark matter at flux tubes of Earth's magnetic field with Planck constant equal to $\hbar/\hbar_0 = \frac{1}{4}\frac{E}{E_{rf}}$ transforms radio frequency photons to dark photons or induces resonantly the generation of cyclotron photons,

which in turn leak out from magnetic flux tubes and form ordinary photons inducing the burning of water. $E_\gamma = .4$ eV would give $\hbar/\hbar_0 == 1.063 \times 2^{21}$ and $E_\gamma = .36$ eV would give $\hbar/\hbar_0 = .920 \times 2^{21}$.

3. Magnetic fields of magnitude.2 Gauss are in central role in TGD based model of living matter and there are excellent reasons to expect that this mechanism could be involved also with processes involved with living matter. There is indeed evidence for this. The experiments of Gariaev demonstrated that the irradiation of DNA with 2 eV laser photons (which correspond to one particular metabolic energy quantum) induced generation of radio wave photons having unexpected effects on living matter (enhanced metabolic activity) [I13], and that even a realization of genetic code in terms of the time variation of polarization direction could be involved. TGD based model [K17, K114] identifies radio-wave photons as dark photons with same energy as possessed by incoming visible photons so that a transformation of ordinary photons to dark photons would have been in question. The model assumed hierarchy of values of magnetic fields in accordance with the idea about onion like structure of the magnetic body.

There are several questions to be answered.

1. Is there some trivial explanation for why salt must be present or is new physics involved also here. What comes in mind are Cooper pairs dark Na^+ ions (or their exotic counterparts which are bosons) carrying Josephson currents through the cell membrane in the model of the cell membrane as a Josephson junction which is almost vacuum extremal of Kähler action. In the experimental arrangement leading to the generation of exclusion zones the pH of water was important control factor, and it might be that the presence of salt has an analogous role to that of protons.

2. Does this effect occur also for solutions of other molecules and other solutes than water? This can be tested since the rotational spectra are readily calculable from data which can be found at net.

3. Are the radio wave photons dark or does water - which is very special kind of liquid - induce the transformation of ordinary radio wave photons to dark photons by fusing $r = \hbar/\hbar_0$ radio wave massless extremals (MEs) to single ME. Does this transformation occur for all frequencies? This kind of transformation might play a key role in transforming ordinary EEG photons to dark photons and partially explain the special role of water in living systems.

4. Why the radiation does not induce spontaneous combustion of living matter which contains salt. And why cancer cells seem to burn: is salt concentration higher inside them? As a matter fact, there are reports about [D17]. One might hope that there is a mechanism inhibiting this since otherwise military would be soon developing new horror weapons unless it is doing this already now. Is it that most of salt is ionized to Na^+ and Cl^- ions so that spontaneous combustion can be avoided? And how this relates to the sensation of spontaneous burning [D16] - a very painful sensation that some part of body is burning?

5. Is the energy heating solely due to rotational excitations? It might be that also a "dropping" of ions to larger space-time sheets is induced by the process and liberates zero point kinetic energy. The dropping of proton from k=137 (k=139) atomic space-time sheet liberates about.5 eV (0.125 eV). The measured temperature corresponds to the energy.15 eV. This dropping is an essential element in the ealier of remote metabolism and provides universal metabolic energy quanta. It is also involved with TGD based models of "free energy" phenomena. No perpetuum mobile is predicted since there must be a mechanism driving the dropped ions back to the original space-time sheets.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

6. The electrolysis of water and also cavitation produces what is known as Brown's gas which should consist of water vapour and there might be a connection to the burning of salt water.

The properties of Brown's gas [H19] however do not support this interpretation: for instance, Brown's gas has temperature of about 130 C but is able to melt metals so that some un-known mechanism liberating energy must be involved explaining also the claims about over-unity energy production in water splitting using electrolysis. TGD inspired model for Brown's gas [K58] suggests that activated water and Brown's gas correspond to same phase involving polymer sequences formed from exotic water molecules for which one hydrogen nucleus is dark and defining the analogs of basic biopolymers. The bond binding protons to a polymer like sequence would serve as the counterpart of covalent bond.

One also ends up with a more detailed TGD inspired view about basic mechanism of metabolism in living matter predicting a tight correlation between p-adic length scale hypothesis and hierarchy of Planck constants. The model differs in some aspects from the rough models considered hitherto assuming that metabolic energy is liberated as zero point kinetic energy when particle drops to a larger space-time sheet or as cyclotron energy when cyclotron quantum number decreases. Now a phase transition increasing the p-adic length scale of the space-time surface would liberate either kinetic energy of cyclotron energy. Quantum numbers would not change: rather, t the scale appearing as a parameter in the expression of kinetic or cyclotron energy would change adiabatically and in this manner guarantee coherence. Also a phase transition in which the changes of scale due to a reduction of Planck constant and increase of the p-adic length scale compensate each other liberate metabolic energy.

Recall that one of the empirical motivations for the hierarchy of Planck constants came from the observed quantum like effects of ELF em fields at EEG frequencies on vertebrate brain and also from the correlation of EEG with brain function and contents of consciousness difficult to understand since the energies of EEG photons are ridiculously small and should be masked by thermal noise.

11.7 Minimization of Gibbs free energy as thermodynamical variational principle in TGD framework

Minimization of Gibbs free energy is applied routinely in bio-chemistry as a thermodynamical variational principle. I have however not applied thermodynamical variational principles systematically in TGD inspired quantum biology. My excuse could be that it is not clear whether dark matter as $h_{eff} = n \times h_0$ phases is in thermal equilibrium with the ordinary matter. Therefore the arguments have been based mostly on energy minimization and make sense thermodynamically at zero temperature limit.

This article was inspired by highly interesting findings related to the stability of DNA double strand. It has been thought that hydrogen bonds between the bases of the two strands are responsible for the stability. This explanation has been challenged (for a popular article see `http://tinyurl.com/yyvkeq8y`). According to the article [I10] (see `http://tinyurl.com/y5kwo5b4`) of Bobo Feng *et al*, the experimental findings support the proposal that hydrophobic forces are actually responsible for the stability. The function of hydrogen bonds would be to take care of correct base pairing rather than stabilization.

In passive state DNA strands would bind together by hydrophobic forces keeping water out of the interior of DNA double strand forming a kind of dry pocket. When DNA is active - say replication or transcription is occurring - an appropriate enzyme opens DNA by splitting the hydrogen bonds and the interior parts get in contact with water. This process requires energy provided by ATP. After than the process could proceed in TGD Universe as discussed in [L88].

The attempt to gain an improved understanding of hydrophobic interactions led to the realization that I have not been considered the possibility that Gibbs free energy might provide a thermodynamical variational principle applicable also to dark matter as $h_{eff} = n \times h_0$ phases, in particular allowing to get a quantitative grasp on the model of water as a multi-phase system involving magnetic flux tubes with various values of h_{eff} [L80].

11.7.1 TGD based view about hydrophobia

Hydrophobic interactions play fundamental role in biology, and there are good motivations for gaining some understanding about the thermodynamics involved. Here the appropriate variational principle is minimization of Gibbs free energy G.

One hydrophobic in water

While reading the popular article I realized that my understanding about hydrophobic forces is rather limited. I decided to go to web and an found a rather nice article about hydrophobic forces (see `http://tinyurl.com/yyerhvte`).

1. Consider first what hydrophobia at molecular level means. Hydrophobic molecules do not dis-solve in water. When this kind of molecule is put into water, a water a chlathrate gage surrounding it is formed. Hydrogen bonds between water molecules surrounding the molecule are split and new hydrogen bonds giving rise to the chlathrate are created. Splitting requires heat energy which corresponds to a decrease of a thermodynamical function of state known as enthalpy: $\Delta H < 0$ (the formation of hydrogen bonds occurs spontaneously and must release energy). When the temperature is above $T = 0$, also entropy matters. Now entropy decreases since order is created in the formation of chlathrate.

2. Physicists and chemists love variational principles. Now the thermodynamical variational principle is minimization of Gibbs free energy G. Process occurs spontaneously if the change ΔG of Gibbs free energy in the process is negative: $\Delta G < 0$.

   One has $\Delta G = \Delta H - T\Delta S$, where ΔS is the change of entropy. $\Delta H < 0$ is known to be small in the recent case but ΔS is large and negative due to the formation of the chlathrate cage generating order order. Hence one has $\Delta G > 0$ and the hydrophobic molecule does not dis-solve to water. Hydrophilic molecules in turn are polar and form bonds with water and dissolve.

3. Organic molecules tend to turn their polar parts towards water and non-polar parts (say long hydrocarbon sequences) inwards to form dry pockets. Double lipid layer giving rise to cell membrane is a good example. The lipids turn their charged ends to the water in the interior and exterior of cell and the hydrocarbon sequences of lipids reside in the interior layer containing no water. Protein folding in turn leads to a situation in which hydrophobic parts of protein are directed towards interior of the folded protein and hydrophilic parts bind with the surrounding water by hydrogen bonds.

Two hydrophobics in water

What happens when one puts two hydrophobics in water? It is easy to guess if one takes seriously what phobia means.

1. Hydrophobics are like two sociophobics in a big celebration. They seek protection from the crowd and can provide it to each other. Two hydrophobics in water come as close to each other as possible so that there is no water between them anymore. As they bind together, hydrogen bonds in the interior of the volume possessed by them are split. This requires energy ($\Delta H > 0$) but the entropy increases in the reduction of the size of the chlathrate area and the net effect is $\Delta G = \Delta H - T\Delta S < 0$ so that the process occurs spontaneously implying that hydrophobic substance does not dissolve.

One can apply this picture in order to understand the formation DNA double strand.

1. The formation of DNA double strands would be a process in which the hydrophobic sides of the strands become in a close contact and exclude the water from the interior of DNA. This would give rise to the helical double strand. The hydrogen bonds connecting the strands would not be responsible for the binding. Their formation generates order and the corresponding reduction of entropy should be smaller than the increase of entropy due to the splitting of hydrogen bonds of DNA strands with water.

2. The hydrophilic parts of DNA codons are directed towards the surrounding water. To open the double strand metabolic energy is needed. Also an enzyme catalyzing the process is needed but this is different story in which TGD view about quantum theory predicting mechanisms for how the reacting bio-molecules can find each other in the molecular crowd and how the potential wall making the reaction extremely slow can be overcome.

Is hydrophobia enough for the stability? My strong personal suspicion is that the stability of DNA is far from understood in bio-chemistry approach. In vitro DNA is unstable. The reason is that DNA nucleotides have negative charge and could cause instability of strands and double strand. In TGD based model the negatively region around DNA would be exclusion zone and represent ordered water. The model brings in dark matter as dark nuclei identified as dark proton sequences at flux tubes and generated in Pollack effect requiring metabolic energy feed.

The great surprise was that in a simple model for dark nuclei, the states of dark proton triplets correspond to DNA,RNA,tRNA, and amino-acids and vertebrate genetic code emerges [L70, L88]. Genetic code could be realized already at the level of water. In TGD framework the pairing of DNA strand with dark DNA strands carrying dark proton sequences with 3 proton units and charge of +3 units in 1-1 correspondence with DNA codons with total charge of -3 units could induce the stability. The formation of DNA could involve Pollack effect [L24] causing charge separation and forming negatively charged regions: part of protons would transform to dark protons at flux tubes.

11.7.2 Minimization of Gibbs free energy and TGD view about the role of water in life

Coherence of bio-matter is one of the characteristic of the living systems having no explanation in life-as-mere- bio-chemistry approach. The TGD based view of about water and its role in biology relies on the presence of long magnetic flux tubes containing dark protons as $h_{eff} = n \times h_0$ phases making possible quantum coherence in long scales. Flux tubes with varying values of h_{eff} would form a master-slave hierarchy having ordinary matter at the bottom. The quantum coherence of the master would induce the coherence of the ordinary matter serving as a slave.

All self-organizing systems generate long range correlations and an energy feed is necessary for the self-organization. Could they all be quantum critical with h_{eff} phases realizing the quantum criticality? If so, the energy feed would be needed to preserve the distribution of large h_{eff} phases: dark matter would be directly visible in the physics of every-day life [L102]!

This picture suggests that water involves several phases [L80]. These phases would correspond to the presence of long flux tubes characterized by the values of $h_{eff} = n \times h_0$ and n can have several values: already water would be a living system [L94], and dark proton sequences at the flux tubes might realize genetic code [L70]. Interesting questions relate to the description of the proposed long flux tubes perhaps giving also rise to long variants of hydrogen bonds having non-standard effective value $h_{eff} = n \times h_0$ of Planck constant.

1. Could one apply thermodynamical considerations to the situation? This would require that dark protons and dark ions at the flux tubes are in thermal equilibrium with ordinary matter. Assume that this is the case. Under what conditions one has $\Delta G = \Delta H - T\Delta S < 0$ so that the formation of dark flux tube network is possible thermodynamically?

2. What ΔH is now? ΔH should contain the sum of magnetic and volume energy of the flux tube. Magnetic flux is quantized so that the magnetic energy in a simple model is proportional to L/S, L the length of the flux tube and S its transversal area taken to be non-dynamical. Volume energy is proportional to SL so that one has $E = aSL + bS/L$. In equilibrium L is fixed from energy minimization with respect to L as $L = \sqrt{b/a}$. The energy in equilibrium is given by $E = 2\sqrt{ab}S = 2aSL$. The local value of the length scale dependent cosmological constant determines the ratio $\sqrt{b/a} = L$.

   The naïve expectation is that ΔH contains also the energy of dark matter at the flux tube. Quantum classical correspondence however suggests that classical energy equals to the energy of dark particles. For nuclei identified in TGD as nuclear strings [K31] this would mean that there is string tension which of order of m_p^2 (one proton mass m_p per proton Compton length $\hbar/m_p$). This is of same order of magnitude as hadronic string tension in the string model of hadrons. For dark proton sequences the tension would correspond to roughly one proton mass per electron Compton length: that this $2^{-11}m_p^2$.

3. There should be a contribution do the reduction of the total energy of the system due to the formation of the flux tube and this should win the energy of the flux tube. For instance, this energy could correspond to interaction energy of particles at the ends of the flux tube mediated by classical em fields along the flux tube.

   Coulomb energy between particles of opposite charge at the ends of the flux tube would be essentially that in 1-D world and proportional to the $q_1q_2L < 0$ and increase with the length of the flux tube. This would favor long flux tubes. The large interaction energy would be due to the channeling of the electric flux. There would be a competition between the negative Coulomb interaction energy and the energy of the flux tube. This energy should be included to the energy minimized and would modify the expression for the value of L obtained above to give $E = -Q^2e^2/L + S(aL + b/L)$. Energy minimum would correspond to $L = (b/(a + Q^2e^2/S))^{1/2}$. a is proportional to cosmological constant and b inversely proportional to Kähler coupling strength. a degreases as cosmological constant decreases so that also L increases. If volume energy is approximately constant ($SL = V_0 = constant$), one has $L^2a-bV_0+L^3Q^2e^2 = 0$ in energy minimum and the term $Q^2e^2/S \propto L$ in the denominator reduces the value of L.

4. The naïve and optimistic expectation is that one has $\Delta H < 0$ also for the formation of long flux tubes possibly accompanied by the analogs of hydrogen bonds so that the process would be energetically favourable at low enough temperatures and take place spontaneously.

5. ΔG contains also the competing contribution $-T\Delta S$ and the formation of flux tube structures brings in order so that this term is positive and tends to prevent this process. Could there be a critical temperature T_c above which this term wins and the formation of the flux tube network is not possible anymore? Could T_c be around the physiological temperature as biology and also the findings about thermodynamical anomalies of water would suggest

   Living matter stays conscious in a rather narrow temperature range. Where does the lower bound on temperature come from? Quantum criticality indeed suggests that there is also a lower bound for this temperature. Could it be that at temperatures near critical temperature the magnetic body of the system is maximally flexible and can change its structure. Residing at the border of order and chaos would make the cellular water very sensitive to external perturbations and provide its magnetic body with sensory and motor system. The bio-chemical realizations of sensory and motor systems would have emerged later.

11.7.3 Snow flakes and macroscopic quantum self-organization

Thanks for Nikolina Benedikovic for a link (see `https://www.treehugger.com/natural-sciences/macro-photos-snowflakes-show-impossibly-perfect-designs.html`) representing images of snowflakes. This led to a very interesting discussion generating new details to the view about self-organization in TGD Universe. Also phase transitions liberating heat as a new manner to generate dark matter in TGD sense in phase transition liberating heat energy suggest themselves and could provide a way to generate artificial life in quantum sense.

The link told about snowflakes having incredibly precise symmetry. Their formation is still poorly understood and their precise symmetries remain a mystery. One would expect something like this in atomic length scales, where one has quantum coherence but certainly not in macroscopic scales. This inspires heretic questions. Could it be that the snowflakes reflect quantum coherence in their own size scale? Snowflakes are not macroscopically quantum coherent. What could be the quantum coherent system involved?

I can reveal my cards. This was mere rhetoric. I have made these questions 15 years ago but in different context. The outcome of these questions is TGD view about living matter and matter in general based now of adelic physics providing number theoretic vision about TGD [L63, L77] .

Magnetic body containing dark matter as $h_{eff} = nh_0$ phases ($h/h_0 = 6$ is a good guess [L42]) and inducing self-organization of ordinary matter with quantum coherence of dark matter inducing the ordinary long range coherence of ordinary matter. The relevance for quantum biology would be that the highly problematic quantum coherence of ordinary bio-matter would not be needed.

Could this explain snowflakes as impossibly perfect designs as self-organization patterns forced in ordinary matter by quantum coherent magnetic body of water? I remember that some-one has said that snowflakes are like zoom-ups of atomic systems reflecting basic molecular symmetries. They could be indeed analogous to zoom-ups of atomic systems with zooming factor given by n. Quite concretely, the lengths of hydrogen bonds would be scaled up by n.

Concerning a concrete model for snowflakes there is clear hint. The self-organization would increase the values of h_{eff} and this requires energy feed. Where does it come from?

Freezing of water liberates energy: this could serve as source of metabolic energy. More generally phase transitions liberating heat energy could generate h_{eff} ¿ h phases and generate highly ordered structures. Here might a possible method to create dark matter in TGD sense.

An interesting application is to the findings of Masaru Emoto [L84] that emotional expressions of humans seem to affect water at criticality for freezing. Angry voices are claimed to create ugly patterns and friendly voices beautiful ones. The metabolic energy needed to induce phase transition transforming ordinary matter to dark matter as exotic phase of water would come from the latent heat liberated in freezing. By macroscopic quantum coherence of MB the resulting dark parts of water's MB would be sensitive to human emotional expressions.

Could living systems utilize quantum critical phase transition liberating energy?

Wes Johnson commented about the ability of living systems to use heat as metabolic energy. Could phase transitions liberating heat produce this energy and lead to a generation of large h_{eff} phases?

1. In TGD Universe the efficiency of living matter to use heat as metabolic energy would a characteristic of not only life but all self-organizing systems. The distinction between living and in-animate would be only quantitative. The evolutionary aspect of self-organization would be generation of coherence in longer scales and would be induced by generation of large h_{eff} phases at magnetic body becoming thus quantum coherent in long scales. Energy feed would generate these phases and at criticality for a phase transition liberating heat energy (enthalpy) this is easy.

2. Living systems are conscious in a narrow temperature range. Perhaps this relates to the criticality for phase transition liberating energy in turn generating especially important h_{eff} phases. Water has special anomalies around the physiological temperature and looks like a two-phase system (at least). This kind of a phase transition of water could be fundamental for living matter.

   This could have a direct connection with the Pollack effect [**?**] creating charge separation: in TGD part of protons would become dark protons at magnetic flux tubes - dark nuclei providing a fundamental representation for genetic code [L88].

3. Carbohydrates are carriers of metabolic energy. Could this mean that they have molecular bonds (valence bonds) with non-standard value of Planck constant h_{eff} and that their energy is liberated when these bonds disappear in the splitting of these bonds or even in the reduction of h_{eff} , which would be basic element of bio-catalysis. I have indeed proposed a model for valence bonds in terms of dark flux tubes with $h_{eff} > h$ [L60]. The values of n involved would be relatively small and would correspond to the many-sheetedness for the space-time surface as covering of $H = M^4 \times CP_2$ coordinates would be n-valued. n would increase towards right end of the rows of the periodic end and this would explain the different roles of the molecules at opposite ends of the rows in biology.

The two aspects of self-organization

Note that these phase transitions producing phases with a non-standard value of h_{eff} represent evolution as a statistical increase of the dimension of extension of rationals and relying on "big" (ordinary) state function reductions (BSFRs). This active, evolutionary aspect could be seen as quantal aspect of self-organization.

There is also classical, passive, aspect assignable to the evolution of subsystem by "small" state function reductions (SSFRs) serving as counterparts of weak measurements. In TGD inspired theory of consciousness, motor-sensory duality corresponds to these two aspects. Motor actions correspond to BSFRs and sensory experience to SSFRs.

1. ZEO predicts that time reversal occurs in ordinary state function reductions (BSFRs) and that these reductions occur in all scales and look like ordinary classical evolutions leading to the final state smoothly and deterministically: this was discovered by Minev *et all* in atomic systems [L90]. This would remove the conflict between classicality and no-determinism at the level of conscious experience. Quantum systems would do their best to look like classical.
2. Self-organization as a generation of structures at space-time level (passive aspect) can be understood in terms of zero energy ontology (ZEO) alone [L105]. Self-organization (its sensory aspect) and metabolism (use of energy) could be seen as a dissipation in opposite direction of time: no separate models or mechanisms would be needed. Gradients would increase, structure would be generated. Basic biological processes at bio-molecular level would be controlled by magnetic bodies in time reversed states. The only challenge is to understand how living matter generates the sources of metabolic energy - how living system stores energy.

11.8 The experiments of Masaru Emoto with emotional imprinting of water

Sini Kunnas sent a link to a video telling about experiments of Masaru Emoto (see `http://tinyurl.com/pqy57jj`) with water, which is at criticality with respect to freezing and then frozen. Emoto reports is that words expressing emotions are transmitted to water: positive emotions tend to generate beautiful crystal structures and negative emotions ugly ones. Also music and even pictures are claimed to have similar effects. Emoto has also carried out similar experiments with rice in water. Rice subjected to words began to ferment and water subject to words expressing negative emotions began to rotten.

Remark: Fermentation is a metabolic process consuming sugar in absence of oxygen. Metabolism is a basic signature of life so that at least in this aspect the water+rice system would become alive. The words expressing positive emotions or even music would serve as a signal "waking up" the system.

One could define genuine skeptic as a person who challenges existing beliefs and pseudo-skeptic (PS in the sequel) as a person challenging - usually denying - everything challenging the mainstream beliefs. The reception of the claims of Emoto is a representative example about the extremely hostile reactions of PSs as aggressive watchdogs of materialistic science towards anything that challenges their belief system. The psychology behind this attitude is same as behind religious and political fanatism.

I must emphasize that I see myself as a thinker and regard myself as a skeptic in the old-fashioned sense of the word challenging the prevailing world view rather than phenomena challenging the prevailing world view. I do not want to be classified as believer or non-believer. The fact is that if TGD inspired theory of consciousness and quantum biology describes reality, a revolution in the world view is unavoidable. Therefore it is natural to consider the working hypothesis that the effects are real and see what the TGD based explanation for them could be.

The Wikipedia article about Masaru Emoto (see `http://tinyurl.com/pqy57jj`) provides a good summary of the experiments of Emoto and provides a lot of links so that I will give here only a brief sketch. According to the article Emoto believed that water was a "blueprint for our reality" and that emotional "energies" and "vibrations" could change the physical structure of water. The water crystallization experiments of Emoto consisted of exposing water in glasses to different words, pictures or music, and then freezing and examining the aesthetic properties of the resulting crystals with microscopic photography. Emoto made the claim that water exposed to positive speech and thoughts would result in visually "pleasing" crystals being formed when that water was frozen, and that negative intention would yield "ugly" crystal formations.

In 2008, Emoto and collaborators published and article titled "Double-Blind Test of the Effects of Distant Intention on Water Crystal Formation" about his about experiments with water in the Journal of Scientific Exploration, a peer reviewed scientific journal of the Society for Scientific Explorations (see `http://tinyurl.com/ycsnu2oc`). The work was performed by Masaru Emoto and Takashige Kizu of Emoto's own IHM General Institute, along with Dean Radin and Nancy Lund of the Institute of Noetic Sciences, which is on Stephen Barrett's Quackwatch (see `http://tinyurl.com/y99kol2e`) blacklist of questionable organizations. PSs are the modern jesuits and for jesuits the end justifies the means.

Emoto has also carried experiments with rice samples in water. There are 3 samples. First sample "hears" words with positive emotional meaning, second sample words with negative emotional meaning, and the third sample serving as a control sample. Emoto reports (see `https://youtu.be/Wc-ZmvxfBxE`) that the rice subjected to words with positive emotional content began to ferment whereas water subject to words expressing negative emotions began to rotten. The control sample also began to rotten but not so fast.

In the sequel I will consider the working hypothesis that the effects are real, and develop an explanation based on TGD inspired quantum biology [K108, K84, K83]. The basic ingredients of the model are following: magnetic body (MB) carrying dark matter as $h_{eff}/h = n$ phases of ordinary matter; communications between MB and biological body (BB) using dark photons able to transform to ordinary photons identifiable as bio-photons; the special properties of water explained in TGD framework by assuming dark component of water implying that criticality for freezing involves also quantum criticality, and the realization of genetic code and counterparts of the basic bio-molecules as dark proton sequences and as 3-chords consisting of light or sound providing a universal language allowing universal manner to express emotions in terms of bio-harmony realized as music of light or sound. The entanglement of water sample and the subject person (with MBs included) realized as flux tube connections would give rise to a larger conscious entity expressing emotions via language realized in terms of basic biomolecules in a universal manner by utilizing genetic code realized in terms of both dark proton sequences and music of light of light and sound.

11.8.1 The reception of the findings of Emoto

The findings of Emoto challenge the materialistic world view and have received both genuine criticism and "criticism".

Criticism and "criticism"

Commentators have criticized Emoto for insufficient experimental controls and for not sharing enough details of his approach with the scientific community. Prof. emeritus William A. Tiller, a researcher featured in the documentary "*What The Bleep Do We Know?*", states that experiments of Emoto fall short of proof, since they do not control for other factors in the supercooling of water. It is easy to agree that scientific proof is not in question. William Tiller claims that supercooling of water involved with the experiments might have delicate effects difficult to control.

Remark: Supercooling of water makes it critical system, even quantum critical and in TGD Universe, and this makes it ideal target of remote mental interactions.

A lot of experiments are needed: in particular, the possible dependence on the person who utters the words with emotional content, deserves to be studied. Just taking randomly chosen group of people and control system might not be enough to achieve a significant effect. Situation could be similar to that in the recent double slit experiments of Radin [L52] (see `http://tinyurl.com/y72b87p7`), in which subject person tries to intentionally affect the interference pattern for light travelling through slits. The effect is clear in the case of experienced meditators. That very few of us are not concert pianists, cannot be used to argue that there are no concert pianists.

There is also the authoritative "criticism", which carefully avoids stating anything about contents of the work and directs the efforts on rhetoric tricks. These "criticisms" do not deserve serious attention except as perfect examples of the empty rhetorics so typical for PSs. The following examples are citations from the Wikipedia article (see `http://tinyurl.com/pqy57jj`).

> Emoto has been criticized for designing his experiments in ways that leave them prone to manipulation or human error influencing the findings. Biochemist and Director of Microscopy at University College Cork William Reville wrote, "*It is very unlikely that there is any reality behind claims of Emoto.*". Reville noted the lack of scientific publication and pointed out that anyone who could demonstrate such a phenomenon would become immediately famous and probably wealthy.

Remark:The absence of scientific publication (in respected journal of course) often reflects the fact that PSs have reached their goal to prevent publishing anything challenging their beliefs.

I have experienced this myself during four decades very concretely. At nineties it became even impossible to get anything into arXiv.

> Writing about Emoto's ideas in the Skeptical Inquirer, physician Harriet A. Hall concluded that it was "*hard to see how anyone could mistake it for science*". Commenting on Emoto's ideas about clearing water polluted by algae, biologist Tyler Volk stated, "*What he is saying has nothing to do with science as I know it.*" Stephen Kiesling wrote in Spirituality & Health Magazine, "*Perhaps Emoto is an evangelist who values the message of his images more than the particulars of science; nevertheless, this spiritual teacher might focus his future practice less on gratitude and more on honesty.*".

Needless to restate that these comment say nothing about contents.

Emoto is not the only victim of pseudo-skepticism

The criticism of the experiments of Emoto mostly reflects the prevailing materialistic dogmas, which do not allow these effects so that depending on the authority Emoto is concluded to be mad, charlatan, or evangelist. The rage of PSs is really frightening and demonstrates how powerful effects ideology can have.

Emoto shares the fate of experimenters studying water memory and homeopathy. "Homeopathy" is indeed a word making skeptic growl and drool: one can hardly imagine a more impressive demonstration of words on water than this! An almost- Nobelist Benveniste was labelled as swindler as he announced about experiments providing support for water memory and homeopathy. Magician Randi - Randi again(!) - participated the investigation of the mind-police of science, in which Benveniste and laboratory staff was treated like criminals unless otherwise proven.

There is a lot of support about the representation of water memory as extremely low frequencies (ELF) of radiation associated with water [I6, I7]. These ELF frequencies can be stored electronically and they produce the same effects as the bio-active chemical, whose presence induced these frequencies in water. These facts PSs simply neglect because they do not fit the belief system of PSs dating back to 18th century. At the age of IT the idea about the existence of representations of bio-active molecules as frequency patterns able to induce the biological effects of molecules without the presence of molecules should not raise aggressions.

Few years ago HIV Nobelist Montagnier did experiments giving support for water memory and the procedure involved a part very similar to that used in preparing homeopathic remedies [I16] [L16]. In TGD framework these frequencies wuold correspond to cyclotron frequencies assignable to MBs of molecules, and immune system is proposed to have emerged from the ability of water to mimic the magnetic bodies of invader molecules and learning to recognize them [K51]. This interpretation could mean a breakthrough in biology but unfortunately the time is not mature for this yet.

Remote mental interactions/paranormal phenomena [K108] belong also to the pariah phenomena having no place in materialistic world and people having the courage to challenge this view are labelled as science criminals by PSs.

Analyzing the mindset of PS

People calling themselves skeptics are rarely skeptics in the original meaning of the word but believers, even fanatic believers. The basic un-challengeable belief is materialism stating that consciousness is only an epiphenomenon - illusion as David Dennett puts it without explaining what he means with the claim that consciousness does not exist but is only one particular phenomenon of consciousness - namely illusion. There is no free will and there are no genuine intentional actions. Moral and ethics are illusions. And certainly, human can have no intentional effects on water since even genuine intentional effects on our own body are impossible. This leads to the notion of objectivity as PS understands it.

This notion of objectivity implies that the outcome of given experiment cannot depend on who carries it or on who the subject persons are. If this turns out to not be the case, the experiment is not well-done and experimenter can be ridiculed. Water is dead matter for PS, even the PS himself should be dead matter if the materialistic logic is taken to its bitter end. I dare guess that most PSs privately believe - without even realizing that this is the case - that their intentions genuinely affect the sack of water with some chemicals that is called their body. It is extremely difficult pretend that one is not conscious when one is conscious.

The conclusion of the PS is that the outcome of Emoto's experiments with water and rice cannot depend at all on the person who utters the words expressing positive or negative emotions. PS calls this assumption objectivity but is actually only an assumption that there is no such thing as intentional free will and that we live in a deterministic world of billiard balls. This view is known to be wrong: quantum entanglement has been verified for cell sized system in macroscopic scales and quantum world is non-deterministic - mentioning this fact is carefully avoided in text books. PSs also unashamedly put under the rug hundreds of anomalies related to the physics of water.

If human intention and emotion can have effects on water, the first question is whether the intention and emotion of some humans these effects are stronger. Belief moves mountains and since Emoto believes that intention can have effects, it would be only natural that the effects are stronger. If this is true, one cannot demand the repeatability of the experiment anymore. In paranormal research the experimenter effect is well-known - some experimenters are more successful than others without being charlatans - as also in medicine. This is the case always when living systems are involved. There is another amusing example demonstrating the shallowness of the thinking of PSs: PSs love to say that the effects of healing practices produce nothing but placebo effects without realizing that placebo effect as such is a fascinating mind-over-matter effect begging for explanation!

Of course, if Emoto believed that the emotions have effects on water, his desire to prove this belief might have produced these effects - not by cheating but by intentional rather than emotional imprinting based on remote mental interactions affecting water. The words as such need not have caused the effect. This would represent an example of remote mental interactions. Note however that also music and even pictures were reported to have effects on water and it is not easy to explain this as experimenter effect.

An amusing "experiment" on rice was carried out by a hard-nosed skeptic Carry Poppy (see `http://tinyurl.com/y8g9jgal`). The extremely nasty tone of the article reveals the hatred of Poppy towards Emoto and people challenging the materialist world view. The outcome of the "experiment" carried by Poppy was of course negative. Perhaps not surprising, the outcome would express faithfully the real intention and desire of the experimenter!

11.8.2 TGD based model for Emoto's findings

In TGD based view the notion of magnetic body (MB) is central [K84, K83]. MB carries dark phases of matter identified as phases of ordinary matter with $h_{eff}/h = n$ making possible macroscopic quantum coherence explaining the coherence of living matter not understandable in the biochemistry based approach. The interactions between MB and biological body (BB) are essential remote mental interactions based on signalling using dark photons. Therefore the basic mechanisms of quantum biology would be also mechanisms of remote mental interactions - only the target would be non-standard. We are mostly water and it would not be surprising if these mechanisms would allow intentional and emotional imprinting of also water outside our body and in quantum critical state.

Basic incredients of the model

In TGD universe water is very special substance in that it contains both ordinary water and its dark variant. What makes it dark is that dark magnetic flux tubes representing long hydrogen bonds are present for some portion of water [L80] (see `http://tinyurl.com/y8fvwbp9`): the length of bonds scales as n or perhaps even n^2. The presence of these flux tubes makes any liquid phase a network like structure and one ends up with a model explaining an anomaly of thermodynamics of liquids at criticality known already in Maxwell's time. This leads to a model explaining the numerous anomalies of water in terms of the dark matter.

For instance, the dark part of water with non-standard Planck constant transforms to ordinary water in freezing. As a consequence, a large amount of energy is liberated. This explains why water has anomalously large latent heat of fusion. One can also understand why the volume of water increases in freezing and decreases in heating in the interval 0-4 °C. The anomalies of water are largest at physiological temperature $T_{phys} \sim 37$ °C suggesting that the dark portion of water is largest at T_{phys}. Dark fraction of water would be essential for life.

Dark protons sequences at flux tubes representing genetic code and the analogs of basic biomolecules are realized in water. Pollack effect [L24] (see http://tinyurl.com/oyhstc2) requiring feed of energy - as IR radiation for instance - generates so called exclusion zones (EZs), which are negatively charged regions. A fraction of protons from water must go somewhere and the TGD inspired proposal [L24] (see http://tinyurl.com/gwasd8o) is that the protons transform to dark protons at magnetic flux tubes. The dark variants of particles quite generally have higher energies than ordinary ones and energy feed provides the needed metabolic energy go make the protons dark. In the case of homeopathy and water memory mechanical agitation creates provides the metabolic energy and would generate EZs accompanied by dark proton sequencies at flux tubes [K51].

Remote expression of emotions as crystal patterns - emotional imprinting - is required and communication requires a code so that receiver and sender have same interpretation for the signal. Genetic code would provide the fundamental code making possible universal meanings. TGD leads to two basic proposals predicting the numbers of DNA codons coding for given AA rather successfully.

1. The first proposal [L36] relies on TGD view about dark matter as $h_{eff}/h = n$ phases of ordinary matter [K43, ?, K80] motivated by adelic physics extending physics to include also the correlates of cognition [L63, L64] (see http://tinyurl.com/ycbhse5c and http://tinyurl.com/ybzkfevz). The empirical motivation comes from several sources, in particular from the findings of Pollack.

   Dark genetic code would be realized in terms of dark proton sequences at flux tubes- dark nuclei. The model predicts dark counterparts of DNA, mRNA, tRNA, and AA as dark proton sequences which codons identifiable as dark proton triplets. Bio-chemistry would emerge as a shadow of the much simpler dynamics of dark matter at flux tubes and genetic code would be induced by dark code code.

2. Second model of genetic code emerged accidentally from a geometric model of music harmony [L22, L78] (see http://tinyurl.com/yad4tqwl and http://tinyurl.com/yd8d8x6j) involving icosahedral (12 vertices-12-note scale and 20 faces-number of AAs) and tetrahedral geometries leading to the proposal that DNA codons and possibly also AAs correspond to 3-chords defining the harmony and obtained as unions of 20+20+20 3-chords associated with icosahedral 20-chord harmonies with symmetries Z_6, Z_4, Z_2 plus tetrahedral 4-chord harmony. There is large number of these harmonies bringing in additional degrees of freedom.

   Remark: This model has obviously analogies with the notion of wave genome introduced by Peter Gariaev [I12, I13, I20].

   Since music both expresses and creates emotions, the proposal is that these harmonies assigning additional hidden degrees of freedom to the MBs of dark variants of DNA, RNA, etc... serve as correlates of emotions also at the molecular level. This emotional context could also give rise to context dependence of the code if several harmonies are realizable chemically. Taking seriously TGD inspired theory of consciousness [L66] (see http://tinyurl.com/ycxm2tpd) and model of emotions [L74] (see http://tinyurl.com/ydhxen4g), one might say that the details of the code might depend slightly on the "emotional" state of DNA, RNA, and possibly other molecules.

TGD based mechanism for emotional imprinting

One must not forget that as a passionate researcher Emoto probably had very intimate relationship with water! As we all have with one particular water volume, which we call our body! I can intend raising my hand and it raises. Also my emotions are expressed in this personal bag of water containing also some fraction of biomolecules. I doubt that even the most fanatic PS would not try to tell me that I am performing a sleight of hand as I do this. But they should do this in order to take their materialistic logic to its bitter end.

One can perhaps say that Emoto extended his body by fusing with the MB of water, which in turn controls the ordinary part of water just like it controls our own body. The reports of experiences about extension of body are not unheard in the spiritual practices. Not even in everyday life. If you touch ground with a stick, you experience the touch as if the stick were part of your body. Could the stick really become part of your body in some sense?

What could be the precise mechanism for emotional imprinting (as analog of intentional imprinting that Tiller talks about [J15])?

1. The basic vision is that living matter is a quantum critical system making it extremely sensitive to perturbations (actually TGD Universe is quantum critical in well-defined sense [L81] (see `http://tinyurl.com/yakzlllk`). This makes biological system an ideal sensor and motor instrument. In particular, intentions can affect body water at quantum criticality optimally. At quantum criticality phases with several values of Planck constant $h_{eff}/h = n$ are present and correspond to dark matter which is the key player in TGD inspired model of living systems. As already noticed, the dark portion of water would be maximal at physiological temperature.
2. In the system studied by Emoto the subject person and water must form an entangled quantum critical system. Water - or rather, the MB of water - must have part of it in $h_{eff}/h = n$ dark phase becoming in certain sense part of subject person. Magnetic flux tubes connecting subject person to a sample of water (or of rice and water) and carrying dark matter would serve as correlates of attention.

   What might be called loving attention would provide metabolic energy to the target and might be essential element in generating the dark phase giving rise to the beautiful crystal patterns. $h_{eff}/h = n$ can be seen as kind of universal IQ: the more the system contains subsystems with large n, the higher its ability to generate conscious information, negentropy, is.

   Therefore choosing randomly a subject person who just says a word with positive or negative meaning but without emotion might not be enough to reproduce Emotos findings. It is also quite possible that the outcome of the experiment is a realization of subject person's intention/desire to have the desired effect. This would not however reduce the profound implications of the findings of Emoto if they are true.
3. Thanks to the presence of dark portion of water, super-cooled water is quantum critical system in TGD Universe. In supercooling the temperature can become considerably lower than in the usual freezing and means that also the dark portion of water stays dark. This dark portion would react to the intentions of subject person. The crystal structures would serve as kind of photograph is of the representations of mental images of the system subject person + dark portion of water.

   Remark: Water normally freezes at 273.15 K (0 °C), but it can be supercooled at standard pressure down to its crystal homogeneous nucleation at almost 224.8 K.

What about the effects of music and even visual pictures on water? Also these effects are in principle possible and would rely on universal representation of emotions in living matter at molecular and maybe even at higher levels. Since music represents and creates emotions, the natural assumption is that the collection of allowed 3-chords express emotions both at the molecular level and at the level of MB.

1. The resonant interaction by 3-chords made of photons is possible between any pair formed by taking given member to be either DNA, RNA, tRNA or its dark variant. Dark counterparts of AAs would couple resonantly to the frequencies defined as sums of the frequencies of 3-chords. These dark variants of bio-molecules are present also in water if TGD based explanation of Pollack effect is correct. One actually ends up to a model for prebiotic evolution involving dark nuclei made from dark proton sequences in an essential manner [L70, L78](see `http://tinyurl.com/yalny39x` and `http://tinyurl.com/yd5t82gq`).
2. The frequencies of visible light are rather high for the ordinary value of Planck constant. The original motivation for the hierarchy of Planck constants was the finding that ELF em fields have quantal effects on living matter [J7]. This led to a proposal in which bio-photons at visible and UV frequencies are dark photons at ELF frequencies transformed to ordinary photons [K13]. Also the reverse transformation taking ordinary photons to dark photons is possible so that dark matter - dark variants of AAs responding resonantly to single frequency - at the flux tubes can "see".

3. The effect of words expressing positive emotions would initiate metabolism based on fermentation. The spoken words must serve as encouraging of dis-encouraging control signal just as music of light. The meaning of the words should be same for the subject person and the system rice + water. This can be the case if the systems entangle to single system via flux tube bridges.

   This relates interestingly to the theory of Russian biologist Peter Gariaev based on the assumption that genes define a language in rather concrete sense [I27, I19, I17]. I have developed these ideas from TGD point of view in [L78] (see `http://tinyurl.com/yd5t82gq`): dark variants of genes identified as dark proton sequences - essentially dark variants of nuclei - define a universal language.

4. In the model the 3-chords in question are made of light. In the case of music as we understand it they would be made of sound. In living matter sounds can be transformed to em oscillations by piezo-electric effect. The resulting em oscillations would be accompanied by both ordinary and dark photons, and both the 3-chords and melody of the music would couple to dark dark proton triplets at flux tubes serving as counterparts of DNA, RNA, tRNA, and AAs. If the same mechanism is involved with Emoto's experiments, the sounds should transform to light or they should induce at flux tubes vibrations - dark phonons - at the same frequencies that realize the representation of biomolecules and their dark variants as 3-chords.

   Remark: In TGD Universe physical state as a collection of particles is replaced with a network of flux tubes having particles at its nodes [L40] (see `http://tinyurl.com/y9kwnqfa`). Therefore sound as vibrations of the length of flux tube accompanied by fermionic string connecting pair of nodes becomes fundamental excitation rather than something emerging only at condensed matter physics.

Ugly crystals are assigned with negative emotions and emotions are assigned with harmonies. Harmonies - also those, which are sad (consider only passions of Bach) - are however usually thought of as something beautiful. Can negative emotions really correspond to any bio-harmonies characterized by symmetries. In a discussion with Sini Kunnas I realized that also the notion of disharmony could make sense. There are indeed 6 Hamiltonian cycles without any symmetries [A3, A5, A2]. I neglected them in the model of harmony because they would represent which one might call disharmony. Could one of the contributing 3 Hamiltonian cycles in bio-harmony correspond to this kind of dis-harmony and bring in 20 3-chords without any symmetries? If so the relationship between geometry and aesthetics would become very concrete. The alternative view would be that there are several harmonies realized simultaneously and thi creates disharmony.

11.9 Connection With Mono-Atomic Elements, Cold Fusion, And Sono-luminescence?

Anomalies are treasures for a theoretician and during years I have been using quite a bundle of reported anomalies challenging the standard physics as a test bed for the TGD vision about physics. The so called mono-atomic elements, cold fusion, and sonofusion represent examples of this kind of anomalies not taken seriously by most standard physicists. In the following the possibility that dark matter as large $\hbar$ phase could allow to understand these anomalies.

Of course, I hear the angry voice of the skeptic reader blaming me for a complete lack of source criticism and the skeptic reader is right. I however want to tell him that I am not a soldier in troops of either skeptics or new-agers. My attitude is "let us for a moment assume that these findings are real..." and look for the consequences in this particular theoretical framework.

11.9.1 Mono-Atomic Elements As Dark Matter And High T_c Super-Conductors?

The ideas related to many-sheeted space-time began to develop for a decade ago. The stimulation came from a contact by Barry Carter who told me about so called mono-atomic elements, typically transition metals (precious metals), including Gold. According to the reports these elements, which are also called ORMEs ("orbitally rearranged monoatomic elements") or ORMUS, have following properties.

1. ORMEs were discovered and patented by David [H4] [H4] are peculiar elements belonging to platinum group (platinum, palladium, rhodium, iridium, ruthenium and osmium) and to transition elements (gold, silver, copper, cobalt and nickel).
2. Instead of behaving as metals with valence bonds, ORMEs have ceramic like behavior. Their density is claimed to be much lower than the density of the metallic form.
3. They are chemically inert and poor conductors of heat and electricity. The chemical inertness of these elements have made their chemical identification very difficult.
4. One signature is the infra red line with energy of order .05 eV. There is no text book explanation for this behavior. Hudson also reports that these elements became visible in emission spectroscopy in which elements are posed in strong electric field after time which was 6 times longer than usually.

The pioneering observations of David Hudson [H4] - if taken seriously - suggest an interpretation as an exotic super-conductor at room temperature having extremely low critical magnetic fields of order of magnetic field of Earth, which of course is in conflict with the standard wisdom about super-conductivity. After a decade and with an impulse coming from a different contact related to ORMEs, I decided to take a fresh look on Hudson's description for how he discovered ORMEs [H4] with dark matter in my mind. From experience I can tell that the model to be proposed is probably not the final one but it is certainly the simplest one.

There are of course endless variety of models one can imagine and one must somehow constrain the choices. The key constraints used are following.

1. Only valence electrons determining the chemical properties appear in dark state and the model must be consistent with the general model of the enhanced conductivity of DNA assumed to be caused by large $\hbar$ valence electrons with $r = \hbar/\hbar_0 = n$, $n = 5, 6$ assignable with aromatic rings. $r = 6$ for valence electrons would explain the report of Hudson about anomalous emission spectroscopy.
2. This model cannot explain all data. If ORMEs are assumed to represent very simple form of living matter also the presence electrons having $\hbar/\hbar_0 = 2^{k11}$, $k = 1$, can be considered and would be associated with high T_c super-conductors whose model predicts structures with thickness of cell membrane. This would explain the claims about very low critical magnetic fields destroying the claimed superconductivity.

Below I reproduce Hudson's own description here in a somewhat shortened form and emphasize that must not forget professional skepticism concerning the claimed findings.

Basic findings of Hudson

Hudson was recovering gold and silver from old mining sources. Hudson had learned that something strange was going on with his samples. In molten lead the gold and silver recovered but when "I held the lead down, I had nothing". Hudson tells that mining community refers to this as "ghost-gold", a non-assayable, non-identifiable form of gold.

Then Hudson decided to study the strange samples using emission spectroscopy. The sample is put between carbon electrodes and arc between them ionizes elements in the sample so that they radiate at specific frequencies serving as their signatures. The analysis lasts 10-15 seconds since for longer times lower electrode is burned away. The sample was identified as Iron, Silicon, and Aluminium. Hudson spent years to eliminate Fe, Si, and Al. Also other methods such as Cummings Microscopy, Diffraction Microscopy, and Fluorescent Microscopy were applied and the final conclusion was that there was nothing left in the sample in spectroscopic sense.

After this Hudson returned to emission spectroscopy but lengthened the time of exposure to electric field by surrounding the lower Carbon electrode with Argon gas so that it could not burn. This allowed to reach exposure times up to 300 s. The sample was silent up to 90 s after which emission lines of Palladium (Pd) appeared; after 110 seconds Platinum (Pt); at 130 seconds Ruthenium (Ru); at about 140-150 seconds Rhodium; at 190 seconds Iridium; and at 220 seconds Osmium appeared. This is known as fractional vaporization.

Hudson reports the boiling temperatures for the metals in the sample having in mind the idea that the emission begins when the temperature of the sample reaches boiling temperature

Element	Ca	Fe	Si	Al	Pd	Rh
$T_B/^oC$	1420	1535	2355	2327	>2200	2500
Element	Ru	Pt	Ir	Os	Ag	Au
$T_B/^oC$	4150	4300	> 4800	> 5300	1950	2600

Table 11.2: Boiling temperatures of elements appearing in the samples of Hudson.

inspired by the observation that elements become visible in the order which is same as that for boiling temperatures.

The boiling temperatures for the elements appearing in the sample are given by **Table 11.2**.

Hudson experimented also with commercially available samples of precious metals and found that the lines appear within 15 seconds, then follows a silence until lines re-appear after 90 seconds. Note that the ratio of these time scales is 6. The presence of some exotic form of these metals suggests itself: Hudson talks about mono-atomic elements.

Hudson studied specifically what he calls mono-atomic gold and claims that it does not possess metallic properties. Hudson reports that the weight of mono-atomic gold, which appears as a white powder, is 4/9 of the weight of metallic gold. Mono-atomic gold is claimed to behave like super-conductor.

Hudson does not give a convincing justification for why his elements should be mono-atomic so that in following this attribute will be used just because it represents established convention. Hudson also claims that the nuclei of mono-atomic elements are in a high spin state. I do not understand the motivations for this statement.

Remark: More than decade after writing this text (I am writing this 2018) I realized that Hudson's claim about high spin nuclei could make sense in TGD framework. If some valence nucleons inside nucleus, say neutrons in the halo, are dark - just as valence electrons in the model for the findings of Hudson - in the sense of having non-standard value $h_{eff}/h_0 = n$ of Planck constant, the unit for the quantization of angular momentum increases for them. The most plausible identification of the ordinary Planck constant is as $h = 6h_0$ [L42, L73] so that the unit of angular momentum would become $(n/6)\hbar/2$ for these exotic nuclei, and one could understand the large values of nuclear angular momenta.

Claims of Hudson about ORMEs as super conductors

The claims of Hudson that ORMES are super conductors [H4] are in conflict with the conventional wisdom about super conductors.

1. The first claim is that ORMEs are super conductors with gap energy about $E_g = .05$ eV and identifies photons with this energy resulting from the formation of Cooper pairs. This energy happens to correspond one of the absorption lines in high T_c superconductors.
2. ORMEs are claimed to be super conductors of type II with critical fields H_{c1} and H_{c2} of order of Earth's magnetic field having the nominal value $.5 \times 10^{-4}$ Tesla [H4]. The estimates for the critical parameters for the ordinary super conductors suggests for electronic super conductors critical fields, which are about .1 Tesla and thus by a factor $\sim 2^{12}$ larger than the critical fields claimed by Hudson.
3. It is claimed that ORME particles can levitate even in Earth's magnetic field. The latter claim looks at first completely nonsensical. The point is that the force giving rise to the levitation is roughly the gradient of the would-be magnetic energy in the volume of levitating super conductor. The gradient of average magnetic field of Earth is of order B/R, R the radius of Earth and thus extremely small so that genuine levitation cannot be in question.

Minimal model

Consider now a possible TGD inspired model for these findings assuming for definiteness that the basic Hudson's claims are literally true.

1. In what sense mono-atomic elements could be dark matter?

The simplest option suggested by the applicability of emission spectroscopy and chemical inertness is that mono-atomic elements correspond to ordinary atoms for which valence electrons are dark electrons with large value of $r = \hbar/\hbar_0$. Suppose that the emission spectroscopy measures the energies of dark photons from the transitions of dark electrons transforming to ordinary photons before the detection by de-coherence increasing the frequency by r. The size of dark electrons and temporal duration of basic processes would be zoomed up by r.

Since the time scale after which emission begins is scaled up by a factor 6, there is a temptation to conclude that $r = 6$ holds true. Note that $n = 6$ corresponds to Fermat polygon and is thus preferred number theoretically in TGD based model for preferred values of $\hbar$ [K43]. The simplest possibility is that the group G_b is trivial group and $G_a = A_6$ or D_6 so that ring like structures containing six dark atoms are suggestive.

This brings in mind the model explaining the anomalous conductivity of DNA by large $\hbar$ valence electrons of aromatic rings of DNA. The zooming up of spatial sizes might make possible exotic effects and perhaps even a formation of atomic Bose-Einstein condensates of Cooper pairs. Note however that in case of DNA $r = 6$ not gives only rise to conductivity but not super-conductivity and that $r = 6$ cannot explain the claimed very low critical magnetic field destroying the super-conductivity.

2. Loss of weight

The claimed loss of weight by a factor $p \simeq 4/9$ is a very significant hint if taken seriously. The proposed model implies that the density of the partially dark phase is different from that of the ordinary phase but is not quantitative enough to predict the value of p. The most plausible reason for the loss of weight would be the reduction of density induced by the replacement of ordinary chemistry with $r = 6$ chemistry for which the Compton length of valence electrons would increase by this factor.

3. Is super-conductivity possible?

The overlap criterion is favorable for super-conductivity since electron Compton lengths would be scaled up by factor $n_a = 6, n_b = 1$. For $r = \hbar/\hbar_0 = n_a = 6$ Fermi energy would be scaled up by $n_a^2 = 36$ and if the same occurs for the gap energy, T_c would increase by a factor 36 from that predicted by the standard BCS theory. Scaled up conventional super-conductor having $T_c \sim 10$ K would be in question (conventional super-conductors have critical temperatures below 20 K). 20 K upper bound for the critical temperature of these superconductors would allow 660 K critical temperature for their dark variants!

For large enough values of r the formation of Cooper pairs could be favored by the thermal instability of valence electrons. The binding energies would behave as $E = r^2 Z_{eff}^2 E_0/n^2$, where Z_{eff} is the screened nuclear charge seen by valence electrons, n the principal quantum number for the valence electron, and E_0 the ground state energy of hydrogen atom. This gives binding energy smaller than thermal energy at room temperature for $r > (Z_{eff}/n)\sqrt{2E_0/3T_{room}} \simeq 17.4 \times (Z_{eff}/n)$. For $n = 5$ and $Z_{eff} < 1.7$ this would give thermal instability for $r = 6$.

Interestingly, the reported .05 eV infrared line corresponds to the energy assignable to cell membrane voltage at criticality against nerve pulse generation, which suggests a possible connection with high T_c superconductors for which also this line appears and is identified in terms of Josephson energy. .05 eV line appears also in high T_c superconductors. This interpretation does not exclude the interpretation as gap energy. The gap energy of the corresponding BCS super-conductor would be scaled down by $1/r^2$ and would correspond to 14 K temperature for $r = 6$.

Also high T_c super-conductivity could involve the transformation of nuclei at the stripes containing the holes to dark matter and the formation of Cooper pairs could be due to the thermal instability of valence electrons of Cu atoms (having $n = 4$). The rough extrapolation for the critical temperature for cuprate superconductor would be $T_c(Cu) = (n_{Cu}/n_{Rh})^2 T_c(Rh) = (25/36)T_c(Rh)$. For $T_c(Rh) = 300$ K this would give $T_c(Cu) = 192$ K: according to Wikipedia cuprate perovskite has the highest known critical temperature which is 138 K. Note that quantum criticality suggests the possibility of several values of (n_a, n_b) so that several kinds of super-conductivities might be present.

ORMEs as partially dark matter, high T_c super conductors, and high T_c super-fluids

The appearance of .05 eV photon line suggest that same phenomena could be associated with ORMEs and high T_c super-conductors. The strongest conclusion would be that ORMEs are T_c super-conductors and that the only difference is that Cu having single valence electron is replaced by a heavier atom with single valence electron. In the following I shall discuss this option rather independently from the minimal model.

1. ORME super-conductivity as quantum critical high T_c superconductivity

ORMEs are claimed to be high T_c superconductors and the identification as quantum critical superconductors seems to make sense.

1. According to the model of high T_c superconductors as quantum critical systems, the properties of Cooper pairs should be more or less universal so that the observed absorption lines discussed in the section about high T_c superconductors should characterize also ORMEs. Indeed, the reported 50 meV photon line corresponds to a poorly understood absorption line in the case of high T_c cuprate super conductors having in TGD framework an interpretation as a transition in which exotic Cooper pair is excited to a higher energy state. Also Copper is a transition metal and is one of the most important trace elements in living systems [D2]. Thus the Cooper pairs could be identical in both cases. ORMEs are claimed to be superconductors of type II and quantum critical superconductors are predicted to be of type II under rather general conditions.
2. The claimed extremely low value of H_c is also consistent with the high T_c superconductivity. The supra currents in the interior of flux tubes of radius of order $L_w = .4$ μm are BCS type supra currents with large $\hbar$ so that T_c is by a factor 2^{14} ($127 - 113 = 14$ is inspired by the Mersenne hypothesis for the preferred p-adic length scales) higher than expected and H_c is reduced by a factor 2^{-10}. This indeed predicts the claimed order of magnitude for the critical magnetic field.
3. The problem is that $r = 2^{14}$ is considerably higher that $r = 6$ suggested by the minimum model explaining the emission spectroscopic results of Hudson. Of course, several values of $\hbar$ are possible so that internal consistency would be achieved if ORMEs are regarded as a very simple form of living matter with relatively small value of r and giving up the claim about the low value of critical magnetic field.
4. The electronic configurations of Cu and Gold are chemically similar. Gold has electronic configuration $[Xe, 4f^{14}5d^{10}]6s$ with one valence electron in s state whereas Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages to think that the doping by holes needed to achieve superconductivity induces the dropping of these electrons to $k = 151$ space-time sheets and gives rise to exotic Cooper pairs.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

   Also this model assumes the phase transition of some fraction of Cu nuclei to large $\hbar$ phase and that exotic Cooper pairs appear at the boundary of ordinary and large $\hbar$ phase.

   More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. Both Cu and Au atoms are bosons. More generally, if the atom in question is boson, the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. Thus elements with odd value of A and Z possessing full shells plus single s wave valence electron are of special interest. The six stable elements satisfying these conditions are ^{5}Li, ^{39}K, ^{63}Cu, ^{85}Rb, ^{133}Cs, and ^{197}Au.

2. "Levitation" and loss of weight

The model of high T_c superconductivity predicts that some fraction of Cu atoms drops to the flux tube with radius $L_w = .4$ μm and behaves as a dark matter. This is expected to occur also in the case of other transition metals such as Gold. The atomic nuclei at this space-time sheet have high charges and make phase transition to large $\hbar$ phase and form Bose-Einstein condensate and superfluid behavior results. Electrons in turn form large $\hbar$ variant of BCS type superconductor. These flux tubes are predicted to be negatively charged because of the Bose-Einstein condensate of exotic Cooper pairs at the boundaries of the flux tubes having thickness $L(151)$. The average charge density equals to the doping fraction times the density of Copper atoms.

The first explanation would be in terms of super-fluid behavior completely analogous to the ability of ordinary superfluids to defy gravity. Second explanation is based on the electric field of Earth which causes an upwards directed force on negatively charged BE condensate of exotic Cooper pairs and this force could explain both the apparent levitation and partial loss of weight. The criterion for levitation is $F_e = 2eE/x \geq F_{gr} = Am_pg$, where $g \simeq 10$ m^2/s is gravitational acceleration at the surface of Earth, A is the atomic weight and m_p proton mass, E the strength of electric field, and x is the number of atoms at the space-time sheet of a given Cooper pair. The condition gives $E \geq 5 \times 10{-}10Ax$ V/m to be compared with the strength $E = 10^2 - 10^4$ V/m of the Earths electric field.

An objection against the explanation for the effective loss of weight is that it depends on the strength of electric field which varies in a wide range whereas Hudson claims that the reduction factor is constant and equal to 4/9. A more mundane explanation would be in terms of a lower density of dark Gold. This explanation is quite plausible since there is no atomic lattice structure since nuclei and electrons form their own large $\hbar$ phases.

4. The effects on biological systems

Some monoatomic elements such as White Gold are claimed to have beneficial effects on living systems [H4]. 5 per cent of brain tissue of pig by dry matter weight is claimed to be Rhodium and Iridium. Cancer cells are claimed to be transformed to healthy ones in presence of ORMEs. The model for high T_c super conductivity predicts that the flux tubes along which interior and boundary supra currents flow has same structure as neuronal axons. Even the basic length scales are very precisely the same. On basis of above considerations ORMEs are reasonable candidates for high T_c superconductors and perhaps even super fluids.

The common mechanism for high T_c, ORME- and bio- super-conductivities could explain the biological effects of ORMEs.

1. In unhealthy state superconductivity might fail at the level of cell membrane, at the level of DNA or in some longer length scales and would mean that cancer cells are not anymore able to communicate. A possible reason for a lost super conductivity or anomalously weak super conductivity is that the fraction of ORME atoms is for some reason too small in unhealthy tissue.
2. The presence of ORMEs could enhance the electronic bio- superconductivity which for some reason is not fully intact. For instance, if the lipid layers of cell membrane are, not only wormhole-, but also electronic super conductors and cancer involves the loss of electronic super-conductivity then the effect of ORMEs would be to increase the number density of Cooper pairs and make the cell membrane super conductor again. Similar mechanism might work at DNA level if DNA: s are super conductors in "active" state.

5. Is ORME super-conductivity associated with the magnetic flux tubes of dark magnetic field $B_d = 0.2$ Gauss?

The general model for the ionic super-conductivity in living matter, which has developed gradually during the last few years and will be discussed in detail later, was originally based on the assumption that super-conducting particles reside at the super-conducting magnetic flux tubes of Earth's magnetic field with the nominal value $B_E = .5$ Gauss. It became later clear that the explanation of ELF em fields on vertebrate brain requires $B_d = .2$ Gauss rather than $B_E = .5$ Gauss [K41]. The interpretation was as dark magnetic field $B_d = .2$ Gauss. The model of EEG led also to the hypothesis that Mersenne primes and their Gaussian counterparts define preferred p-adic length scales and their dark counterparts. This hypothesis replaced the earlier $r = 2^{11k}$ hypothesis.

For $r = 2^{127-113=14}$ the predicted radius $L_w = .4$ μm is consistent with the radius of neuronal axons. If one assumes that the radii of flux tubes are given by this length scale irrespective of the value of r, one must replace the quantization condition for the magnetic flux with a more general condition in which the magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint (p - eA) \cdot dl = n\hbar$ and assume $n = 0$. The supra currents would be present inside living organism but in the faraway region where flux quanta from organism fuse together, the quantization conditions $e \int B \cdot dS = n\hbar$ would be satisfied.

The most natural interpretation would be that these flux tubes topologically condense at the flux tubes of B_E. Both bosonic ions and the Cooper pairs of electrons or of fermionic ions can act as charge carriers so that actually an entire zoo of super-conductors is predicted. There is even some support for the view that even molecules and macromolecules can drop to the magnetic flux tubes [K57].

Nuclear physics anomalies and ORMEs

At the homepage of Joe Champion [H21] information about claimed nuclear physics anomalies can be found.

1. The first anomaly is the claimed low temperature cold fusion. For instance, Champion claims that Mercury (Z=80), decays by emission of proton and neutrons to Gold with Z=79 in the electrochemical arrangement described in [H21].
2. Champion mentions also the anomalous production of Cadmium isotopes electrochemically in presence of Palladium reported by Tadahiko Mizuno.

The simplest explanation of the anomalies would be based on genuine nuclear reactions. The interaction of dark nuclei with ordinary nuclei at the boundary between the two phases would make possible genuine nuclear transmutations since the Coulomb wall hindering usually cold fusion and nuclear transmutations would be absent (Trojan horse mechanism). Both cold fusion and reported nuclear transmutations in living matter could rely on this mechanism as suggested in [K103, L4, K40], [L4].

Possible implications

The existence of exotic atoms could have far reaching consequences for the understanding of bio-systems. If Hudson's claims about super-conductor like behavior are correct, the formation of exotic atoms in bio-systems could provide the needed mechanism of electronic super-conductivity. One could even argue that the formation of exotic atoms is the magic step transforming chemical evolution to biological evolution.

Equally exciting are the technological prospects. If the concept works it could be possible to manufacture exotic atoms and build room temperature super conductors and perhaps even artificial life some day. It is very probable that the process of dropping electron to the larger space-time sheet requires energy and external energy feed is necessary for the creation of artificial life. Otherwise the Earth and other planets probably have developed silicon based life for long time ago. Ca, K and Na ions have central position in the electrochemistry of cell membranes. They could actually correspond to exotic ions obtained by dropping some valence electrons from $k = 137$ atomic space-time sheet to larger space-time sheets. For instance, the $k = 149$ space-time sheet of lipid layers could be in question.

The status of ORMEs is far from certain and their explanation in terms of exotic atomic concept need not be correct. The fact is however that TGD predicts exotic atoms: if they are not observed TGD approach faces the challenge of finding a good explanation for their non-observability.

Interestingly, Palladium is one of the "mono-atomic" elements used also in cold fusion experiments as a target material [C46, C112]. This inspires the question whether mono-atomic phase is one of the prerequisites for cold fusion.

11.9.2 Basic Ideas About Cold Fusion

The basic prediction of TGD is a hierarchy of fractally scaled variants of QCD like theories and that color dynamics is fundamental even for our sensory qualia (visual colors identified as increments of color quantum numbers in quantum jump). The model for ORMEs suggest that exotic protons obey QCD like theory in the size scale of atom. If this identification is correct, QCD like dynamics might be studied some day experimentally in atomic or even macroscopic length scales of order cell size and there would be no need for ultra expensive accelerators!

What makes possible cold fusion?

I have proposed that cold fusion might be based on Trojan horse mechanism in which incoming and target nuclei feed their em gauge fluxes to different space-time sheets so that electromagnetic Coulomb wall disappears [K103]. If part of Palladium nuclei are "partially dark", this is achieved. Another mechanism could be the de-localization of protons to a larger volume than nuclear volume induced by the increase of h_{eff} meaning that reaction environment would differ dramatically from that appearing in the usual nuclear reactions and the standard objections against cold fusion would not apply anymore [K103]: this de-localization could correspond to the darkness of electromagnetic and perhaps also electroweak field bodies of protons.

A third proposal is perhaps the most elegant and relies on the nuclear string model [L4] predicting a large number of exotic nuclei obtained by allowing the color bonds connecting nucleons to have all possible em charges $1, 0, 1$. Many ordinary heavy nuclei would be exotic in the sense that some protons would correspond to protons plus negatively charged color bonds. The exchange of an exotic weak boson between D and Pd nuclei transforming D nuclei to exotic neutral D nuclei would occur. The range of the exotic weak interaction correspond to atomic length scale meaning that it behaves as massless particle below this length scale. For instance, W boson could be $r = 2^{24}$ dark variant of $k = 113$ weak boson for which the dark variant of p-adic scale would correspond to the atomic scale $k = 137$ but also other options are possible.

How standard objections against cold fusion can be circumvented?

The following arguments against cold fusion are from an excellent review article by Storms [C48].

1. Coulomb wall requires an application of higher energy. Now electromagnetic Coulomb wall disappears in both models.
2. If a nuclear reaction should occur, the immediate release of energy can not be communicated to the lattice in the time available. In the recent case the time scale is however multiplied by the factor $r = n_a$ and the situation obviously changes. For $n_a = 2^{24}$ the time scale corresponding to MeV energy becomes that corresponding to keV energy which is atomic time scale.
3. When such an energy is released under normal conditions, energetic particles are emitted along with various kinds of radiation, only a few of which are seen by various CANR (Chemically Assisted Nuclear Reactions) studies. In addition, gamma emission must accompany helium, and production of neutrons and tritium, in equal amounts, must result from any fusion reaction. None of these conditions is observed during the claimed CANR effect, no matter how carefully or how often they have been sought. The large value of $\hbar(M^4)$ implying large Compton lengths for protons making possible geometric coupling of gamma rays to condensed matter would imply that gamma rays do not leave the system. If only protons form the quantum coherent state then fusion reactions do not involve the protons of the catode at all and production of ^3He and thus of neutrons in the fusion of D and exotic D.
4. The claimed nuclear transmutation reactions (reported to occur also in living matter [C32]) are very difficult to understand in standard nuclear physics framework.
   (a) The model of [K103] allows them since protons of different nuclei can re-arrange in many different ways when the dark matter state decays back to normal.
   (b) Nuclear string model [L4] allows transmutations too. For instance, neutral exotic tritium produced in the reactions can fuse with Pd and other nuclei.
5. Many attempts to calculate fusion rates based on conventional models fail to support the claimed rates within PdD (Palladium-Deuterium). The atoms are simply too far apart. This objections also fails for obvious reasons.

Mechanisms of cold fusion

In TGD framework exotic nuclei are needed to explain the selection rules which do not conform with standard nuclear physics. There are several options for what exotic nuclei could be.

1. Nuclei might be partially dark with some nucleons in dark state with Compton length of order atomic length scale.
2. Nuclei can also be exotic in the sense that some neutral color bonds have transformed to charged ones by exchange of dark W bosons effectively massless below atomic length scale. This could transform D nuclei to neutral ones and eliminate Coulomb wall. The presence of two oppositely charged bonds by (possibly dark) W exchange could give rise to a nucleus with same em charge as the original but different mass: presumably mass difference would be of order keV.
3. Also the emitted em radiation - say gamma rays - and particles - say protons or neutrons - could be dark and could remain undetected using standard means.

From this it is clear that it easy to invent models consistent with observations: careful consideration of data might however allow to fix the model to a high degree. One can try to deduce a more detailed model for cold fusion from observations, which are discussed systematically in [C48] and in the references discussed therein.

1. A critical phenomenon is in question. The average D/Pd ratio must be in the interval $(.85, .90)$. The current must be over-critical and must flow a time longer than a critical time. The effect occurs in a small fraction of samples. D at the surface of the catode is found to be important and activity tends to concentrate in patches. The generation of fractures leads to the loss of the anomalous energy production. Even the shaking of the sample can have the same effect. The addition of even a small amount of H_2O to the electrolyte (protons to the catode) stops the anomalous energy production.
   (a) These findings are consistent the view that patches correspond to a macroscopic quantum phase involving de-localized nuclear protons. The added ordinary protons and fractures could serve as a seed for a phase transition leading to the ordinary phase [K103].
   (b) An alternative interpretation is in terms of the formation of neutral exotic D and exotic Pd via exchange of exotic, possibly dark, W bosons massless below atomic length scale [L4].
2. When D_2O is used as an electrolyte, the process occurs when PdD acts as a catode but does not seem to occur when it is used as anode. This suggests that the basic reaction is between the ordinary deuterium $D = pn$ of electrolyte with the exotic nucleus of the catode. Denote by $\hat{p}$ the exotic proton and by $\hat{D} = n\hat{p}$ exotic deuterium at the catode.
   For ordinary nuclei fusions to tritium and ^3He occur with approximately identical rates. The first reaction produces neutron and ^3He via $D + D \rightarrow n +^3 He$, whereas second reaction produces proton and tritium by $3H$ via $D + D \rightarrow p +^3 H$. The prediction is that one neutron per each tritium nucleus should be produced. Tritium can be observed by its beta decay to ^3He and neutron flux is several orders of magnitude smaller than tritium flux as found for instance by Tadahiko Mizuno and his collaborators (Mizuno describes the experimental process leading to this discovery in his book [C82]). Hence the reaction producing ^3He cannot occur significantly in cold fusion which means a conflict with the basic predictions of the standard nuclear physics.
   (a) The explanation discussed in [K103] does not involve exotic nuclei with charged color bonds. The assumption is that the proton in the target deuterium $\hat{D}$ is in the exotic state with large Compton length and the production of ^3He occurs very slowly since $\hat{p}$ and p correspond to different space-time sheets. Since neutrons and the proton of the D from the electrolyte are in the ordinary state, Coulomb barrier is absent and tritium production can occur. The mechanism also explains why the cold fusion producing ^3He and neutrons does not occur using water instead of heavy water.
   (b) Nuclear string model [L4] model with charged color bonds predicts that only neutral exotic tritium is produced considerably when incoming deuterium interacts with neutral exotic deuterium in the target. This requires that in target D nuclei exchange large $\hbar$ W boson with electron or Pd or other D nucleus. In the latter case the outcome is two exotic nuclei looking chemically like di-neutron and ^3He.

3. The production of ^4He has been reported although the characteristic gamma rays have not been detected.
   (a) ^4He can be produced in reactions such as $D + \hat{D} \rightarrow^4 He$ or its exotic counterpart in the model of [K103].
   (b) Nuclear string model [K103] does not allow direct production of ^4He in D-D collisions.
4. Also more complex reactions between D and Pd for which protons are in exotic state, can occur. These can lead to the reactions transforming the nuclear charge of Pd and thus to nuclear transmutations.

   Both models allow nuclear transmutations. In nuclear string model [K103] the resulting exotic tritium can fuse with Pd and other nuclei and produce nuclear transmutations.

   The reported occurrence of nuclear transmutation such as $^{23}Na +^{16} O \rightarrow^{39} K$ in living matter [C32] allowing growing cells to regenerate elements K, Mg, Ca, or Fe, could be understood in nuclear string model if also neutral exotic charge states are possible for nuclei in living matter. The experimental signature for the exotic ions would be cyclotron energy spectrum containing besides the standard lines also lines with ions with anomalous mass number. This could be seen as a splitting of lines. For instance, exotic variants of ions such Na^+, K^+, Cl^-, Ca^{++} with anomalous mass numbers should exist. It would be easy to mis-interpret the situation unless the actual strength of the magnetic field is not checked.
5. Gamma rays, which should be produced in most nuclear reactions such as ^4He production to guarantee momentum conservation are not observed.
   (a) The explanation of the model of [K103] is that the recoil momentum goes to the macroscopic quantum phase and eventually heats the electrolyte system. This provides obviously the mechanism by which the liberated nuclear energy is transferred to the electrolyte difficult to imagine in standard nuclear physics framework. The emitted gamma rays could be also dark and observed only if they transform to ordinary ones.
   (b) In nuclear string model [L4] ^4He is not produced at all.
6. Both models explain why neutrons are not produced in amounts consistent with the anomalous energy production. The addition of water to the electrolyte is however reported to induce neutron bursts.
   (a) In the model of [K103] (no charged color bonds) a possible mechanism is the production of neutrons in the phase transition $\hat{p} \rightarrow p$. $\hat{D} \rightarrow p + n$ could occur as the proton contracts back to the ordinary size in such a manner that it misses the neutron. This however requires energy of 2.23 MeV if the rest masses of $\hat{D}$ and D are same. Also $\hat{D} + \hat{D} \rightarrow n +^3 He$ could be induced by the phase transition to ordinary matter when $\hat{p}$ transformed to p does not combine with its previous neutron partner to form D but recombines with $\hat{D}$ to form $^3\hat{H}e \rightarrow^3 He$ so that a free neutron is left.
   (b) Nuclear string model [L4] would suggest that the collisions of protons of water with exotic neutral D with negatively charged color bond produce neutron and ordinary D. This requires the transformation of negatively charged color bond between p and n of target D to a neutral color bond between incoming p and neutron of target.

A cautious conclusion is that nuclear string model with exotic color bonds and dark weak bosons is the more natural option. Also dark protons suggested strongly by the model for the dark portion of water can be considered but partial darkness of nuclei is perhaps an artificial idea. Note that all nuclei might appear as dark variants with size scale of molecules and analogous to folded proteins. This intriguing similarity creates the question whether the physics of linear biomolecules mimics nuclear physics and whether dark nuclei are involved with this mimicry natural in the fractal Universe of TGD.

11.9.3 Does Rossi's Reactor Give Rise To Cold Fusion?

Lubos Motl has been raging several times about the cold fusion gadget of Andrea Rossi and I decided to write the following response as he returned to the topic again (see `http://tinyurl.com/ot5kfok`). The claim of Rossi and physicist Fogardi [C102] is that the cold fusion reaction of H and Ni producing Cu takes place in the presence of some "additives" (Palladium catalyst as in may cold fusion experiments gathering at its surface Ni?).

Objections claiming that the evaporation of water does not actually take place

Lubos Motl of course “knows” before hand that the gadget cannot work: Coulomb barrier. Since Lubos Motl is true believer in naïve text book wisdom, he simply refuses to consider the possibility that the physics that we learned during student days might not be quite right. Personally I do not believe or disbelieve cold fusion: I just take it seriously as any person calling himself scientist should do. I have been developing for more than 15 years ideas about possible explanation of cold fusion in TGD framework. The most convincing idea is that large value of Planck constant associated with nuclei could be involved scaling up the range of weak interactions from 10^{-17} meters to atomic size scale and also scaling up the size of nucleus to atomic size scale so that nucleus and even quarks would like constant charge densities instead of point like charge. Therefore Coulomb potential would be smoothed and the wall would become much lower [K103, L4].

One must say in honor of Lubos Motl that at this time he had detailed arguments about what goes wrong with the reactor of Rossi: this is in complete contrast with the usual arguments of skeptics which as a rule purposefully avoid saying anything about the actual content and concentrate on ridiculing the target. The reason is of course that standard skeptic is just a soldier who has got the list of targets to be destroyed and as a good soldier does his best to achieve the goal. Thinking is not what a good soldier is expected to do since the professors in the consultive board take care of this and give orders to those doing the dirty job.

As a theoretician I have learned the standard arguments used to debunk TGD: logic is circular, text is mere world salad, everything is just cheap numerology, too many self references, colleagues have not recognized my work, the work has not been published in respected journals, and so on. The additional killer arguments state that I have used certain words which are taboos and already for this reason am a complete crackpot. Examples of bad words are “water memory”, “homeopathy”, “cold fusion”, “crop circles”, “quantum biology”, “quantum consciousness”. There is of course no mention about the fact that I have always emphasized that I am skeptic, not a believer or disbeliever, and only make the question “What if....” and try to answer it in TGD framework. Intellectual honesty does not belong to the virtues of skeptics who are for modern science what jesuits were for the catholic church. Indeed, as Loyola said: the purpose sanctifies the deeds.

Lubos Motl has real arguments but they suffer from the strong negative emotional background coloring so that one cannot be trust the rationality of the reasoning. The core of the arguments of Lubos Motl is following.

1. The water inside reactor is heated to a temperature of 100.1 C. This is slightly above 100 C defining the nominal value of the boiling point temperature at normal pressure. The problem is that if the pressure is somewhat higher, the boiling point increases and the it could happen that the no evaporation of the water takes place. If this is the case, the whole energy fed into the reactor could go to the heating of the water. The input power is indeed somewhat higher than the power needed to heat the water to this temperature without boiling so that this possibility must be taken seriously and the question is whether the water is indeed evaporated.

   Comments:

   (a) This looks really dangerous. Rossi uses water only as a passive agent gathering the energy assumed to be produced in the fusion of hydrogen and nickel to copper. This would allow to assume that the water fed in is at lower temperature and also the water at outlet is below boiling boiling. Just by measuring the temperature at the outlet one can check whether the outgoing water has temperature higher than it would be if all input energy goes to its heating.

   (b) This is only one particular demonstration and it might be that there are other demonstrations in which the situation is this. As a matter fact, from an excellent video interview of Nobelist Brian Josephson (see `http://tinyurl.com/ya2n6mbd`) one learns that there are also demonstrations in which water is only heated so that the argument of Lubos Motl does not bite here. The gadget of Rossi is already used to heat university building. The reason why the evaporation is probably that this provides an effective manner to collect the produced energy. Also by reading the Nyteknik report (see `http://tinyurl.com/ohal8cd`) [C102] one learns that the energy production is directly measured rather than being based on the assumption that evaporation occurs.

2. Is the water evaporated or not? This is the question posed by Lubos Motl. The demonstration shows explicitly that there is a flow of vapor from the outlet. As Rossi explains there is some condensation. Lubos Motl claims that the flow of about 2 liters of vapor per second resulting from the evaporation 2 ml of water per second should produce much more dramatic visual effect. More vapor and with a faster flow velocity. Lubos Motl claims that water just drops from the tube and part of it spontaneously evaporates. This is what Lubos Motl wants to see and I have no doubt that he is seeing it. Strong belief can move mountains! Or at least can make possible the impression that they are moving!

   Comments:

   (a) I do not see what Lubos Motl sees but I am not able to tell how many liters of vapor per second comes out. Therefore the visual demonstration as such is not enough.

   (b) I wonder why Rossi has not added flow meter measuring the amount of vapor going through the tube. Second possibility is to allow the vapor condense back to water in the tube by using heat exchanger. This would allow to calculate the energy gain without making the assumption that all that comes out is vapor. It might be that in some experiments this is done.

3. But why would Rossi use this kind of questionable arrangement susceptible to accusations about fraud? Why not use lower temperature in which evaporation does not take place (Josephson reports that this has been done in some demonstrations)? The presence of dark matter phase is essential in TGD based model for cold fusion by proton absorption, and TGD vision about the generation of dark matter allows to image a possible good reason for working near thermodynamical criticality.

   The phases with large value of Planck constant are associated with quantum criticality involving long range quantum fluctuations, and large scale quantum coherence is assignable to a large value of h_{eff}. To generate dark matter one must create quantum criticality. If thermodynamical criticality is accompanied by quantum criticality at the deeper level, cold fusion would be most effective near thermodynamical criticality. In the similar manner, the doping ratio of Palladium by deuterium in $p + D$ cold fusion must be critical.

   A possible concrete model relies on the generation of large h_{eff} variants of weak bosons effectively massless below the dark weak scale, which relates to the weak scale by a factor h_{eff}/h or $(h_{eff}/h)^{1/2}$ (depending on whether the p-adic length scale is proportional to h_{eff} as suggested by the definition of Compton length or to $(h_{eff}/h)^{1/2}$ as suggested by p-adic mass calculations). In any case case, the weak scale would be scaled down from about 10^{-17} meters to atomic length scale 10^{-10} meters. This would make weak interactions as strong as em interaction below dark weak scale and proton could exchange dark W boson with target nucleus transforming therefore to neutron experiencing no Coulomb wall. Dark weak boson would be absorbed by color bond between nuclei of nuclear string [L4].

To sum up, Lubos Motl in his eagerness to debunk forgets that he is concentrating on single demonstration and forgetting other demonstrations altogether and also the published report [C102] to which his argument do not apply. I remain however skeptic (I mean real skeptic, the skepticism of Lubos Motl and -sad to say- of quite too many skeptics- has nothing to do with a real skeptic attitude). Rossi should give information about the details of his invention and quantitative tests really measuring the heat produced should be carried out and published. Presumably the financial aspects related to the invention explain the secrecy in a situation in which patenting is difficult.

Objections from nuclear physics

The reading of Rossi's paper and Wikipedia article led me to consider in more detail also various nuclear physics based objections (see `http://tinyurl.com/yd8wka4w`) against Rossi's reactor [C15]. Coulomb barrier, the lack of gamma rays, the lack of explanation for the origin of the extra energy, the lack of the expected radioactivity after fusing a proton with ^{58}Ni (production of neutrino and positron in beta decay of ^{59}Cu), the unexplained occurrence of 11 per cent iron in the spent fuel, the 10 per cent copper in the spent fuel strangely having the same isotopic ratios as natural copper, and the lack of any unstable copper isotopes in the spent fuel as if the reactor only produced stable isotopes.

1. Could natural isotope ratios be determined by cold fusion?

The presence of Cu in natural isotope ratios and the absence of unstable copper isotopes of course raise the question whether the copper is just added there. Also the presence of iron is strange. Could one have an alternative explanation for these strange co-incidences?

1. Whether unstable isotopes of Cu are present or not, depends on how fast ^{A}Cu, $A < 63$ decays by neutron emission: this decay is expected to be fast since it proceeds by strong interactions. I do not know enough about the detailed decay rates to be able to say anything about this.
2. Why the isotope ratios would be the same as for naturally occurring copper isotopes? The simplest explanation would be that the fusion cascades of two stable Ni isotopes determine the ratio of naturally occurring Cu isotopes so that cold fusion would be responsible for their production. As a matter fact, TGD based model combined with what is claimed about bio-fusion led to the proposal that stable isotopes are produced in interstellar space by cold fusion and that this process might even dominate over the production in stellar interiors. This wold solve among other things also the well-known Lithium problem. The implications of the ability to produce technologically important elements artificially at low temperatures are obvious.

   If the reaction rate does not depend on isotope of Ni, the ratio ^{63}Cu/ ^{65}Cu= 69.1/30.9=2.23 should be equal to ^{62}Ni/^{64}Ni= 3.66/1.16=3.15. This is not the case if the isotope ratios are natural.
3. The presence of only stable isotopes is a further serious objection. Why the unstable isotopes would not be created in the process. Ni has several stable isotopes with mass numbers 58, 60, 61, 62, 64 with abundances 67.8, 26.23, 1.25, 3.66, 1.16 per cent. The stable isotopes of Cu have mass numbers 63,65. Isotopes with mass number 59, 61, 62, 63(stable), 65 (stable) should be created. ^{59}Cu is very shortlived. ^{61}Cu and ^{62}Cu have half-lifes of 3.33 h and 9.80 min. Their absence could be understood if the isotope ratios are determined after long enough time, say next day.

2. Could standard nuclear physics view about cold fusion allow to overcome the objections?

Consider now whether one could answer the objections in standard nuclear physics framework as a model for cold fusion processes.

1. By inspecting stable nuclides (see `http://tinyurl.com/2etfs4m`) one learns that there are two fusion cascades. In the first cascade the isotopes of copper would be produced in a cascade starting from with $^{58}Ni + n \rightarrow ^{59} Cu$ and stopping at ^{63}Cu. All isotopes ^{A}Cu, $A \in \{55, 62\}$ are unstable with lifetime shorter than one day. The second fusion cascade begins from ^{63}Ni and stops at ^{65}Cu.
2. The first cascade involves five cold fusions and 4 weak decays of Cu. Second cascade involves two cold fusions and one weak decay of Cu. The time taken by the cascade would be same if there is single slow step involved having same duration. The only candidates for the slow step would be the fusion of the stable Ni isotope with the neutron or the fusion producing the stable Cu isotope. If the fusion time is long and same irrespective of the neutron number of the stable isotope, one could understand the result. Of course, this kind of co-incidence does not look plausible.
3. ^{A-5}Fe could be produced via alpha decay $^{A}Cu \rightarrow ^{A-4} Co + \alpha$ followed by $^{A-4}Co \rightarrow ^{A-5} Fe + p$.

3. Could TGD view about cold fusion allow to overcome the objections?

The claimed absence of positrons from beta decays and the absence of gamma rays are strong objections against the assumption that standard nuclear physics is enough. In TGD framework it is possible to ask whether the postulated fusion cascades really occur and whether instead of it weak interactions in dark phase of nuclear matter with range of order atomic length scale are responsible for the process because weak bosons would be effectively massless below atomic length scale. For TGD inspired model of cold fusion see http://tinyurl.com/y73ydac9 and hhttp://tinyurl.com/zofj62f [K103, L4].

1. The nuclear string model assumes that nucleons for nuclear strings with nucleons connected with color bonds having quark and antiquark at their ends. Color bonds could be also charged and this predicts new kind of internal structure for nuclei. Suppose that the space-time sheets mediating weak interactions between the color bonds and nucleons correspond to so large value of Planck constant that weak interaction length scale is scaled up to atomic length scale. The generalization of this hypothesis combined with the p-adic length scale hypothesis is actually standard piece of TGD inspired quantum biology (http://tinyurl.com/y9mmqzk2) [K40].
2. The energy scale of the excitations of color bond excitations of the exotic nuclei would be measured in keVs. One could even consider the possibility that the energy liberated in cold fusion would correspond to this energy scale. In particular, the photons emitted would be in keV range corresponding to wavelength of order atomic length sale rather than in MeV range. This would resolve gamma ray objection.
3. Could the fusion process $^{58}Ni + n$ actually lead to a generation of Ni nucleus ^{59}Ni with one additional positively charged color bond? Could the fusion cascade only generate exotic Ni nuclei with charged color bonds, which would transform to stable Cu by internal dark W boson exchange transferring the positive charge of color bond to neutron and thus transforming it to neutron? This would not produce any positrons. This cascade might dominate over the one suggested by standard nuclear physics since the rates for beta decays could be much slower than the rate for direct generation of Ni isotopes with positively charged color bonds.
4. In this case also the direct alpha decay of Ni with charged color bond to Fe with charged color bond decaying to ordinary Fe by positron emission can be imagined besides the proposed mechanism producing Fe.
5. If one assumes that this process is responsible for producing the natural isotope ratios, one could overcome the basic objections against Rossi's reactor.

The presence of em radiation in keV range would be a testable basic signature of the new nuclear physics as also effects of X-ray irradiation on measured nuclear decay and reaction rates due to the fact that color bonds are excited. As a matter fact, it is known that X-ray bursts from Sun in keV range has effects on the measured nuclear decay rates and I have proposed that the proposed exotic nuclear physics in keV range is responsible for the effect. Quite generally, the excitations of color bonds would couple nuclear physics with atomic physics and I have proposed that the anomalies of water could involve classical Z^0 force in atomic length scales. Also the low compressibility of condensed matter phase could involve classical Z^0 force. The possible connections with sono-luminescence and claimed sonofusion are also obvious (http://tinyurl.com/ycofa7jx) [K42].

More recent results concerning heat production in Rossi's reactor

According to the article "Indication of anomalous heat energy production in a reactor device containing hydrogen loaded nickel powder" [H18] (http://tinyurl.com/l22dxgk) cold fusion has been demonstrated quite convincingly so that "indication" in the title can be take as a humorous understatement.

The studied system is the E-Cat HT of Rossi containing Ni power plus unknown catalyst under hydrogen pressure. The durations of test runs were about 100 hours. Heat cameras were used to measure the temperature at the upper surface of the cylinder. The lower bound for the heat power estimated theoretically from the temperature distribution using estimates for radiation power, very small conduction power through the contacts with environment, and from estimate convection power through the surrounding air. In one of the runs the input power was 360 W and output power 2034 W giving $COP \simeq 5.6$. The run took 96 hours and the weight of Ni cylinder was.236 kg. On basis of this the heat energy per weight is higher than.68 MJ/kg which is higher than for any conventional energy source. This is a lower bound since only the heat energy produced during the test run is included.

To my opinion, it seems safe to conclude that low energy nuclear reactions can be regarded as an established fact and the commercialization is indeed in full swing. It is a pity that at the same time academic theoretical physics after the results from LHC has reached dead end basically due to the sticking to the reductionistic dogma, which does not allow any new physics above elementary particle length scale - and if we believe string theorists- above Planck length length scale.

11.9.4 Sono-Luminescence, Classical Z^0 Force, And Hydrodynamic Hierarchy Of P-Adic Length Scales

Sono-luminescence [D38], [D38] is a peculiar phenomenon, which might provide an application for the hydrodynamical hierarchy. The radiation pressure of a resonant sound field in a liquid can trap a small gas bubble at a velocity node. At a sufficiently high sound intensity the pulsations of the bubble are large enough to prevent its contents from dissolving in the surrounding liquid. For an air bubble in water, a still further increase in intensity causes the phenomenon of sono-luminescence above certain threshold for the sound intensity. What happens is that the minimum and maximum radii of the bubble decrease at the threshold and picosecond flash of broad band light extending well into ultraviolet is emitted. Rather remarkably, the emitted frequencies are emitted simultaneously during very short time shorter than 50 picoseconds, which suggests that the mechanism involves formation of coherent states of photons. The transition is very sensitive to external parameters such as temperature and sound field amplitude.

A plausible explanation for the sono-luminescence is in terms of the heating caused by shock waves launched from the boundary of the adiabatically contracting bubble [D38], [D38] . The temperature jump across a strong shock is proportional to the square of Mach number and increases with decreasing bubble radius. After the reflection from the minimum radius $R_s(min)$ the outgoing shock moves into the gas previously heated by the incoming shock and the increase of the temperature after focusing is approximately given by $T/T_0 = M^4$, where M is Mach number at focusing and $T_0 \sim 300\ K$ is the temperature of the ambient liquid. The observed spectrum of sono-luminescence is explained as a brehmstrahlung radiation emitted by plasma at minimum temperature $T \sim 10^5\ K$. There is a fascinating possibility that sono-luminescence relates directly to the classical Z^0 force.

Even standard model reproduces nicely the time development of the bubble and sono-luminescence spectrum and explains sensitivity to the external parameters [D38], [D38]. The problem is to understand how the length scales are generated and explain the jump-wise transition to sono-luminescence and the decrease of the bubble radius at sono-luminescence: ordinary hydrodynamics predicts continuous increase of the bubble radius. The length scales are the ambient radius R_0 (radius of the bubble, when gas is in pressure of 1 atm) and the minimum radius $R_s(min)$ of the shock wave determining the temperature reached in shock wave heating. Zero radius is certainly not reached since shock front is susceptible to instabilities.

p-Adic length scale hypothesis and the length scales of sono-luminescence

Since p-adic length scale hypothesis introduces a hierarchy of hydrodynamics with each hydrodynamics characterized by a p-adic cutoff length scale there are good hopes of achieving a better understanding of these length scales in TGD. The change in bubble size in turn could be understood as a change in the "primary" condensation level of the bubble.

1. The bubble of air is characterized by its primary condensation level k. The minimum size of the bubble at level k must be larger than the electron Compton scale $L_e(k) = \sqrt{5}L(k)$. This suggests that the transition to photo-luminescence corresponds to the change in the primary condensation level of the air bubble. In the absence of photo-luminescence the level can be assumed to be $k = 163$ with $L_e(163) \sim .76\ \mu m$ in accordance with the fact that the minimum bubble radius is above $L_e(163)$. After the transition the primary condensation level of the air bubble one would have $k = 157$ with $L_e(157) \sim .07\ \mu m$. In the transition the minimum radius of the bubble decreases below $L_e(163)$ but should not decrease below $L_e(157)$: this hypothesis is consistent with the experimental data [D38], [D38].
2. The particles of hydrodynamics at level k have minimum size $L(k_{prev})$. For $k = 163$ one has $k_{prev} = 157$ and for $k = 157$ $k_{prev} = 151$ with $L_e(151) \sim 11.8\ nm$. It is natural to assume that the minimum size of the particle at level k gives also the minimum radius for the spherical shock wave since hydrodynamic approximation fails below this length scale. This

means that the minimum radius of the shock wave decreases from $R_s(min, 163) = L_e(157)$ to $R_s(min, 157) = L_e(151)$ in the transition to sono-luminescence. The resulting minimum radius is 11 nm and much smaller than the radius .1 μ m needed to explain the observed radiation if it is emitted by plasma.

A quantitative estimate goes along lines described in [D38], [D38].

1. The radius of the spherical shock is given by

$$R_s = At^\alpha \ , \tag{11.9.1}$$

where t is the time to the moment of focusing and α depends on the equation of state (for water one has $\alpha \sim .7$).

2. The collapse rate of the adiabatically compressing bubble obeys

$$\frac{dR}{dt} = c_0(\frac{2}{3\gamma}\frac{\rho_0}{\rho}(\frac{R_m}{R_0})^3)^{1/2} \ , \tag{11.9.2}$$

where c_0 is the sound velocity in gas, γ is the heat capacity ratio and ρ_0/ρ is the ratio of densities of the ambient gas and the liquid.

3. Assuming that the shock is moving with velocity c_0 of sound in gas, when the radius of the bubble is equal to the ambient radius R_0 one obtains from previous equations for the Mach number M and for the radius of the shock wave

$$\begin{aligned} M &= \frac{\frac{dR_s}{dt}}{c_0} = (t_0/t)^{\alpha-1} \ , \\ R_s &= R_0(t/t_0)^\alpha \ , \\ t_0 &= \frac{\alpha R_0}{c_0} \ . \end{aligned} \tag{11.9.3}$$

where t_0 is the time that elapses between the moment, when the bubble radius is R_0 and the instant, when the shock would focus to zero radius in the ideal case. For $R_0 = L_e(167)$ (order of magnitude is this) and for $R_s(min) = L_e(151)$ one obtains $R_0/R_s(min) = 256$ and $M \simeq 10.8$ at the minimum shock radius.

4. The increase of the temperature immediately after the focusing is approximately given by

$$\frac{T}{T_0} \simeq M^4 = (\frac{R_0}{R_s})^{\frac{4(1-\alpha)}{\alpha}} \simeq 1.3 \cdot 10^4 \ . \tag{11.9.4}$$

For $T_0 = 300\ K$ this gives $T \simeq 4 \cdot 10^6\ K$: the temperature is far below the temperature needed for fusion.

In principle the further increase of the temperature can lead to further transitions. The next transition would correspond to the transition $k = 157 \rightarrow k = 151$ with the minimum size of particle changing as $L_e(k_{prev}) \rightarrow L_e(149)$. The next transition corresponds to the transition to $k = 149$ and $L_e(k_{prev}) \rightarrow L_e(141)$. The values of the temperatures reached depend on the ratio of the ambient size R_0 of the bubble and the minimum radius of the shock wave. The fact that R_0 is expected to be of the order of $L_e(k_{next})$ suggests that the temperatures achieved are not sufficiently high for nuclear fusion to take place.

Could sonoluminescence involve the formation of a phase near vacuum extremals?

In TGD inspired model of cell membrane [K88] a key role is played by almost vacuum extremals for which the induced Kähler field is very small. Vacuum extremals are accompanied by a strong classical Z^0 field proportional to classical electromagnetic field and given by $Z^0 = -2\gamma/p$, $p = sin^2(\theta_W)$. One could also imagine that em field is vanishing in which case Z^0 field is proportional to Kähler field and also strong because of $Z^0 = 6J/p$, $p = sin^2(\theta_W)$ proportionality. In this case also classical color fields are present. It is however not clear whether these fields can be realized as preferred extremals of Kähler action.

The classical Z^0 field should have a source and the vacuum polarization in the sense that flux tubes are generated with many fermion state and its conjugate at its opposite ends would generate it. The Compton scale of weak bosons must correspond to $L_e(157)$ so that either dark variants of ordinary weak bosons or their light variants would be in question. Both would be effectively massless below $L_e(157)$. The simplest situation corresponds to many-neutrino state for vacuum extremals but also many quark states are possible when em field for the flux tube vanishes.

The length scales involved correspond to Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$ and together with $k = 151$ and $k = 167$ define biologically important length scales [K88]. The p-adically scaled up variants and dark variants of of QCD and weak physics have been conjectured to play key role in biology between length scales 10 nm (cell membrane thickness) and 2.5 μm (the size scale of nucleus). This motivates the question whether a nearly vacuum extremal phase (as far as induced gauge fields are considered) accompanies the transition changing the p-adic length scale associated with the bubble from $k = 163$ to $k = 157$. The acceleration in the strong Z^0 field associated with the flux tubes could generate the visible light as brehmstrahlung radiation, perhaps also Z^0 and W bremstrahlung could be generated and would decay to photons and charged particles and generate a plasma in this manner. If the weak scale is given by $k_W = 157$, the mass scale of weak bosons is $2^{-31} \simeq 10^{-9}/2$ times smaller than that of ordinary weak bosons (about 50 eV which corresponds to a temperature of 5×10^5 K). A further transition to $k = 151$ would correspond to gauge boson mass scale 400 eV and temperature or order 4×10^6 K.

Could phase transitions increasing Planck constant and p-adic prime accompany sono-luminescence

In sonoluminescence external sound source induces oscillation of the radius of a bubble of water containing noble gas atoms. The unexpected observation is generation of radiation even at gamma ray energies and it is proposed that nuclear fusion might take place.

A possible new element in the model is h_{eff} increasing phase transition of the space-time sheet containing the water vapour and other atoms to dark phase during the expansion phase and reduction back to the ordinary value during implosion period now forced by the sound wave. If implosion actually takes place spontaneously then the energy of sound wave could be liberated as luminescence. If also dark hydrogen atoms are generated, dark protons could be able to circumvent the Coulomb wall so that low energy nuclear reactions could occur. On the other hand, if the phase transition reducing the Planck constant and increasing p-adic length scale takes place for the water space-time sheet in such a way that the two scale changes compensate each other (this requires $h_{eff} = 2^k h$ and $p \rightarrow 2^{2k} p$ (this in excellent approximation), zero point kinetic energy (ZPKE) is liberated and could heat the bubble and induce high energy radiation and perhaps even the proposed ordinary fusion. Cold fusion however seems more elegant alternative. The fact that neutron yield has not been observed in sonoluminescence suggests that ordinary hot fusion is not involved.

I have earlier considered the possibility that classical long ranged Z^0 fields predicted by TGD might be involved and give rise to a new interaction possibly related to sonoluminescence. I have proposed that classical Z^0 fields could play a role in the physics of cell membrane. The speculative proposal is that cell membrane could be in two possible states: the first ("ordinary") state would correspond to far from vacuum extremal for which electric field dominates. Second state would be near to vacuum extremal: in this case classical Z^0 field would dominate and give rise to rather radical modification of the model for cell membrane since Z^0 membrane potential would replace the ordinary one. Neurons serving as sensory receptors might correspond to this phase.

This model remains very speculative as also the possible role of classical Z^0 fields in sono-fusion. Note however that the phase transition increasing h_{eff} implies a dilution to vapour like phase ("electrically expanded water")and means that the state is near vacuum. By quantum classical correspondence classical Z^0 fields might become important. In the case of cell membrane Z^0 Coulomb energy defined by Z^0 potential is much stronger than its electronic counterpart and corresponds to voltage of order few eV and therefore to visible photon energies roughly 50 times higher than the energies assignable to the ordinary membrane potential of about.06 eV. One can wonder whether similar effect could appear also in electrolysis where also strong local electric fields appear.

11.10 The TGD Variant Of The Model Of Widom And Larsen For Cold Fusion

Widom and Larsen (for articles see the Widom Larsen LENR Theory Portal [C13] (see `http://tinyurl.com/boq2u2z`) have proposed a theory of cold fusion (LENR) (see `http://tinyurl.com/y8ejwxom`) [C11], which claims to predict correctly the various isotope ratios observed in cold fusion and accompanying nuclear transmutations. The ability to predict correctly the isotope ratios suggests that the model is on the right track. A further finding is that the predicted isotope ratios correspond to those appearing in Nature which suggests that LENR is perhaps more important than hot fusion in solar interior as far as nuclear abundances are considered. TGD leads to the same proposal and Lithium anomaly could be understood as one implication of LENR [L4]. The basic step of the reaction would rely on weak interactions: the proton of hydrogen atom would transform to neutron by capturing the electron and therefore would overcome the Coulomb barrier.

11.10.1 Challenges Of The Model

The model has to meet several challenges.

1. The electron capture reaction $p + e \rightarrow n + \nu$ is not possible for ordinary atom since the mass difference of neutron is 1.3 MeV and larger than electron mass.5 MeV (electron has too small kinetic energy). The proposal is that strong electric fields at the catalyst surface imply renormalization effects for the plasmon phase at the surface of the catalyst increasing electron mass so that it has width of few MeVs [C153]. Physically this would mean that strong em radiation helps to overcome the kinematical threshold for the reaction. This assumption [C106]: the claim is that the mass renormalization is much smaller than claimed by Widom and Larsen.

2. Second problem is that weak interactions are indeed very weak. The rate is proportional to $1/m_W^4$, $m_W \sim 100$ GeV whereas for the exchange of photon with energy E it would be proportional to $1/E^4$. For $E \sim 1$ keV the ratio of the rates would be of the order of 10^{-48}!

   This problem could be circumvented if the transition from proton to neutron occurs coherently for large enough surface patch. This would give rate proportional to N^2, where N is the number electrons involved. Another mechanism hoped to help to get high enough reaction rate is based on the assumption that the neutron created by the capture process has ultra-low momentum. This is the case if the mass renormalization of electron is such that the energies of the neutrons produced in the reaction are just above the kinematical threshold. Note however that this reduces the electron capture cross section. The argument is that the absorption rate for neutron by target nucleus is by very general arguments proportional to $1/v_n$, v_n the velocity of neutron. Together these two mechanisms are hoped to give high enough rate for cold fusion.

3. The model must also explain why gamma radiation is not observed and why neutrons are produced much less than expected. Concerning gamma rays one must assume that the heavy electrons of the plasmon phase assigned to the surface of the catalyst absorb the gamma rays and re-emit them as infrared light emitted to environment as heat. Ordinary electrons cannot absorb gamma rays but heavy electrons can [C152], and the claim is that they do transform gamma rays to infrared photons. If the neutrons created in LENR have ultra-low energies

their capture cross sections are enormous and the claim is that they do not get out of the system.

The assumption that electron mass is renormalized so that the capture reaction can occur but occurs only very near threshold so that the resulting neutrons are ultraslow has been criticized [C106].

11.10.2 TGD Variant Of The Model

TGD allows to consider two basic approaches to the LENR.

1. **Option I** involves only dark nucleons and dark quarks. In this case, one can imagine that the large Compton length of dark proton - at least of order atomic scale - implies that it overlaps target nucleus, which can see the negatively charged d quark of the proton so that instead of Coulomb wall one has Coulomb well.
2. **Option II** involves involves both dark weak bosons and possibly also dark nucleons and dark electrons. The TGD inspired model for living matter - in particular, the model for cell membrane involving also Z^0 membrane potential in the case of sensory receptor neurons [K40] - favors the model involving both dark weak bosons, nucleons, and even electrons. Chiral selection for biomolecules is extremely difficult to understand in standard model but could be understood in terms of weak length scale of order atomic length scale at least: below this scale dark weak bosons would be effectively massless and weak interactions would be as strong as em interactions. The model for electrolysis based on plasmoids identified as primitive life forms supports also this option. The presence of dark electrons is suggested by Tesla's cold currents and by the model of cell membrane.

   This option is fixed quantitatively by the condition that the Compton length of dark weak bosons is of the order of atomic size scale at least. The ratio of the corresponding p-adic size scales is of order 10^7 and therefore one has $h_{eff} \sim 10^{14}$. The condition that $h_{eff}/h = 2^k$ guarantees that the phase transition reducing h_{eff} to h and increasing p-adic prime p by about 2^k and p-adic length scale by $2^{k/2}$ does not change the size scale of the space-time sheet and liberates cyclotron magnetic energy $E_n(1-2^{-k}) \simeq E_n$.

Consider next **Option II** by requiring that the Coulomb wall is overcome via the transformation of proton to neutron. This would guarantee correct isotope ratios for nuclear transmutations. There are two options to consider depending on whether a) the W boson is exchanged between proton nucleus (this option is not possible in standard model) or b) between electron and proton (the model of Widom and Larsen relying on the critical massivation of electron).

1. **Option II.1**. Proton transforms to neutron by exchanging W boson with the target nucleus.
   (a) In this case kinematics poses no obvious constraints on the process. There are two options depending on whether the neutron of the target nucleus or quark in the neutral color bond receives the W boson.
   (b) If electron and proton are dark with $h_{eff}/h = n = 2^k$ in the range $[10^{12}, 10^{14}]$ the situation can change since W boson has its usual mass from the point of view of electron and proton. $\hbar^4/m_W^4$ factor in differential cross section for 2-to-2 scattering by W exchange is scaled up by n^4 (see the appendix of [B22] so that effectively m_W would be of order 10 keV for ordinary $\hbar$.
   (c) One can argue that in the volume defined by proton Compton length $\lambda_p \simeq 2^{-11}\lambda_e \in [1.2, 12]$ nm one has a superposition of amplitudes for the absorption of dark proton by nucleus. If there are N nuclei in this volume, the rate is proportional to N^2. One can expect at most $N \in [10^3, 10^6]$ target nuclei in this volume. This would give a factor in the range $10^9 - 10^{12}$.
2. **Option II.2**: Electron capture by proton is the Widom-Larsen candidate for the reaction in question. As noticed, this process cannot occur unless one assumes that the mass of electron is renormalized to have a value in a range of few MeV. If dark electrons are heavier than ordinary, the process could be mediated by W boson exchange and if the electron and proton have their normal sizes the process occurs with same rate as em processes.

If electron and proton are dark with $h_{eff}/h = n \in [10^{12}, 10^{14}]$ the situation can change since W boson has its usual mass from the point of view of electron and proton. 2-to-2 cross section is proportional to $\hbar^4$ and is scaled up by n^4. One the other hand, the naïve expectation is that $|\Psi(0)|^2 \propto m_e^3/h_{eff}^3 \propto 1/n^{-3}$ for electron is scaled by n^{-3} so that the rate is increased by a factor of order $n \in [10^{12}, 10^{14}]$ (electron Compton length is of order cell size scale! instead of Angstrom) from its ordinary value. This is not enough.

On the other hand, one can argue in the volume defined by proton Compton size one has a superposition of amplitudes for the absorption of electron. If there are N dark electrons in this volume, the rate is proportional to N^2. One can expect at most 10^6 dark electrons in the volume of scale 10 nm so that this could give a factor 10^{12}. This would give amplification factor 10^{26} to the weak rate so that it would be only by two orders of magnitude smaller than the rate for massless weak bosons.

There are also other strange features to be understood.

1. The absence of gamma radiation could be due to the fact that the produced gamma rays are dark. For $h_{eff}/h \in [10^{12}, 10^{14}]$ the energy frequency of 1 MeV dark gamma ray would correspond to that of photon with energy of [1, .1] μeV and thus to radio wave photon with wavelength of order 1 m and frequency of order 3×10^8 Hz. In Widom-Larsen model the photons would be infrared photons. The decay of the dark gamma ray to a bunch of ordinary radio wave photons should be observed as radio noise. Note that Gariaev has observed transformation of laser light scattered from DNA to radio wave photons with frequencies down to 1 kHz at least.
2. The absence of the neutrons could be understood if they are dark and simply do not interact with visible matter before phase transition to ordinary neutrons. One can imagine an alternative interpretation allowing the interaction and assuming that nuclei are dark in the reaction volume. The large Compton wavelength implies that dark neutrons are absorbed by dark nuclei coherently in a volume of order 1.2-12 nm so that an additional amplification factor $N^2 \in [10^9, 10^{12}]$ would be obtained. The absorption cross section for neutrons should be proportional to $\hbar^2$ giving a huge amplification factor in the range $[10^{24}, 10^{48}]$. Effectively this corresponds to the assumption of Widom and Larsen stating that neutrons have ultra-low momentum.

The natural question is why h_{eff} us such that the resulting scale as photon wavelength corresponds to energy in scale 10-100 keV. The explanation could relate to the predicted exotic nuclei obtained by replacing some neutral color bonds connecting nucleons with charged ones and exchange of weak boson would affect this replacement. Could the weak physics associated with $h_{eff} \in [10^{12}, 10^{14}]$ be associated with dark color bonds? The reported annual variations of the nuclear reaction rates correlating with the distance of Earth from Sun suggest that these variations are induced by solar X rays [C74].

11.11 Dark Atomic Physics

Dark matter might be relevant also for atomic physics and in the sequel some speculations along these lines are represented. Previous considerations assumed that only field bodies can be dark and this is assumed also now. The notion of dark atom depends strongly on the precise meaning of the generalized embedding space and I have considered several options.

1. The first option was based on the singular coverings $CD \times CP_2 \rightarrow CD/G_a \times CP_2/G_b$. This approach has a concrete connection to the quantization and the selection of quantization axes correlates closely with the identification of groups G_a and G_b. The questionable assumption is that elementary particle like partonic 2-surfaces remain invariant under the cyclic groups $G_a \times G_b$.
2. The next proposal was that both factor spaces and coverings of H are possible. For this option the notion of covering is somewhat unsatisfactory because it lacks concreteness. Singular factor of CD and CP_2 spaces make possible all rational values of Planck constant and one loses the vision about evolution as drift to the sectors of embedding space characterized by increasing value of Planck constant.

3. The last proposal is based on the realization that basic quantum TGD could well explain the hierarchy of Planck constants in terms of singular covering spaces emerging naturally when the time derivatives of the embedding space coordinates are many-valued functions of the canonical momentum densities. In this framework singular factors spaces are not possible and the formula $r \equiv \hbar/\hbar_0 = n_a n_b$ emerges naturally as well as charge fractionization. One also ends up to a unique recipe for how to obtain binding energies in this kind of situation and the results are consistent with the earlier formulas deduced on purely formal arguments. Groups G_a and G_b do not directly correspond to subgroups of isometry groups but the fractionization of quantum numbers implied by the scaling of Planck constant implies that wave functions for the selected quantization axes behave as if the maximal cyclic subgroups of G_a and G_b had a geometric meaning.

For covering space option fermion number is fractionized. The group algebra of $G_a \times G_b$ defines $n_a n_b$ single particle wave functions in the covering. The simplest option is that total fermion number is integer valued so that the many-sheeted structure is analogous to a full Fermi sphere containing $n_a n_b$ fermions with fractional fermion number $1/n_a n_b$. A more general option allows states with fractional total fermion number varying from from $1/n_a n_b$ to 1. One could generalize the condition about integer fermion number so that it holds for the entire quantum state involving several covering regions and the condition would correspond to the $G_a \times G_b$ singletness of the physical states.

11.11.1 Dark Atoms And Dark Cyclotron States

The development of the notion of dark atom involves many side tracks which make me blush. The first naïve guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. After some obligatory twists and turns it became clear that this assumption is indeed the most plausible one. The main source of confusion has been the lack of precise view about what the hierarchy of Planck constants means at the level of embedding space at space-time.

The rules are very simple when one takes the singular coverings assigned to the many-valuedness of the time-derivatives of embedding space coordinates as functions of canonical momentum densities as a starting point.

1. The mass and charge of electron are fractionized as is also the reduced mass in Schrödinger equation. This implies the replacements $e \rightarrow e/r$, $m \rightarrow m/r$, and $\hbar \rightarrow r\hbar_0$, $r = n_a n_b$, in the general formula for the binding energy assigned with single sheet of the covering. If maximal number $n_a n_b$ are present corresponding to a full "Fermi sphere", the total binding energy is r times the binding energy associated with single sheet.
2. In the case of hydrogen atom the proportionality $E \propto m/\hbar^2$ implies that the binding energy for single sheet of the covering scales as $E \rightarrow E/(n_a n_b)^3$ and maximal binding energy scales as $E \rightarrow E/(n_a n_b)^2$. This conforms with the naïve guess. For high values of the nuclear charge Z it can happen that the binding energy is larger than the rest mass and fractionization might take place when binding energy is above critical fraction of the rest mass.
3. In the case of cyclotron energies one must must decide what happens to the magnetic flux. Magnetic flux quantization states that the flux is proportional to $\hbar$ for each sheet separately. Hence one has $\Phi \rightarrow r\Phi$ for each sheet and the total flux scales as r^2. Since the dimensions of the flux quantum are scaled up by r the natural scaling of the size of flux quantum is by r^2. Therefore the quantization of the magnetic flux requires the scaling $B \rightarrow B/r$. The cyclotron energy for single sheet satisfies $E \propto \hbar qB/m$ and since both mass m and charge q become fractional, the energy E for single sheet remains invariant whereas total cyclotron energy is scaled up by r in accordance with the original guess and the assumption used in applications.
4. Dark cyclotron states are expected to be stable up to temperatures which are r times higher than for ordinary cyclotron states. The states of dark hydrogen atoms and its generalizations are expected to be stable at temperatures scaled down by $1/r^2$ in the first approximation.
5. Similar arguments allow to deduce the values of binding energies in the general case once the formula of the binding energy given by standard quantum theory is known.

The most general option option allows fractional atoms with proton and electron numbers varying from $1/r$ to 1. One can imagine also the possibility of fractional molecules. The analogs of chemical bonds between fractional hydrogen atoms with $N-k$ and k fractional electrons and protons can be considered and would give rise to a full shell of fractional electrons possessing an exceptional stability. These states would have proton and electron numbers equal to one.

Catalytic sites are one possible candidate for fractal electrons and catalyst activity might be perhaps understood as a strong tendency of fractal electron and its conjugate to fuse to form an ordinary electron.

11.11.2 Could Q-Laguerre Equation Relate To The Claimed Fractionation Of The Principal Quantum Number For Hydrogen Atom?

The so called hydrino atom concept of Randell Mills [D58] represents one of the notions related to free energy research not taken seriously by the community of university physicists. What is claimed that hydrogen atom can exists as scaled down variants for which binding energies are much higher than usually due to the large Coulomb energy. The claim is that the quantum number n having integer values $n = 0, 1, 2, 3..$ and characterizing partially the energy levels of the hydrogen atom can have also inverse integer values $n = 1/2, 1/3, ...$ The claim of Mills is that the laboratory BlackLight Inc. led by him can produce a plasma state in which transitions to these exotic bound states can occur and liberate as a by-product usable energy.

The National Aeronautic and Space Administration has dispatched mechanical engineering professor Anthony Marchese from Rowan University to BlackLight's labs in Cranbury, NJ, to investigate whether energy plasmas-hot, charged gases- produced by Mills might be harnessed for a new generation of rockets. Marchese reported back to his sponsor, the NASA Institute for Advanced Concepts, that indeed the plasma was so far unexplainably energetic. An article about the findings of Mills and collaborators have been accepted for publication in Journal of Applied Physics so that there are reasons to take seriously the experimental findings of Mills and collaborators even if one does not take seriously the theoretical explanations.

The fractionized principal quantum number n claimed by Mills [D58] is reported to have at least the values $n = 1/k$, $k = 2, 3, 4, 5, 6, 7, 10$. First explanation would be in terms of Plack constant having also values smaller than $\hbar_0$ possible if singular factor spaces of causal diamond CD and CP_2 are allowed. q-Deformations of ordinary quantum mechanics are suggested strongly by the hierarchy of Jones inclusion associated with the hyper-finite factor of type II_1 about which WCW spinors are a basic example. This motivates the attempt to understand the claimed fractionization in terms of q-analog of hydrogen atom. The safest interpretation for them would be as states which can exist in ordinary embedding space (and also in other branches)

The Laguerre polynomials appearing in the solution of Schrödinger equation for hydrogen atom possess quantum variant, so called q-Laguerre polynomials [A13], and one might hope that they would allow to realize this semiclassical picture at the level of solutions of appropriately modified Schrödinger equation and perhaps also resolve the difficulty associated with $n = 1/2$. Unfortunately, the polynomials discussed in [A13] correspond to $0 < q \leq 1$ rather than complex values of $q = exp(i\pi/m)$ on circle and the extrapolation of the formulas for energy eigenvalues gives complex energies.

q-Laquerre equation for $q = exp(i\pi/m)$

The most obvious modification of the Laguerre equation for S-wave sates (which are the most interesting by semiclassical argument) in the complex case is based on the replacement

$$\begin{aligned}\partial_x &\rightarrow \frac{1}{2}(\partial_x^{q)} + \partial_x^{\overline{q})}) \\ \partial_x^{q)} f &= \frac{f(qx) - f(x)}{(q-1)x} \ , \\ q &= exp(i\pi/m)\end{aligned} \tag{11.11.1}$$

to guarantee hermiticity. When applied to the Laguerre equation

$$x\frac{d^2L_n}{dx^2} + (1-x)\frac{dL_n}{dx} = nL_n \quad , \tag{11.11.2}$$

and expanding L_n into Taylor series

$$L_n(x) = \sum_{n\geq 0} l_n x^n \quad , \tag{11.11.3}$$

one obtains difference equation

$$\begin{aligned}
a_{n+1}l_{n+1} &+ b_n l_n = 0 \quad , \\
a_{n+1} &= \frac{1}{4R_1^2}\left[R_{2n+1} - R_{2n} + 2R_{n+1}R_1 + 3R_1)\right] + \frac{1}{2R_1}\left[R_{n+1} + R_1\right] \\
b_n &= \frac{R_n}{2R_1} - n^{q)} + \frac{1}{2} \quad , \\
R_n &= 2cos\left[(n-1)\pi/m\right] - 2cos\left[n\pi/m\right] \quad .
\end{aligned} \tag{11.11.4}$$

Here $n^{q)}$ is the fractionized principal quantum number determining the energy of the q-hydrogen atom. One cannot pose the difference equation on l_0 since this together with the absence of negative powers of x would imply the vanishing of the entire solution. This is natural since for first order difference equations lowest term in the series should be chosen freely.

Polynomial solutions of q-Laquerre equation

The condition that the solution reduces to a polynomial reads as

$$b_n = 0 \tag{11.11.5}$$

and gives

$$n^{q)} = \frac{1}{2} + \frac{R_n}{2R_1} \quad , \tag{11.11.6}$$

For $n=1$ one has $n^{q)} = 1$ so that the ground state energy is not affected. At the limit $N\rightarrow\infty$ one obtains $n^{q)} \rightarrow n$ so that spectrum reduces to that for hydrogen atom. The periodicity $R_{n+2Nk} = R_n$ reflects the corresponding periodicity of the difference equation which suggests that only the values $n \leq 2m-1$ belong to the spectrum. Spectrum is actually symmetric with respect to the middle point $[N/2]$ which suggests that only $n < [m/2]$ corresponds to the physical spectrum. An analogous phenomenon occurs for representations of quantum groups [K12]. When m increases the spectrum approaches integer valued spectrum and one has $n > 1$ so that no fractionization in the desired sense occurs for polynomial solutions.

Non-polynomial solutions of q-Laquerre equation

One might hope that non-polynomial solutions associated with some fractional values of $n^{q)}$ near to those claimed by Mills might be possible. Since the coefficients a_n and b_n are periodic, one can express the solution ansatz as

$$\begin{aligned}
L_n(x) &= P_a^{2m)}(x)\sum_k a^k x^{2mk} = P_a^{2m)}(x)\frac{1}{1-ax^{2m}} \quad , \\
P_a^{2m)}(x) &= \sum_{k=0}^{2m-1} l_k x^k \quad , \\
a &= \frac{l_{2m}}{l_0} \quad ,
\end{aligned} \tag{11.11.7}$$

This solution behaves as $1/x$ asymptotically but has pole at $x_\infty = (1/a)^{1/2m}$ for $a > 0$.

The expression for $l_{2m}/l_0 = a$ is

$$a = \prod_{k=1}^{2m} \frac{b_{2m-k}}{a_{2m-k+1}} . \qquad (11.11.8)$$

This can be written more explicitly as

$$\begin{aligned} a &= (2R_1)^{2m} \prod_{k=1}^{2m} X_k , \\ X_k &= \frac{R_{2m-k} + (-2n^{q)} + 1)R_1}{R_{4m-2k+1} - R_{4m-2k} + 4R_{2m-k+1}R_1 + 2R_1^2 + 3R_1} , \\ R_n &= 2cos\left[(n-1)\pi/m\right] - 2cos\left[n\pi/m\right] . \end{aligned} \qquad (11.11.9)$$

This formula is a specialization of a more general formula for $n = 2m$ and resulting ratios l_n/l_0 can be used to construct $P_a^{2m)}$ with normalization $P_a^{2m)}(0) = 1$.

Results of numerical calculations

Numerical calculations demonstrate following.

1. For odd values of m one has $a < 0$ so that a a continuous spectrum of energies seems to result without any further conditions.
2. For even values of m a has a positive sign so that a pole results.

For even value of m it could happen that the polynomial $P_a^{2m)}(x)$ has a compensating zero at x_∞ so that the solution would become square integrable. The condition for reads explicitly

$$P_a^{2m)}\left((\frac{1}{a})^{\frac{1}{2m}} \right) = 0 . \qquad (11.11.10)$$

If $P_a^{2m)}(x)$ has zeros there are hopes of finding energy eigen values satisfying the required conditions. Laguerre polynomials and also q-Laguerre polynomials must posses maximal number of real zeros by their orthogonality implied by the hermiticity of the difference equation defining them. This suggests that also $P_a^{2m)}(x)$ possesses them if a does not deviate too much from zero. Numerical calculations demonstrate that this is the case for $n^{q)} < 1$.

For ordinary Laguerre polynomials the naïve estimate for the position of the most distant zero in the units used is larger than n but not too much so. The naïve expectation is that L_{2m} has largest zero somewhat above $x = 2m$ and that same holds true a small deformation of L_{2m} considered now since the value of the parameter a is indeed very small for $n^{q)} < 1$. The ratio $x_\infty/2m$ is below .2 for $m \leq 10$ so that this argument gives good hopes about zeros of desired kind.

One can check directly whether x_∞ is near to zero for the experimentally suggested candidates for $n^{q)}$. **Table 11.3** summarizes the results of numerical calculations.

1. **Table 11.3** gives the exact eigenvalues $1/n_{q)}$ with a 4-decimal accuracy and corresponding approximations $1/n^{q)}_{\simeq} = k$ for $k = 3, ..., 10$. For a given value of m only single eigenvalue $n^{q)} < 1$ exists. If the observed anomalous spectral lines correspond to single electron transitions, the values of m for them must be different. The value of m for which $n^{q)} \simeq 1/k$ approximation is optimal is given with boldface. The value of k increases as m increases. The lowest value of m allowing the desired kind of zero of $P^{2m)}$ is $m = 18$ and for $k \in \{3, 10\}$ the allowed values are in range $18, .., 38$.
2. $n^{q)} = 1/2$ does not appear as an approximate eigenvalue so that for even values of m quantum calculation produces same disappointing result as the classical argument. Below it will be however found that $n^{q)} = 1/2$ is a universal eigenvalue for odd values of m.

m	$1/n^{q)}_{\simeq}$	$1/n^{q)}$	m	$1/n^{q)}_{\simeq}$	$1/n^{q)}$
18	**3**	2.7568	30	8	7.5762
20	**4**	3.6748	**32**	**8**	8.3086
22	5	4.5103	**34**	**9**	9.0342
24	**5**	5.3062	**36**	**10**	9.7529
26	**6**	6.0781	38	10	10.4668
28	**7**	6.8330			

Table 11.3: Table gives the approximations $1/n^q)_{\simeq} = 1/k$ and corresponding exact values $1/n^q)$ in the range $k = 3, ..., 10$ for which $P_a^{2m)}(x_\infty)$ is nearest to zero. The corresponding values of $m = 2k$ vary in the range, $k = 18, ..., 38$. For odd values of m the value of the parameter a is negative so that there is no pole. Boldface marks for the best approximation by $1/n^{q)}_{\simeq} = k$.

How to obtain $n^{q)} = 1/2$ state?

For odd values of m the quantization recipe fails and physical intuition tells that there must be some manner to carry out quantization also now. The following observations give a hunch about the desired condition.

1. For the representations of quantum groups only the first m spins are realized [K12]. This suggests that there should exist a symmetry relating the coefficients l_n and l_{n+m} and implying $n^{q)} = 1/2$ for odd values of m. This symmetry would remove also the double degeneracy associated with the almost integer eigenvalues of $n^{q)}$. Also other fractional states are expected on basis of physical intuition.
2. For $n^{q)} = 1/2$ the recursion formula for the coefficients l_n involves only the coefficients R_m.
3. The coefficients R_k have symmetries $R_k = R_{k+2m}$ and $R_{k+m} = -R_m$.

There is indeed this kind of symmetry. From the formula

$$\begin{aligned}
\frac{l_n}{l_0} &= (2R_1)^n \prod_{k=1}^{n} X_k \ , \\
X_k &= \frac{R_{n-k} + (-2n^{q)} + 1)R_1}{[R_{2n-2k+1} - R_{n-2k} + 4R_{n-k+1}R_1 + 2R_1^2 + 3R_1}
\end{aligned} \quad (11.11.11)$$

one finds that for $n^{q)} = 1/2$ the formula giving l_{n+m} in terms of l_n changes sign when n increases by one unit

$$\begin{aligned}
A_{n+1} &= (-1)^m A_n \ , \\
A_n &= \prod_{k=1}^{m} \frac{b_{n+m-k}}{a_{n+m-k+1}} = \prod_{k=1}^{m} (2R_1)^m \prod_{k=1}^{m} X_{k+n} \ .
\end{aligned} \quad (11.11.12)$$

The change of sign is essentially due to the symmetries $a_{n+m} = -a_n$ and $b_{n+m} = b_n$. This means that the action of translations on A_n in the space of indices n are represented by group Z_2.

This symmetry implies $a = l_{2m}/l_0 = -(l_m)(l_0)^2$ so that for $n^{q)} = 1/2$ the polynomial in question has a special form

$$\begin{aligned}
P_a^{2m)} &= P_a^{m)}(1 - Ax^m) \ , \\
A &= A_0 \ .
\end{aligned} \quad (11.11.13)$$

The relationship $a = -A^2$ implies that the solution reduces to a form containing the product of m^{th} (rather than $(2m)^{th}$) order polynomial with a geometric series in x^m (rather than x^{2m}):

$$L_{1/2}(x) = \frac{P_a^{m)}(x)}{1+Ax^m} \ . \qquad (11.11.14)$$

Hence the n first terms indeed determine the solution completely. For even values of m one obtains similar result for $n^{q)} = 1/2$ but now A is negative so that the solution is excluded. This result also motivates the hypothesis that for the counterparts of ordinary solutions of Laguerre equation sum (even m) or difference (odd m) of solutions corresponding to n and $2m-n$ must be formed to remove the non-physical degeneracy.

This argument does not exclude the possibility that there are also other fractional values of n allowing this kind of symmetry. The condition for symmetry would read as

$$\begin{aligned} \prod_{k=1}^{m}(R_k+\epsilon R_1) &= \prod_{k=1}^{m}(R_k-\epsilon R_1) \ , \\ \epsilon &= (2n^{q)}-1 \ . \end{aligned} \qquad (11.11.15)$$

The condition states that the odd part of the polynomial in question vanishes. Both ϵ and $-\epsilon$ solutions so that $n^{q)}$ and $1-n^{q)}$ are solutions. If one requires that the condition holds true for all values of m then the comparison of constant terms in these polynomials allows to conclude that $\epsilon = 0$ is the only universal solution. Since ϵ is free parameter, it is clear that the m: th order polynomial in question has at most m solutions which could correspond to other fractionized eigenvalues expected to be present on basis of physical intuition.

This picture generalizes also to the case of even n so that also now solutions of the form of Eq. 11.11.14 are possible. In this case the condition is

$$\prod_{k=1}^{m}(R_k+\epsilon R_1) = -\prod_{k=1}^{m}(R_k-\epsilon R_1) \ . \qquad (11.11.16)$$

Obviously $\epsilon = 0$ and thus $n = 1/2$ fails to be a solution to the eigenvalue equation in this case. Also now one has the spectral symmetry $n_\pm = 1/2 \pm \epsilon$.

The symmetry $R_n = (-1)^m R_{n+m-1} = (-1)^m R_{n-m-1} = (-1)^m R_{m-n+1}$ can be applied to show that the polynomials associated with ϵ and $-\epsilon$ contain both the terms $R_n - \epsilon$ and $R_n + \epsilon$ as factors except for odd m for $n = (m+1)/2$. Hence the values of n can be written for even values of m as

$$n^{q)}(n) = \frac{1}{2} \pm \frac{R_n}{2R_1} \ , \ n = 1, ..., \frac{m}{2} \ , \qquad (11.11.17)$$

and for odd values of m as

$$\begin{aligned} n_\pm^{q)}(n) &= \frac{1}{2} \pm \frac{R_n}{2R_1} \ , \ n = 1, ..., \frac{m+1}{2} - 1 \ , \\ n^{q)} &= 1/2 \ . \end{aligned} \qquad (11.11.18)$$

Plus sign obviously corresponds to the solutions which reduce to polynomials and to $n^{q)} \simeq n$ for large m. The explicit expression for $n^{q)}$ reads as

$$n_\pm^{q)}(n) = \frac{1}{2} \pm \frac{(sin^2(\pi(n-1)/2m) - sin^2(\pi n/2m))}{2sin^2(\pi/2m)} \ . \qquad (11.11.19)$$

At the limit of large m one has

$$n_+^{q)}(n) \simeq n \ , \ n_-^{q)}(n) \simeq 1-n \ . \qquad (11.11.20)$$

so that the fractionization $n \simeq 1/k$ claimed by Mills is not obtained at this limit. The minimum for $|n^{q)}|$ satisfies $|n^{q)}| < 1$ and its smallest value $|n^{q)}| = .7071$ corresponds to $m = 4$. Thus these zeros cannot correspond to $n^{q)} \simeq 1/k$ yielded by the numerical computation for even values of m based on the requirement that the zero of $P^{2m)}$ cancels the pole of the geometric series.

Some comments

Some closing comments are in order.

1. An open question is whether there are also zeros $|n^{q)}| > 1$ satisfying $P_a^{2m)}((1/a)^{1/2m}) = 0$ for even values of m.
2. The treatment above is not completely general since only s-waves are discussed. The generalization is however a rather trivial replacement $(1-x)d/dx \rightarrow (l+1-x)d/dx$ in the Laguerre equation to get associated Laguerre equation. This modifies only the formula for a_{n+1} in the recursion for l_n so that expression for $n^{q)}$, which depends on b_n: s only, is not affected. Also the product of numerators in the formula for the parameter $a = l_{2m}/l_0$ remains invariant so that the general spectrum has the spectral symmetry $n^{q)} \rightarrow 1 - n^{q)}$. The only change to the spectrum occurs for even values of m and is due to the dependence of $x_\infty = (1/a)^{1/2m}$ on l and can be understood in the semiclassical picture. It might happen that the value of l is modified to its q counterpart corresponding to q-Legendre functions.
3. The model could partially explain the findings of Mills and $n^{q)} \simeq 1/k$ for $k > 2$ also fixes the value of corresponding m to a very high degree so that one would have direct experimental contact with generalized embedding space, spectrum of Planck constants, and dark matter. The fact that the fractionization is only approximately correct suggests that the states in question could be possible for all sectors of embedding space appear as intermediate states into sectors in which the spectrum of hydrogen atom is scaled by $n_b/n_a = k = 2, 3, ...$
4. The obvious question is whether q-counterparts of angular momentum eigenstates ($idf_m/d\phi = mf_m$) are needed and whether they make sense. The basic idea of construction is that the phase transition changing $\hbar$ does not involve any other modifications except fractionization of angular momentum eigenvalues and momentum eigenvalues having purely geometric origin. One can however ask whether it is possible to identify q-plane waves as ordinary plane waves. Using the definition $L_z = 1/2(\partial_u^q + \partial_u^{\overline{q}})$, $u = exp(i\phi)$, one obtains $f_n = exp(in\phi)$ and eigenvalues as $n^{q)} = R_n/R_1 \rightarrow n$ for $m \rightarrow \infty$. Similar construction applies in the case of momentum components.

11.11.3 Shy Positrons

The latest weird looking effect in atomic physics is the observation that positrium atoms consisting of positron and electron scatter particles almost as if they were lonely electrons [C105, C57]. The effect has been christened cloaking effect for positron.

The following arguments represent the first attempts to understand the cloaking of positron in terms of these notions.

1. Let us start with the erratic argument since it comes first in mind. If positron and electron correspond to different space-time sheets and if the scattered particles are at the space-time sheet of electron then they do not see positron's Coulombic field at all. The objection is obvious. If positron interacts with the electron with its full electromagnetic charge to form a bound state, the corresponding electric flux at electron's space-time sheet is expected to combine with the electric flux of electron so that positronium would look like neutral particle after all. Does the electric flux of positron return back to the space-time sheet of positronium at some distance larger than the radius of atom? Why should it do this? No obvious answer.
2. Assume that positron dark but still interacts classically with electron via Coulomb potential. In TGD Universe darkness means that positron has large $\hbar$ and Compton size much larger than positronic wormhole throat (actually wormhole contact but this is a minor complication) would have more or less constant wave function in the volume of this larger space-time sheet characterized by zoomed up Compton length of electron. The scattering particle would see point-like electron plus background charge diffused in a much larger volume. If the value of $\hbar$ is large enough, the effect of this constant charge density to the scattering is small and only electron would be seen.
3. As a matter fact, I have proposed this kind of mechanism to explain how the Coulomb wall, which is the basic argument against cold fusion could be overcome by the incoming deuteron nucleus [L4], [L4]. Some fraction of deuteron nuclei in the palladium target would be dark

and have large size just as positron in the above example. It is also possible that only the protons of these nuclei are dark. I have also proposed that dark protons explain the effective chemical formula $H_{1.5}O$ of water in scattering by neutrons and electrons in atto-second time scale [L4], [L4]. The connection with cloaked positrons is highly suggestive.

4. Also one of TGD inspired proposals for the absence of antimatter is that antiparticles reside at different space-time sheets as dark matter and are apparently absent [K99]. Cloaking positrons (shy as also their discoverer Dirac!) might provide an experimental supports for these ideas.

The recent view about the detailed structure of elementary particles forces to consider the above proposal in more detail.

1. According to this view all particles are weak string like objects having wormhole contacts at its ends and magnetically charged wormhole throats (four altogether) at the ends of the string like objects with length given by the weak length cale connected by a magnetic flux tube at both space-time sheets. Topological condensation means that these structures in turn are glued to larger space-time sheets and this generates one or more wormhole contacts for which also particle interpretation is highly suggestive and could serve as space-time correlate for interactions described in terms of particle exchanges. As far electrodynamics is considered, the second ends of weak strings containing neutrino pairs are effectively non-existing. In the case of fermions also only the second wormhole throat carrying the fermion number is effectively present so that for practical purposes weak string is only responsible for the massivation of the fermions. In the case of photons both wormhole throats carry fermion number.
2. An interesting question is whether the formation of bound states of two charged particles at the same space-time sheet could involve magnetic flux tubes connecting magnetically charged wormhole throats associated with the two particles. If so, Kähler magnetic monopoles would be part of even atomic and molecular physics. I have proposed already earlier that gravitational interaction in astrophysical scales involves magnetic flux tubes. These flux tubes would have o interpretation as analogs of say photons responsible for bound state energy. In principle it is indeed possible that the energies of the two wormhole throats are of opposite sign for topological sum contact so that the net energy of the wormhole contact pair responsible for the interaction could be negative.
3. Also the interaction of positron and electron would be based on topological condensation at the same space-time sheet and the formation of wormhole contacts mediating the interaction. Also now bound states could be glued together by magnetically charged wormhole contacts. In the case of dark positron, the details of the interaction are rather intricate since dark positron would correspond to a multi-sheeted structure analogous to Riemann surface with different sheets identified in terms of the roots of the equation relating generalized velocities defined by the time derivatives of the embedding space coordinates to corresponding canonical momentum densities.

Chapter 12

Dark Forces and Living Matter

12.1 Introduction

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether electro-weak charges of elementary particles are screened in electro-weak length scale or not. The TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale.

The large value of $\hbar$ in dark matter phase implies that Compton lengths and -times are scaled up. In particular, the sizes of nucleons and nuclei become of order atom size so that dark nuclear physics would have direct relevance for condensed matter physics. It becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore. This view forces a profound re-consideration of the earlier ideas in nuclear and condensed physics context. It however seems that most of the earlier ideas related to the classical Z^0 force and inspired by anomaly considerations survive in a modified form.

The weak form of electric-magnetic duality led to the identification of the long sought for mechanism causing the weak screening in electroweak scales. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers. Weak charges would be therefore screened for ordinary matter in electro-weak length scale but dark electro-weak bosons correspond to much longer symmetry breaking length scale for weak field body. Large values of Planck constant would make it possible to zoop up elementary particles and study their internal structure without any need for gigantic accelerators.

One can still worry about large parity breaking effects - say in nuclear physics- since the couplings of spinors to classical weak fields are there. Around 2012 it became clear that the condition that induced spinor fields have well defined em charge localizes their modes in the generic case to 2-surfaces carrying vanishing induced W gauge fields. It is quite possible that this localization is consistent with Kähler-Dirac equation only in ther Minkowskian regions were the effective metric defined by Kähler-Dirac gamma matrices can be effectively 2-dimensional.

On can pose the additional condition that also classical Z^0 field vanishes - at least above weak scale. Fundamental fermions would experience only em field so that the worries related to large parity breaking effects would disappear. The proportionality of weak scale to $h_{eff} = n \times h$ however predicts that weak fields are effectively massless belong scaled up weak scale. Therefore worries about large parity breaking effects in ordinary nuclear physics can be forgotten.

In its original form this chapter was an attempt to concretize and develop ideas related to dark matter by using some experimental inputs with emphasis on the predicted interaction between the new nuclear physics and condensed matter. As the vision about dark matter became more coherent and the nuclear string model developed in its recent form, it became necessary to update the chapter and throw away the obsolete material. I dare hope that the recent representation is more focused than the earlier one.

12.1.1 Evidence For Long Range Weak Forces And New Nuclear Physics

There is a lot of experimental evidence for long range electro-weak forces, dark matter, and exotic nuclear physics giving valuable guidelines in the attempts to build a coherent theoretical scenario.

Cold fusion

Cold fusion [C48] is a phenomenon involving new nuclear physics and the known selection rules give strong constraints when one tries to understand the character of dark nuclear matter. The simplest model for cold fusion found hitherto is based on the nuclear string model [L4]. [L4] and will be taken as the basis of the considerations of this chapter. Also comparisons with the earlier variant of model of cold fusion [K103] will be made in the section about cold fusion.

Large parity breaking effects

Large parity breaking effects in living matter indicate the presence of long ranged weak forces, and the reported nuclear transmutations in living matter [C33, C150] suggest that new nuclear physics plays a role also now. For instance, the Gaussian Mersennes $(1+i)^k-1$ for $k = 113, 151, 157163, 167$ could correspond to weak length scales and four biologically important length scales in the range 10 nm-25 μm, which seem to relate directly to the coiling hierarchy of DNA double strands.

Anomalies of the physics of water

The physics of water involves a large number of anomalies and life depends in an essential way on them. As many as 41 anomalies are discussed in the excellent web page “Water Structure and Behavior” of M. Chaplin [D104]. The fact that the physics of heavy water differs much more from that of ordinary water as one might expect on basis of different masses of water molecules suggests that dark nuclear physics is involved.

1. The finding that one hydrogen atom per two water molecules remain effectively invisible in neutron and electron interactions in atto-second time scale [D104, D93] suggests that water is partially dark. These findings have been questioned in [D119] and thought to be erroneous in [D60]. If the findings are real, dark matter phase made of super-nuclei consisting of protons connected by dark color bonds could explain them as perhaps also the clustering of water molecules predicting magic numbers of water molecules in clusters. If so, dark nuclear physics could be an essential part of condensed matter physics and biochemistry. For instance, the condensate of dark protons might be essential for understanding the properties of bio-molecules and even the physical origin of van der Waals radius of atom in van der Waals equation of state.
2. The observation that the binding energy of dark color bond for $n = 2^{11} = 1/v_0$ of the scaling of $\hbar$ corresponds to the bond energy.5 eV of hydrogen bond raises the fascinating possibility that hydrogen bonds is accompanied by a color bond between proton and oxygen nucleus. Also more general chemical bonds might be accompanied by color bonds so that dark color physics might be an essential part of molecular physics. Color bonds might be also responsible for the formation of liquid phase and thus solid state. Dark weak bonds between nuclei could be involved and might be responsible for the repulsive core of van der Waals force and be part of molecular physics too. There is evidence for two kinds of hydrogen bonds [D101] : a possible identification is in terms of p-adic scaling of hydrogen bonds by a factor 2. This kind of doubling is predicted by nuclear string model [L4], [L4].

3. Years after writing this piece of text emerged the idea that covalent bonds of biopolymers might be accompanied by color bonds carrying the metabolic energy liberated in the decay of these polymers [K58]. Polymer like sequences of "half-dark" water molecules with one dark proton with dark protons connected by color bonds to form dark nucleus could have emerged as prebiotic counterparts of biomolecules and carry metabolic energy in color bonds and realize genetic code [K51, L4]. They could accompany ordinary bio-bolymers in water environment and color bonds could carry the metabolic energy. There are of course many other options, and one must have open mind since the belief that biochemistry is understood reduces to high extent to the belief in the reductionistic dogma.

4. Tetrahedral water clusters consisting of 14 water molecules would contain 8 dark protons which corresponds to a magic number for a dark nucleus consisting of protons. Icosahedral water clusters in turn consist of 20 tetrahedral clusters. This raises the question whether fractally scaled up super-nuclei could be in question. If one accepts the vision about dark matter hierarchy based in Jones inclusions to be discussed briefly later, tetrahedral and icosahedral structures of water could correspond directly to the unique genuinely 3-dimensional $G_a = E_6$ and E_8 coverings of CP_2 with $n_a = 3$ and $n_a = 5$ assignable to dark electrons. Icosahedral structures are also very abundant in living matter, mention only viruses.

Other anomalies

There are also other anomalies which might relate to the hierarchy of Planck constants and also to dark weak forces.

1. Exotic chemistries

Exotic chemistries [D116] in which clusters of atoms of given given type mimic the chemistry of another element. These systems behave as if nuclei would form a jellium (constant charge density) defining a harmonic oscillator potential for electrons. Magic numbers correspond to full electron shells analogous to noble gas elements. It is difficult to understand why the constant charge density approximation works so well. If nuclear protons are in large $\hbar(M^4)$ phase with Fermat integer $n_F = 3 \times 2^{11}$, the electromagnetic sizes of nuclei would be about 2.4 Angstroms and the approximation would be natural.

As a matter, fact nuclear string model predicts that the nuclei can have as many as $3A$ exotic charge states obtained by giving neutral color bond charge ± 1: this would give rise to quite different kind of alchemy [L4]. [L4] revealing itself in cold fusion.

2. Free energy anomalies

The anomalies reported by free energy researchers such as over unity energy production in devices involving repeated formation and dissociation of H_2 molecules based on the original discovery of Nobelist Irwing Langmuir [D84] (see for instance [H11]) suggest that part of H atoms might end up to dark matter phase liberating additional energy. The "mono-atomic" elements of Hudson suggest also dark nuclear physics [H4]. There is even evidence for macroscopic transitions to dark phase [H23, H13, H10].

3. Tritium beta decay anomaly and findings of Shnoll

Tritium beta decay anomaly [C80, C95, C117, C103] suggests exotic nuclear physics related to weak interactions. The evidence for the variation of the rates of nuclear and chemical processes correlating with astrophysical periods [E26] , [E26] could be understood in terms of weak fields created by dark matter and affect by astrophysical phenomena.

12.1.2 Dark Rules

I have done a considerable amount of trials and errors in order to identify the basic rules allowing to understand what it means to be dark matter is and what happens in the phase transition to dark matter. It is good to try to summarize the basic rules of p-adic and dark physics allowing to avoid obvious contradictions.

The notion of field body

The notion of "field body" implied by topological field quantization is essential. There would be em, $Z0$, W, gluonic, and gravitonic field bodies, each characterized by its one prime. The motivation for considering the possibility of separate field bodies seriously is that the notion of induced gauge field means that all induced gauge fields are expressible in terms of four CP_2 coordinates so that only single component of a gauge potential allows a representation as and independent field quantity. Perhaps also separate magnetic and electric field bodies for each interaction and identifiable as flux quanta must be considered. This kind of separation requires that the fermionic content of the flux quantum (say fermion and anti-fermion at the ends of color flux tube) is such that it conforms with the quantum numbers of the corresponding boson.

What is interesting that the conceptual separation of interactions to various types would have a direct correlate at the level of space-time topology. From a different perspective inspired by the general vision that many-sheeted space-time provides symbolic representations of quantum physics, the very fact that we make this conceptual separation of fundamental interactions could reflect the topological separation at space-time level.

The p-adic mass calculations for quarks encourage to think that the p-adic length scale characterizing the mass of particle is associated with its electromagnetic body and in the case of neutrinos with its Z^0 field body. Z^0 field body can contribute also to the mass of charged particles but the contribution would be small. It is also possible that these field bodies are purely magnetic for color and weak interactions. Color flux tubes would have exotic fermion and anti-fermion at their ends and define colored variants of pions. This would apply not only in the case of nuclear strings but also to molecules and larger structures so that scaled variants of elementary particles and standard model would appear in all length scales as indeed implied by the fact that classical electro-weak and color fields are unavoidable in TGD framework.

One can also go further and distinguish between magnetic field body of free particle for which flux quanta start and return to the particle and "relative field" bodies associated with pairs of particles. Very complex structures emerge and should be essential for the understanding the space-time correlates of various interactions. In a well-defined sense they would define space-time correlate for the conceptual analysis of the interactions into separate parts. In order to minimize confusion it should be emphasized that the notion of field body used in this chapter relates to those space-time correlates of interactions, which are more or less *static* and related to the formation of *bound states*.

What dark variant of elementary particle means

It is not at all clear what the notion of dark variant of elementary particle or of larger structures could mean.

1. *Are only field bodies dark?*

One variety of dark particle is obtained by making some of the field bodies dark by increasing the value of Planck constant. This hypothesis could be replaced with the stronger assumption that elementary particles are maximally quantum critical systems so that they are same irrespective of the value of the Planck constant. Elementary particles would be represented by partonic 2-surfaces, which belong to the universal orbifold singularities remaining invariant by all groups $G_a \times G_b$ for a given choice of quantization axes. If $G_a \times G_b$ is assumed to leave invariant the choice of the quantization axes, it must be of the form $Z_{n_a} \times Z_{n_b} \subset SO(3) \times SU(3)$. Partonic 2-surface would belong to $M^2 \times CP_2/U(1) \times U(1)$, where M^2 is spanned by the quantization axis of angular momentum and the time axis defining the rest system.

A different way to say this is that the CP_2 type extremal representing particle would suffer multiple topological condensation on its field bodies so that there would be no separate "particle space-time sheet".

Darkness would be restricted to particle interactions if it is assigned with topological field quanta mediating interactions. The value of the Planck constant would be assigned to a particular interaction between systems rather than system itself. This conforms with the original finding that gravitational Planck constant satisfies $\hbar_{gr} = GM_1M_2/v_0$, $v_0 \simeq 2^{-11}$. Since each interaction can give rise to a hierarchy dark phases, a rich variety of partially dark phases is predicted. The standard assumption that dark matter is visible only via gravitational interactions would mean that gravitational field body would not be dark for this particular dark matter. Note however that gravitational Planck constant h_{fr} having gigantic values could have different origin as Planck constant h_{eff} emerging from considerations related to biology: this is discussed in [K96].

Complex combinations of dark field bodies become possible and the dream is that one could understand various phases of matter in terms of these combinations. All phase transitions, including the familiar liquid-gas and solid-liquid phase transitions, could have a unified description in terms of dark phase transition for an appropriate field body. At mathematical level Jones inclusions would provide this description.

The book metaphor for the interactions at space-time level is very useful in this framework. Elementary particles correspond to ordinary value of Planck constant analogous to the ordinary sheets of a book and the field bodies mediating their interactions are the same space-time sheet or at dark sheets of the book.

2. Can also elementary particles be dark?

Also dark elementary particles themselves rather than only the flux quanta could correspond to dark space-time sheet defining multiple coverings of $H/G_a \times G_b$. This would mean giving up the maximal quantum criticality hypothesis in the case of elementary particles. These sheets would be exact copies of each other. If single sheet of the covering contains topologically condensed space-time sheet, also other sheets contain its exact copy.

The question is whether these copies of space-time sheet defining classical identical systems can carry different fermionic quantum numbers or only identical fermionic quantum numbers so that the dark particle would be exotic many-fermion system allowing an apparent violation of statistics (N fermions in the same state).

Even if one allows varying number of fermions in the same state with respect to a basic copy of sheet, one ends up with the notion of N-atom in which nuclei would be ordinary but electrons would reside at the sheets of the covering. The question is whether symbolic representations essential for understanding of living matter could emerge already at molecular level via the formation of N-atoms.

Criterion for the transition to dark phase

The criterion $\alpha Q_1 Q_2 > 1$ for the transition to dark matter phase relates always to the interaction between two systems and the interpretation is that when the field strength characterizing the interaction becomes too strong, the interaction is mediated by dark space-time sheets which define $n = n(G_a) \times n(G_b)$-fold covering of $M^4 \times CP_2/G_a \times G_b$. The sharing of flux between different space-time sheets reduces the field strength associated with single sheet below the critical value.

Mersenne hypothesis

The generalization of the embedding space means a book like structure for which the pages are products of singular coverings or factor spaces of CD (causal diamond defined as intersection of future and past directed light-cones) and of CP_2 [K43]. This predicts that Planck constants are rationals and that given value of Planck constant corresponds to an infinite number of different pages of the Big Book, which might be seen as a drawback. If only singular covering spaces are allowed the values of Planck constant are products of integers and given value of Planck constant corresponds to a finite number of pages given by the number of decompositions of the integer to two different integers.

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = \hbar/\hbar_0$. For the most general option the values of $\hbar$ are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a, b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

One can however ask whether a more precise characterization of preferred Mersennes could exist and whether there could exists a stronger correlation between hierarchies of p-adic length scales and Planck constants. Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k-1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ are expected to be physically highly interesting and up to $k = 127$ indeed correspond to elementary particles. The number theoretical miracle is that all the four scaled up electron Compton lengths with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm). The question has been whether these define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$. The proposal that this is the case and that these physics are in a well-defined sense induced by the dark scaled up variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$.

What induction means is that dark variant of exotic nuclear physics induces exotic physics with ordinary value of Planck constant in the new scale in a resonant manner: dark gauge bosons transform to their ordinary variants with the same Compton length. This transformation is natural since in length scales below the Compton length the gauge bosons behave as massless and free particles. As a consequence, lighter variants of weak bosons emerge and QCD confinement scale becomes longer.

This proposal will be referred to as Mersenne hypothesis. It leads to strong predictions about EEG [K41] since it predicts a spectrum of preferred Josephson frequencies for a given value of membrane potential and also assigns to a given value of $\hbar$ a fixed size scale having interpretation as the size scale of the body part or magnetic body. Also a vision about evolution of life emerges. Mersenne hypothesis is especially interesting as far as new physics in condensed matter length scales is considered: this includes exotic scaled up variants of the ordinary nuclear physics and their dark variants. Even dark nucleons are possible and this gives justification for the model of dark nucleons predicting the counterparts of DNA, RNA, tRNA, and amino-acids as well as realization of vertebrate genetic code [K118].

These exotic nuclear physics with ordinary value of Planck constant could correspond to ground states that are almost vacuum extremals corresponding to homologically trivial geodesic sphere of CP_2 near criticality to a phase transition changing Planck constant. Ordinary nuclear physics would correspond to homologically non-trivial geodesic sphere and far from vacuum extremal property. For vacuum extremals of this kind classical Z^0 field proportional to electromagnetic field is present and this modifies dramatically the view about cell membrane as Josephson junction. The model for cell membrane as almost vacuum extremal indeed led to a quantitative breakthrough in TGD inspired model of EEG and is therefore something to be taken seriously. The safest option concerning empirical facts is that the copies of electro-weak and color physics with ordinary value of Planck constant are possible only for almost vacuum extremals - that is at criticality against phase transition changing Planck constant.

12.1.3 Weak Form Of Electric Magnetic Duality, Screening Of Weak Charges, And Color Confinement?

TGD predicts the presence of long range classical weak fields and color fields and one should understand classically why quarks and leptons do not couple to these fields above weak boson length scale. Why the quarks inside ordinary nuclei do not generate long range weak fields and do not couple to them? Obviously the weak charges of quarks must be screened so that only electromagnetic charge remains. The extreme non-linearity of field equations in principle allows non-vanishing vacuum charge densities making possible this kind of screening. I have not been able to develop any detailed model for this.

A rather attractive looking explanation came with the discovery of electric-magnetic duality leading to a considerable progress in the understanding of basic quantum TGD. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers.

One of the basic questions closely related to the weak screening have been whether it is s possible to have a weak analog of the ordinary atom - say neutrino atom. Formally one can of course construct this kind of model and I have indeed doe this. The recent wiew about the screening of weak forces does not however allow neutrino atoms since the weak gauge fluxes flow along flux tubes and are screened by opposite charges at their end rather than being spherically symmetric Coulomb fields. Elementary particles themselves can be regarded as string like objects neutralized above weak boson Compton length. The size of the magnetic flux tubes however scales as $\sqrt{\hbar}$ so that large values of $\hbar$ it is in principle possible to zoom up the elementary particles and see what their interior looks like. This applies to both weak and color forces and might some day make possible study of elementary particles without gigantic accelerators.

12.1.4 Dark Weak Forces And Almost Vacuum Extremals

TGD suggests strongly the presence of long range weak force and the large parity breaking in living matter realized as chiral selection provides support for it. One would however like some more concrete quantitative evidence for the conjecture that the classical weak forces are indeed there. This kind of evidence comes from the model of cell membrane based on the hypothesis that cell membrane correspond to almost vacuum extremal.

1. Induced Kähler form vanishes for vacuum extremals. The condition for vanishing implies that classical Z^0 and electromagnetic fields are proportional to each other so that induced spinor field couples to both these fields. The assumption is that the quarks of nuclei and possibly also neutrinos correspond to a large value of Planck constant and therefore couple to the classical Z^0 field. Atomic electrons would not have these couplings. This modifies dramatically the model for the cell membrane as a Josephson junction and raises the scale of Josephson energies from IR range just above thermal threshold to visible and ultraviolet. The amazing finding is that the Josephson energies for biologically important ions correspond to the energies assigned to the peak frequencies in the biological activity spectrum of photoreceptors in retina suggesting. This suggests that almost vacuum extremals and thus also classical Z^0 fields could be in a central role in the understanding of the functioning of the cell membrane and of sensory qualia. This would also explain the large parity breaking effects in living matter.

   One can construct also a generalization of Josephson junction as transmembrane protein such that Josephson energy is generalized to include also the difference of cyclotron energies over the membrane. This allows to understand the role of protons in metabolism and large value about.5 eV of metabolic energy quantum roughtly 10 times larger that Josephson energy for cell membrane in terms of "square root of thermodynamics" replacing the ordinary thermodynamical model of cell membrane. In this case classical Z^0 force is not necessary. It is of course possible that cell membrane proteins can be in two phases: without or with classical Z^0 fields at string world sheets of dark fermions.

2. A further conjecture is that EEG and its predicted fractally scaled variants which same energies in visible and UV range but different scales of Josephson frequencies correspond to Josephson photons with various values of Planck constant. The decay of dark ELF photons with energies of visible photons would give rise to bunches of ordinary ELF photons. Biophotons in turn could correspond to ordinary visible photons resulting in the phase transition of these photons to photons with ordinary value of Planck constant. This leads to a very detailed view about the role of dark electromagnetic radiation in biomatter and also to a model for how sensory qualia are realized [K47, K88, K41].

What darkness means in the case of nuclei is that the "weak" field bodies of quarks are dark so that the size scale assignable to them is of order cell size. This does not affect their electromagnetic field bodies so that it is possible to speak about ions in the ordinary sense of the word. If the size scale of a given part of field body corresponds to the Compton length proportional proportional to the p-adic length scale scaled up by $\sqrt{\hbar}$ then cell membrane thickness as a Compton scale for the field body of weak bosons means rather large value of $\hbar \sim 2^{151-89} = 2^{62}\hbar_0$. This would scale down 10^{14} Hz frequency of visible photons to about 10^{-4} Hz.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

12.2 Weak Form Electric-Magnetic Duality And Its Implications

The notion of electric-magnetic duality [B2] was proposed first by Olive and Montonen and is central in $\mathcal{N}=4$ supersymmetric gauge theories. It states that magnetic monopoles and ordinary particles are two different phases of theory and that the description in terms of monopoles can be applied at the limit when the running gauge coupling constant becomes very large and perturbation theory fails to converge. The notion of electric-magnetic self-duality is more natural since for CP_2 geometry Kähler form is self-dual and Kähler magnetic monopoles are also Kähler electric monopoles and Kähler coupling strength is by quantum criticality renormalization group invariant rather than running coupling constant. The notion of electric-magnetic (self-)duality emerged already two decades ago in the attempts to formulate the Kähler geometric of world of classical worlds. Quite recently a considerable step of progress took place in the understanding of this notion [K29]. What seems to be essential is that one adopts a weaker form of the self-duality applying at partonic 2-surfaces. What this means will be discussed in the sequel.

Every new idea must be of course taken with a grain of salt but the good sign is that this concept leads to precise predictions. The point is that elementary particles do not generate monopole fields in macroscopic length scales: at least when one considers visible matter. The first question is whether elementary particles could have vanishing magnetic charges: this turns out to be impossible. The next question is how the screening of the magnetic charges could take place and leads to an identification of the physical particles as string like objects identified as pairs magnetic charged wormhole throats connected by magnetic flux tubes.

1. The first implication is a new view about electro-weak massivation reducing it to weak confinement in TGD framework. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement realized in terms of magnetic confinement.

2. This picture generalizes to the case of color confinement. Also quarks correspond to pairs of magnetic monopoles but the charges need not vanish now. Rather, valence quarks would be connected by flux tubes of length of order hadron size such that magnetic charges sum up to zero. For instance, for baryonic valence quarks these charges could be $(2,-1,-1)$ and could be proportional to color hyper charge.

3. The highly non-trivial prediction making more precise the earlier stringy vision is that elementary particles are string like objects: this could become manifest at LHC energies.

4. The weak form electric-magnetic duality together with Beltrami flow property of Kähler leads to the reduction of Kähler action to Chern-Simons action so that TGD reduces to almost topological QFT and that Kähler function is explicitly calculable. This has enormous impact concerning practical calculability of the theory.

5. One ends up also to a general solution ansatz for field equations from the condition that the theory reduces to almost topological QFT. The solution ansatz is inspired by the idea that all isometry currents are proportional to Kähler current which is integrable in the sense that the flow parameter associated with its flow lines defines a global coordinate. The proposed solution ansatz would describe a hydrodynamical flow with the property that isometry charges are conserved along the flow lines (Beltrami flow). A general ansatz satisfying the integrability conditions is found.

   The strongest form of the solution ansatz states that various classical and quantum currents flow along flow lines of the Beltrami flow defined by Kähler current (Kähler magnetic field associated with Chern-Simons action). Intuitively this picture is attractive. A more general ansatz would allow several Beltrami flows meaning multi-hydrodynamics. The integrability conditions boil down to two scalar functions: the first one satisfies massless d'Alembert equation in the induced metric and the gradients of the scalar functions are orthogonal. The interpretation in terms of momentum and polarization directions is natural.

12.2.1 Could A Weak Form Of Electric-Magnetic Duality Hold True?

Holography means that the initial data at the partonic 2-surfaces should fix the WCW metric. A weak form of this condition allows only the partonic 2-surfaces defined by the wormhole throats at which the signature of the induced metric changes. A stronger condition allows all partonic 2-surfaces in the slicing of space-time sheet to partonic 2-surfaces and string world sheets. Number theoretical vision suggests that hyper-quaternionicity *resp.* co-hyperquaternionicity constraint could be enough to fix the initial values of time derivatives of the embedding space coordinates in the space-time regions with Minkowskian *resp.* Euclidian signature of the induced metric. This is a condition on modified gamma matrices and hyper-quaternionicity states that they span a hyper-quaternionic sub-space.

Definition of the weak form of electric-magnetic duality

One can also consider alternative conditions possibly equivalent with this condition. The argument goes as follows.

1. The expression of the matrix elements of the metric and Kähler form of WCW in terms of the Kähler fluxes weighted by Hamiltonians of $\delta M^4_\pm$ at the partonic 2-surface X^2 looks very attractive. These expressions however carry no information about the 4-D tangent space of the partonic 2-surfaces so that the theory would reduce to a genuinely 2-dimensional theory, which cannot hold true. One would like to code to the WCW metric also information about the electric part of the induced Kähler form assignable to the complement of the tangent space of $X^2 \subset X^4$.
2. Electric-magnetic duality of the theory looks a highly attractive symmetry. The trivial manner to get electric magnetic duality at the level of the full theory would be via the identification of the flux Hamiltonians as sums of of the magnetic and electric fluxes. The presence of the induced metric is however troublesome since the presence of the induced metric means that the simple transformation properties of flux Hamiltonians under symplectic transformations -in particular color rotations- are lost.
3. A less trivial formulation of electric-magnetic duality would be as an initial condition which eliminates the induced metric from the electric flux. In the Euclidian version of 4-D YM theory this duality allows to solve field equations exactly in terms of instantons. This approach involves also quaternions. These arguments suggest that the duality in some form might work. The full electric magnetic duality is certainly too strong and implies that space-time surface at the partonic 2-surface corresponds to piece of CP_2 type vacuum extremal and can hold only in the deep interior of the region with Euclidian signature. In the region surrounding wormhole throat at both sides the condition must be replaced with a weaker condition.
4. To formulate a weaker form of the condition let us introduce coordinates (x^0, x^3, x^1, x^2) such (x^1, x^2) define coordinates for the partonic 2-surface and (x^0, x^3) define coordinates labeling partonic 2-surfaces in the slicing of the space-time surface by partonic 2-surfaces and string world sheets making sense in the regions of space-time sheet with Minkowskian signature. The assumption about the slicing allows to preserve general coordinate invariance. The weakest condition is that the generalized Kähler electric fluxes are apart from constant proportional to Kähler magnetic fluxes. This requires the condition

$$J^{03}\sqrt{g_4} = KJ_{12} . \quad (12.2.1)$$

A more general form of this duality is suggested by the considerations of [K53] reducing the hierarchy of Planck constants to basic quantum TGD and also reducing Kähler function for preferred extremals to Chern-Simons terms [B1] at the boundaries of CD and at light-like wormhole throats. This form is following

$$J^{n\beta}\sqrt{g_4} = K\epsilon \times \epsilon^{n\beta\gamma\delta}J_{\gamma\delta}\sqrt{g_4} \ . \tag{12.2.2}$$

Here the index n refers to a normal coordinate for the space-like 3-surface at either boundary of CD or for light-like wormhole throat. ϵ is a sign factor which is opposite for the two ends of CD. It could be also opposite of opposite at the opposite sides of the wormhole throat. Note that the dependence on induced metric disappears at the right hand side and this condition eliminates the potentials singularity due to the reduction of the rank of the induced metric at wormhole throat.

5. Information about the tangent space of the space-time surface can be coded to the WCW metric with loosing the nice transformation properties of the magnetic flux Hamiltonians if Kähler electric fluxes or sum of magnetic flux and electric flux satisfying this condition are used and K is symplectic invariant. Using the sum

$$J_e + J_m = (1+K)J_{12} \ , \tag{12.2.3}$$

where J denotes the Kähler magnetic flux, , makes it possible to have a non-trivial WCW metric even for $K = 0$, which could correspond to the ends of a cosmic string like solution carrying only Kähler magnetic fields. This condition suggests that it can depend only on Kähler magnetic flux and other symplectic invariants. Whether local symplectic coordinate invariants are possible at all is far from obvious, If the slicing itself is symplectic invariant then K could be a non-constant function of X^2 depending on string world sheet coordinates. The light-like radial coordinate of the light-cone boundary indeed defines a symplectically invariant slicing and this slicing could be shifted along the time axis defined by the tips of CD.

Electric-magnetic duality physically

What could the weak duality condition mean physically? For instance, what constraints are obtained if one assumes that the quantization of electro-weak charges reduces to this condition at classical level?

1. The first thing to notice is that the flux of J over the partonic 2-surface is analogous to magnetic flux

$$Q_m = \frac{e}{\hbar}\oint BdS = n \ .$$

n is non-vanishing only if the surface is homologically non-trivial and gives the homology charge of the partonic 2-surface.

2. The expressions of classical electromagnetic and Z^0 fields in terms of Kähler form [L3] , [L3] read as

$$\begin{aligned} \gamma &= \frac{eF_{em}}{\hbar} = 3J - sin^2(\theta_W)R_{03} \ , \\ Z^0 &= \frac{g_Z F_Z}{\hbar} = 2R_{03} \ . \end{aligned} \tag{12.2.4}$$

Here R_{03} is one of the components of the curvature tensor in vielbein representation and F_{em} and F_Z correspond to the standard field tensors. From this expression one can deduce

$$J = \frac{e}{3\hbar}F_{em} + sin^2(\theta_W)\frac{g_Z}{6\hbar}F_Z \ . \tag{12.2.5}$$

3. The weak duality condition when integrated over X^2 implies

$$\begin{aligned} \frac{e^2}{3\hbar}Q_{em} + \frac{g_Z^2 p}{6}Q_{Z,V} &= K\oint J = Kn \ , \\ Q_{Z,V} &= \frac{I_V^3}{2} - Q_{em} \ , \ p = sin^2(\theta_W) \ . \end{aligned} \quad (12.2.6)$$

   Here the vectorial part of the Z^0 charge rather than as full Z^0 charge $Q_Z = I_L^3 + sin^2(\theta_W)Q_{em}$ appears. The reason is that only the vectorial isospin is same for left and right handed components of fermion which are in general mixed for the massive states.

   The coefficients are dimensionless and expressible in terms of the gauge coupling strengths and using $\hbar = r\hbar_0$ one can write

$$\begin{aligned} \alpha_{em}Q_{em} &+ p\frac{\alpha_Z}{2}Q_{Z,V} = \frac{3}{4\pi}\times rnK \ , \\ \alpha_{em} &= \frac{e^2}{4\pi\hbar_0} \ , \ \alpha_Z = \frac{g_Z^2}{4\pi\hbar_0} = \frac{\alpha_{em}}{p(1-p)} \ . \end{aligned} \quad (12.2.7)$$

4. There is a great temptation to assume that the values of Q_{em} and Q_Z correspond to their quantized values and therefore depend on the quantum state assigned to the partonic 2-surface. The linear coupling of the Kähler-Dirac operator to conserved charges implies correlation between the geometry of space-time sheet and quantum numbers assigned to the partonic 2-surface. The assumption of standard quantized values for Q_{em} and Q_Z would be also seen as the identification of the fine structure constants α_{em} and α_Z. This however requires weak isospin invariance.

The value of K from classical quantization of Kähler electric charge

The value of K can be deduced by requiring classical quantization of Kähler electric charge.

1. The condition that the flux of $F^{03} = (\hbar/g_K)J^{03}$ defining the counterpart of Kähler electric field equals to the Kähler charge g_K would give the condition $K = g_K^2/\hbar$, where g_K is Kähler coupling constant which should invariant under coupling constant evolution by quantum criticality. Within experimental uncertainties one has $\alpha_K = g_K^2/4\pi\hbar_0 = \alpha_{em} \simeq 1/137$, where α_{em} is finite structure constant in electron length scale and $\hbar_0$ is the standard value of Planck constant.

2. The quantization of Planck constants makes the condition highly non-trivial. The most general quantization of r is as rationals but there are good arguments favoring the quantization as integers corresponding to the allowance of only singular coverings of CD andn CP_2. The point is that in this case a given value of Planck constant corresponds to a finite number pages of the "Big Book". The quantization of the Planck constant implies a further quantization of K and would suggest that K scales as $1/r$ unless the spectrum of values of Q_{em} and Q_Z allowed by the quantization condition scales as r. This is quite possible and the interpretation would be that each of the r sheets of the covering carries (possibly same) elementary charge. Kind of discrete variant of a full Fermi sphere would be in question. The interpretation in terms of anyonic phases [K81] supports this interpretation.

3. The identification of J as a counterpart of $eB/\hbar$ means that Kähler action and thus also Kähler function is proportional to $1/\alpha_K$ and therefore to $\hbar$. This implies that for large values of $\hbar$ Kähler coupling strength $g_K^2/4\pi$ becomes very small and large fluctuations are suppressed in the functional integral. The basic motivation for introducing the hierarchy of Planck constants was indeed that the scaling $\alpha \to \alpha/r$ allows to achieve the convergence of perturbation theory: Nature itself would solve the problems of the theoretician. This of course does not mean that the physical states would remain as such and the replacement of single particles with anyonic states in order to satisfy the condition for K would realize this concretely.

4. The condition $K = g_K^2/\hbar$ implies that the Kähler magnetic charge is always accompanied by Kähler electric charge. A more general condition would read as

$$K = n \times \frac{g_K^2}{\hbar}, n \in Z \ . \quad (12.2.8)$$

   This would apply in the case of cosmic strings and would allow vanishing Kähler charge possible when the partonic 2-surface has opposite fermion and anti-fermion numbers (for both leptons and quarks) so that Kähler electric charge should vanish. For instance, for neutrinos the vanishing of electric charge strongly suggests $n = 0$ besides the condition that abelian Z^0 flux contributing to em charge vanishes.

It took a year to realize that this value of K is natural at the Minkowskian side of the wormhole throat. At the Euclidian side much more natural condition is

$$K = \frac{1}{hbar} \ . \quad (12.2.9)$$

In fact, the self-duality of CP_2 Kähler form favours this boundary condition at the Euclidian side of the wormhole throat. Also the fact that one cannot distinguish between electric and magnetic charges in Euclidian region since all charges are magnetic can be used to argue in favor of this form. The same constraint arises from the condition that the action for CP_2 type vacuum extremal has the value required by the argument leading to a prediction for gravitational constant in terms of the square of CP_2 radius and α_K the effective replacement $g_K^2 \to 1$ would spoil the argument.

The boundary condition $J_E = J_B$ for the electric and magnetic parts of Kählwer form at the Euclidian side of the wormhole throat inspires the question whether all Euclidian regions could be self-dual so that the density of Kähler action would be just the instanton density. Self-duality follows if the deformation of the metric induced by the deformation of the canonically imbedded CP_2 is such that in CP_2 coordinates for the Euclidian region the tensor $(g^{\alpha\beta}g^{\mu\nu} - g^{\alpha\nu}g^{\mu\beta})/\sqrt{g}$ remains invariant. This is certainly the case for CP_2 type vacuum extremals since by the light-likeness of M^4 projection the metric remains invariant. Also conformal scalings of the induced metric would satisfy this condition. Conformal scaling is not consistent with the degeneracy of the 4-metric at the wormhole.

Reduction of the quantization of Kähler electric charge to that of electromagnetic charge

The best manner to learn more is to challenge the form of the weak electric-magnetic duality based on the induced Kähler form.

1. Physically it would seem more sensible to pose the duality on electromagnetic charge rather than Kähler charge. This would replace induced Kähler form with electromagnetic field, which is a linear combination of induced Kahler field and classical Z^0 field

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \quad (12.2.10)$$

   Here $Z_0 = 2R_{03}$ is the appropriate component of CP_2 curvature form [L3]. For a vanishing Weinberg angle the condition reduces to that for Kähler form.

2. For the Euclidian space-time regions having interpretation as lines of generalized Feynman diagrams Weinberg angle should be non-vanishing. In Minkowskian regions Weinberg angle could however vanish. If so, the condition guaranteeing that electromagnetic charge of the partonic 2-surfaces equals to the above condition stating that the em charge assignable to the fermion content of the partonic 2-surfaces reduces to the classical Kähler electric flux at the Minkowskian side of the wormhole throat. One can argue that Weinberg angle must increase smoothly from a vanishing value at both sides of wormhole throat to its value in the deep interior of the Euclidian region.

3. The vanishing of the Weinberg angle in Minkowskian regions conforms with the physical intuition. Above elementary particle length scales one sees only the classical electric field reducing to the induced Kähler form and classical Z^0 fields and color gauge fields are effectively absent. Only in phases with a large value of Planck constant classical Z^0 field and other classical weak fields and color gauge field could make themselves visible. Cell membrane could be one such system [K88]. This conforms with the general picture about color confinement and weak massivation.

The GRT limit of TGD suggests a further reason for why Weinberg angle should vanish in Minkowskian regions.

1. The value of the Kähler coupling strength mut be very near to the value of the fine structure constant in electron length scale and these constants can be assumed to be equal.
2. GRT limit of TGD with space-time surfaces replaced with abstract 4-geometries would naturally correspond to Einstein-Maxwell theory with cosmological constant which is non-vanishing only in Euclidian regions of space-time so that both Reissner-Nordström metric and CP_2 are allowed as simplest possible solutions of field equations [K117]. The extremely small value of the observed cosmological constant needed in GRT type cosmology could be equal to the large cosmological constant associated with CP_2 metric multiplied with the 3-volume fraction of Euclidian regions.
3. Also at GRT limit quantum theory would reduce to almost topological QFT since Einstein-Maxwell action reduces to 3-D term by field equations implying the vanishing of the Maxwell current and of the curvature scalar in Minkowskian regions and curvature scalar + cosmological constant term in Euclidian regions. The weak form of electric-magnetic duality would guarantee also now the preferred extremal property and prevent the reduction to a mere topological QFT.
4. GRT limit would make sense only for a vanishing Weinberg angle in Minkowskian regions. A non-vanishing Weinberg angle would make sense in the deep interior of the Euclidian regions where the approximation as a small deformation of CP_2 makes sense.

The weak form of electric-magnetic duality has surprisingly strong implications for the basic view about quantum TGD as following considerations show.

12.2.2 Magnetic Confinement, The Short Range Of Weak Forces, And Color Confinement

The weak form of electric-magnetic duality has surprisingly strong implications if one combines it with some very general empirical facts such as the non-existence of magnetic monopole fields in macroscopic length scales.

How can one avoid macroscopic magnetic monopole fields?

Monopole fields are experimentally absent in length scales above order weak boson length scale and one should have a mechanism neutralizing the monopole charge. How electroweak interactions become short ranged in TGD framework is still a poorly understood problem. What suggests itself is the neutralization of the weak isospin above the intermediate gauge boson Compton length by neutral Higgs bosons. Could the two neutralization mechanisms be combined to single one?

1. In the case of fermions and their super partners the opposite magnetic monopole would be a wormhole throat. If the magnetically charged wormhole contact is electromagnetically neutral but has vectorial weak isospin neutralizing the weak vectorial isospin of the fermion only the electromagnetic charge of the fermion is visible on longer length scales. The distance of this wormhole throat from the fermionic one should be of the order weak boson Compton length. An interpretation as a bound state of fermion and a wormhole throat state with the quantum numbers of a neutral Higgs boson would therefore make sense. The neutralizing throat would have quantum numbers of $X_{-1/2} = \nu_L \overline{\nu}_R$ or $X_{1/2} = \overline{\nu}_L \nu_R$. $\nu_L \overline{\nu}_R$ would not be neutral Higgs boson (which should correspond to a wormhole contact) but a super-partner of left-handed neutrino obtained by adding a right handed neutrino. This mechanism would apply separately

to the fermionic and anti-fermionic throats of the gauge bosons and corresponding space-time sheets and leave only electromagnetic interaction as a long ranged interaction.

2. One can of course wonder what is the situation situation for the bosonic wormhole throats feeding gauge fluxes between space-time sheets. It would seem that these wormhole throats must always appear as pairs such that for the second member of the pair monopole charges and I_V^3 cancel each other at both space-time sheets involved so that one obtains at both space-time sheets magnetic dipoles of size of weak boson Compton length. The proposed magnetic character of fundamental particles should become visible at TeV energies so that LHC might have surprises in store!

Well-definedness of electromagnetic charge implies stringiness

Well-definedness of electromagnetic charged at string world sheets carrying spinor modes is very natural constraint and not trivially satisfied because classical W boson fields are present. As a matter fact, all weak fields should be effectively absent above weak scale. How this is possible classical weak fields identified as induced gauge fields are certainly present.

The condition that em charge is well defined for spinor modes implies that the space-time region in which spinor mode is non-vanishing has 2-D CP_2 projection such that the induced W boson fields are vanishing. The vanishing of classical Z^0 field can be poses as additional condition - at least in scales above weak scale. In the generic case this requires that the spinor mode is restricted to 2-D surface: string world sheet or possibly also partonic 2-surface. This implies that TGD reduces to string model in fermionic sector. Even for preferred extremals with 2-D projecting the modes are expected to allow restriction to 2-surfaces. This localization is possible only for Kähler-Dirac action.

A word of warning is however in order. The GRT limit or rather limit of TGD as Einstein Yang-Mills theory replaces the sheets of many-sheeted space-time with Minkowski space with effective metric obtained by summing to Minkowski metric the deviations of the induced metrics of space-time sheets from Minkowski metric. For gauge potentials a similar identification applies. YM-Einstein equations coupled with matter and with non-vanishing cosmological constant are expected on basis of Poincare invariance. One cannot exclude the possibility that the sums of weak gauge potentials from different space-time sheet tend to vanish above weak scale and that well-definedness of em charge at classical level follows from the effective absence of classical weak gauge fields.

Magnetic confinement and color confinement

Magnetic confinement generalizes also to the case of color interactions. One can consider also the situation in which the magnetic charges of quarks (more generally, of color excited leptons and quarks) do not vanish and they form color and magnetic singles in the hadronic length scale. This would mean that magnetic charges of the state $q_{\pm 1/2} - X_{\mp 1/2}$ representing the physical quark would not vanish and magnetic confinement would accompany also color confinement. This would explain why free quarks are not observed. To how degree then quark confinement corresponds to magnetic confinement is an interesting question.

For quark and antiquark of meson the magnetic charges of quark and antiquark would be opposite and meson would correspond to a Kähler magnetic flux so that a stringy view about meson emerges. For valence quarks of baryon the vanishing of the net magnetic charge takes place provided that the magnetic net charges are $(\pm 2, \mp 1, \mp 1)$. This brings in mind the spectrum of color hyper charges coming as $(\pm 2, \mp 1, \mp 1)/3$ and one can indeed ask whether color hypercharge correlates with the Kähler magnetic charge. The geometric picture would be three strings connected to single vertex. Amusingly, the idea that color hypercharge could be proportional to color hyper charge popped up during the first year of TGD when I had not yet discovered CP_2 and believed on $M^4 \times S^2$.

p-Adic length scale hypothesis and hierarchy of Planck constants defining a hierarchy of dark variants of particles suggest the existence of scaled up copies of QCD type physics and weak physics. For p-adically scaled up variants the mass scales would be scaled by a power of $\sqrt{2}$ in the most general case. The dark variants of the particle would have the same mass as the original one. In particular, Mersenne primes $M_k = 2^k - 1$ and Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$

has been proposed to define zoomed copies of these physics. At the level of magnetic confinement this would mean hierarchy of length scales for the magnetic confinement.

One particular proposal is that the Mersenne prime M_{89} should define a scaled up variant of the ordinary hadron physics with mass scaled up roughly by a factor $2^{(107-89)/2} = 512$. The size scale of color confinement for this physics would be same as the weal length scale. It would look more natural that the weak confinement for the quarks of M_{89} physics takes place in some shorter scale and M_{61} is the first Mersenne prime to be considered. The mass scale of M_{61} weak bosons would be by a factor $2^{(89-61)/2} = 2^{14}$ higher and about 1.6×10^4 TeV. M_{89} quarks would have virtually no weak interactions but would possess color interactions with weak confinement length scale reflecting themselves as new kind of jets at collisions above TeV energies.

In the biologically especially important length scale range 10 nm -2500 nm there are as many as four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$: they are associated with Gaussian Mersennes $M_{G,k}$, $k = 151, 157, 163, 167$. This would suggest that the existence of scaled up scales of magnetic-, weak- and color confinement. An especially interesting possibly testable prediction is the existence of magnetic monopole pairs with the size scale in this range. There are recent claims about experimental evidence for magnetic monopole pairs [D61] .

Magnetic confinement and stringy picture in TGD sense

The connection between magnetic confinement and weak confinement is rather natural if one recalls that electric-magnetic duality in super-symmetric quantum field theories means that the descriptions in terms of particles and monopoles are in some sense dual descriptions. Fermions would be replaced by string like objects defined by the magnetic flux tubes and bosons as pairs of wormhole contacts would correspond to pairs of the flux tubes. Therefore the sharp distinction between gravitons and physical particles would disappear.

The reason why gravitons are necessarily stringy objects formed by a pair of wormhole contacts is that one cannot construct spin two objects using only single fermion states at wormhole throats. Of course, also super partners of these states with higher spin obtained by adding fermions and anti-fermions at the wormhole throat but these do not give rise to graviton like states [**?**] . The upper and lower wormhole throat pairs would be quantum superpositions of fermion anti-fermion pairs with sum over all fermions. The reason is that otherwise one cannot realize graviton emission in terms of joining of the ends of light-like 3-surfaces together. Also now magnetic monopole charges are necessary but now there is no need to assign the entities $X_\pm$ with gravitons.

Graviton string is characterized by some p-adic length scale and one can argue that below this length scale the charges of the fermions become visible. Mersenne hypothesis suggests that some Mersenne prime is in question. One proposal is that gravitonic size scale is given by electronic Mersenne prime M_{127}. It is however difficult to test whether graviton has a structure visible below this length scale.

What happens to the generalized Feynman diagrams is an interesting question. It is not at all clear how closely they relate to ordinary Feynman diagrams. All depends on what one is ready to assume about what happens in the vertices. One could of course hope that zero energy ontology could allow some very simple description allowing perhaps to get rid of the problematic aspects of Feynman diagrams.

1. Consider first the recent view about generalized Feynman diagrams which relies ZEO. A highly attractive assumption is that the particles appearing at wormhole throats are on mass shell particles. For incoming and outgoing elementary bosons and their super partners they would be positive it resp. negative energy states with parallel on mass shell momenta. For virtual bosons they the wormhole throats would have opposite sign of energy and the sum of on mass shell states would give virtual net momenta. This would make possible twistor description of virtual particles allowing only massless particles (in 4-D sense usually and in 8-D sense in TGD framework). The notion of virtual fermion makes sense only if one assumes in the interaction region a topological condensation creating another wormhole throat having no fermionic quantum numbers.

2. The addition of the particles $X^\pm$ replaces generalized Feynman diagrams with the analogs of stringy diagrams with lines replaced by pairs of lines corresponding to fermion and $X_{\pm 1/2}$. The members of these pairs would correspond to 3-D light-like surfaces glued together at the

vertices of generalized Feynman diagrams. The analog of 3-vertex would not be splitting of the string to form shorter strings but the replication of the entire string to form two strings with same length or fusion of two strings to single string along all their points rather than along ends to form a longer string. It is not clear whether the duality symmetry of stringy diagrams can hold true for the TGD variants of stringy diagrams.

3. How should one describe the bound state formed by the fermion and $X^{\pm}$? Should one describe the state as superposition of non-parallel on mass shell states so that the composite state would be automatically massive? The description as superposition of on mass shell states does not conform with the idea that bound state formation requires binding energy. In TGD framework the notion of negentropic entanglement has been suggested to make possible the analogs of bound states consisting of on mass shell states so that the binding energy is zero [K65] . If this kind of states are in question the description of virtual states in terms of on mass shell states is not lost. Of course, one cannot exclude the possibility that there is infinite number of this kind of states serving as analogs for the excitations of string like object.

4. What happens to the states formed by fermions and $X_{\pm 1/2}$ in the internal lines of the Feynman diagram? Twistor philosophy suggests that only the higher on mass shell excitations are possible. If this picture is correct, the situation would not change in an essential manner from the earlier one.

The highly non-trivial prediction of the magnetic confinement is that elementary particles should have stringy character in electro-weak length scales and could behaving to become manifest at LHC energies. This adds one further item to the list of non-trivial predictions of TGD about physics at LHC energies [K66] .

12.3 Dark Matter Hierarchy, Genetic Machinery, And The Un-Reasonable Selectivity Of Bio-Catalysis

One of the most fascinating outcomes of ideas related to the dark matter hierarchy is the notion of inherently dark fractional atom (molecule) generalizing the notion of Bose-Einstein condensate to the fermionic case. These notions might provide an elegant manner to understand the mysteries of DNA replication, transcription, and translation, and more generally, the incredible selectivity of bio-catalysis.

As often, the original idea was not quite correct. I spoke about N-atoms rather than fractional atoms. In particular, the mass of N-molecule was N times larger than that of the ordinary molecule apart from corrections from binding energy. The more precise view about dark matter hierarchy led to the realization that fractionization of all quantum numbers occurs. In the most general case one can have fractional particles with particle number $n = k/r$, $k = 1, .., r$, $r = \frac{\hbar}{\hbar_0}$. This leaves the model essentially as such at formal level. The model is however much more realistic than the original one since fractional atoms have mass which is never larger than that of ordinary atom and also conforms with the recent view about the origin of the hierarchy of Planck constants.

12.3.1 Dark Atoms And Dark Cyclotron States

The development of the notion of dark atom involves many side tracks which make me blush. The first naïve guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. After some obligatory twists and turns it became clear that this assumption is indeed the most plausible one. The main source of confusion has been the lack of precise view about what the hierarchy of Planck constants means at the level of embedding space at space-time.

The rules are very simple when one takes the singular coverings assigned to the many-valuedness of the time-derivatives of embedding space coordinates as functions of canonical momentum densities as a starting point.

1. The mass and charge of electron are fractionized as is also the reduced mass in Schrödinger equation. This implies the replacements $e \rightarrow e/r$, $m \rightarrow m/r$, and $\hbar \rightarrow r\hbar_0$, $r = n_a n_b$, in the

general formula for the binding energy assigned with single sheet of the covering. If maximal number $n_a n_b$ are present corresponding to a full "Fermi sphere", the total binding energy is r times the binding energy associated with single sheet.

2. In the case of hydrogen atom the proportionality $E \propto m/\hbar^2$ implies that the binding energy for single sheet of the covering scales as $E \rightarrow E/(n_a n_b)^3$ and maximal binding energy scales as $E \rightarrow E/(n_a n_b)^2$. This conforms with the naïve guess. For high values of the nuclear charge Z it can happen that the binding energy is larger than the rest mass and fractionization might take place when binding energy is above critical fraction of the rest mass.

3. In the case of cyclotron energies one must must decide what happens to the magnetic flux. Magnetic flux quantization states that the flux is proportional to $\hbar$ for each sheet separately. Hence one has $\Phi \rightarrow r\Phi$ for each sheet and the total flux scales as r^2. Since the dimensions of the flux quantum are scaled up by r the natural scaling of the size of flux quantum is by r^2. Therefore the quantization of the magnetic flux requires the scaling $B \rightarrow B/r$. The cyclotron energy for single sheet satisfies $E \propto \hbar q B/m$ and since both mass m and charge q become fractional, the energy E for single sheet remains invariant whereas total cyclotron energy is scaled up by r in accordance with the original guess and the assumption used in applications.

4. Dark cyclotron states are expected to be stable up to temperatures which are r times higher than for ordinary cyclotron states. The states of dark hydrogen atoms and its generalizations are expected to be stable at temperatures scaled down by $1/r^2$ in the first approximation.

5. Similar arguments allow to deduce the values of binding energies in the general case once the formula of the binding energy given by standard quantum theory is known.

The most general option option allows fractional atoms with proton and electron numbers varying from $1/r$ to 1. One can imagine also the possibility of fractional molecules. The analogs of chemical bonds between fractional hydrogen atoms with $N-k$ and k fractional electrons and protons can be considered and would give rise to a full shell of fractional electrons possessing an exceptional stability. These states would have proton and electron numbers equal to one.

Catalytic sites are one possible candidate for fractal electrons and catalyst activity might be perhaps understood as a strong tendency of fractal electron and its conjugate to fuse to form an ordinary electron.

Connection with quantum groups?

The phase $q = exp(i2\pi/r)$ brings unavoidably in mind the phases defining quantum groups and playing also a key role in the model of topological quantum computation [K5]. Quantum groups indeed emerge from the spinor structure in the "world of classical worlds" realized as the space of 3-surfaces in $M^4 \times CP_2$ and being closely related to von Neumann algebras known as hyper-finite factors of type II_1 [K121].

Only singular coverings are allowed if the hierarchy of Planck constants and corresponding hierarchy of singular coverings follows from the basic TGD. If the integer n characterizing the quantum phase allows identification with with $r = \hbar/\hbar_0$, living matter could be perhaps understood in terms of quantum deformations of the ordinary matter, which would be characterized by the quantum phases $q = exp(i2\pi/r)$. Hence quantum groups, which have for long time suspected to have significance in elementary particle physics, might relate to the mystery of living matter and predict an entire hierarchy of new forms of matter.

How to distinguish between fractional particles and ordinary particles?

The unavoidable question is whether bio-molecules in vivo could involve actually fractional atoms molecules as their building blocks. This raises a series of related questions.

1. Could it be that we can observe only the fusion of of dark fractional fold molecules to ordinary molecules or its reversal? Is the behavior of matter matter in vivo dictated by the dark matter commentn and of matter in vitro by ordinary matter? Could just the act of observing the matter in vivo in the sense of existing science make it ordinary dead matter?

2. If fractional atoms and molecules correspond to the maximum number of fractional quanta their masses are same as for ordinary atoms and molecules and only the different binding

energy photon spectrum distinguishes between them. Situation changes all fractional states are possible and one obtains scaled down spectrum as a unique signature.

3. The fusion of fractional molecules to ordinary molecules in principle allows to conclude that fractional molecule was present. Could this process mean just the replacement of DNA in vivo with DNA in vitro?

12.3.2 Spontaneous Decay And Completion Of Dark Fractional Atoms As A Basic Mechanisms Of Bio-Chemistry?

The replication of DNA has remained for me a deep mystery and I dare to doubt that the reductionistic belief that this miraculous process is well-understood involves self deceptive elements. Of course the problem is much more general: DNA replication is only a single very representative example of the miracles of un-reasonable selectivity of the bio-catalysis. I take this fact as a justification for some free imagination inspired by the notion of dark fractional molecule.

Dark fermionic molecules can replicate via decay and spontaneous completion

Unit particle number for fractional atom or molecule means that the analog of closed electronic shell are in question so that the state is especially stable. Note that the analogy with full Fermi electronic sphere makes also sense. These atoms or molecules could decay to fractional atoms or molecules. with fractional particle numbers k/r and $(r-k)/r$.

Suppose that a fractional molecule with unit particle number decays into k/r-molecule and $(r-k)/r$-molecule. If r is even it is possible to have $k = r-k = r/2$ and the situation is especially symmetric. If fermionic $k/r < 1$ fractional atoms or molecules are present, one can imagine that they tend to be completed to full molecules spontaneously. Thus spontaneous decay and completion would favor the spontaneous replication (or rather fractionization) and dark molecules could be ideal replicators (fractionizators) The idea that the mechanisms of spontaneous decay and completion of dark fractional particles somehow lurk behind DNA replication and various high precision bio-catalytic processes is rather attractive.

Reduction of lock and key mechanism to spontaneous completion

DNA replication and molecular recognition by the lock and key mechanism are the two mysterious processes of molecular biology. As a matter fact, DNA replication reduces to spontaneous opening of DNA double strand and to the lock and key mechanism so that it could be enough to understand the opening of double strand in terms of spontaneous decay and lock and key mechanism in terms of spontaneous completion of fractional particle (-atom or -molecule).

Consider bio-molecules which fit like a lock and key. Suppose that they are accompanied by dark fractional atoms or molecules, to be called dark fractional particles in sequel, such that one has $k_1 + k_2 = r$ so that in the formation of bound state dark molecules combine to form r-molecule analogous to a full fermionic shell or full Fermi sea. This is expected to enhance the stability of this particular molecular complex and prefer it amongst generic combinations.

For instance, this mechanism would make it possible for nucleotide and its conjugate, DNA and mRNA molecule, and tRNA molecule and corresponding amino-acid to recognize each other. Spontaneous completion would allow to realize also the associations characterizing the genetic code as a map from RNAs to subset of RNAs and associations of this subset of RNAs with amino-acids (assuming that genetic code has evolved from RNA $\rightarrow$ RNA code as suggested in this chapter).

As such this mechanism allows a rather limited number of different lock and key combinations unless r is very large. There is however a simple generalization allowing to increase the representative power so that lock and key mechanism becomes analogous to a password used in computers. The molecule playing the role of lock *resp.* molecule would be characterized by a set of n fractional particles with $k_1 \in \{k_{1,1}, ...k_{1,n}\}$ *resp.* $k_2 \in \{k_{2,1} = r - k_{1,1}, ..., k_{2,n} = r - k_{1,n}\}$. The molecules with conjugate names would fit optimally together. Fractional molecules or fractional electrons or atoms appearing as their building blocks would be like letters of a text characterizing the name of the molecule.

The mechanism generalizes also to the case of $n > 2$ reacting molecules. The molecular complex would be defined by a partition of n copies of integer r to a sum of m integers $k_{k,i}$: $\sum_i k_{k,i} = r$.

This mechanism could provide a universal explanation for the miraculous selectivity of catalysts and this selectivity would have practically nothing to do with ordinary chemistry but would correspond to a new level of physics at which symbolic processes and representations based on dark fractional particles emerge.

Connection with the number theoretic model of genetic code?

The emergence of partitions of integers in the labelling of molecules by fractional particles suggests a connection with the number theoretical model of genetic code [K32], where DNA triplets are characterized by integers $n \in \{0, ..., 63\}$ and amino-acids by integers 0, 1 and 18 primes $p < 64$. For instance, one can imagine that the integer n means that DNA triplet is labelled by n/r-particle. $r = 64$ would be the obvious candidate for r and conjugate DNA triplet would naturally have $n_c = 64 - n$.

The model relies on number-theoretic thermodynamics for the partitions of n to a sum of integers and genetic code is fixed by the minimization of number theoretic entropy which can be also negative and has thus interpretation as information. Perhaps these partitions could correspond to states resulting in some kind of decays of n-fermion to n_k/r-fermions with $\sum_{k=1}^{r} n_k = n$. The n_k/r-fermions should however not correspond to separate particles but something different. A possible interpretation is that partition corresponds to a state in which n_1/r particle is topologically condensed at $n_2/r \geq n_1/r$ particle topologically condensed....at $n_k/r \geq n_{k-1}/r$-particle. This would also automatically define a preferred ordering of the integers n_i in the partition.

An entire ensemble of labels would be present and depending on the situation codon could be labelled not only by n/r-particle but by any partition $n = \sum_{i=1}^{k} n_i$ corresponding to the state resulting in the decay of n/r-particle to k fractional particles.

Reduction of DNA replication to a spontaneous decay of r-particle

DNA replication could be induced by a spontaneous decay of r-particle inducing the instability of the double strand leading to a spontaneous completion of the component strands.

Strand and conjugate strand would be characterized by k_1/r-particle and $(r-k_1)/r$-particle, which combine to form r-particle as the double strand is formed. The opening of the double strand is induced by the decay of r-particle to k_1/r- and $(r - k_1)/r$-particles accompanying strand and its conjugate and after this both strands would complete themselves to double strands by the completion to r-particle.

It would be basically the stability of fractional particle which would make DNA double strand stable. Usually the formation of hydrogen bonds between strands and more generally, between the atoms of stable bio-molecule, is believed to explain the stability. Since the notion of hydrogen bond is somewhat phenomenological, one cannot exclude the possibility that these two mechanisms might be closely related to each other. I have already earlier considered the possibility that hydrogen bond might involve dark protons [K42]: this hypothesis was inspired by the finding that there seems to exist two kinds of hydrogen bonds [D101].

The reader has probably already noticed that the participating fractional molecules in the model of lock and key mechanism are like sexual partners, and if already molecules are conscious entities as TGD inspired theory of consciousness strongly suggests, one might perhaps see the formation of entangled bound states with positive number theoretic entanglement entropy accompanied by molecular experience of one-ness as molecular sex. Even more, the replication of DNA brings in also divorce and process of finding of new companions!

12.3.3 The New View About Hydrogen Bond And Water

Concretization of the above scenario leads to a new view about hydrogen bond and the role of water in bio-catalysis.

What the fractional particles labelling bio-molecules could be?

What the dark fractional particles defining the letters for the names of various bio-molecules could be? Dark fractional hydrogen atoms are the lightest candidates for the names of bio-molecules. The fusion could give rise to the hydrogen atom appearing in hydrogen bond. One could say the fractional hydrogen atoms belong to the molecules between which the hydrogen bond is formed. In absence of bond the fractional atoms would define active catalyst sites. This mechanism would also conform with the belief that hydrogen bonds guarantee the stability of bio-molecules.

This idea is not a mere speculation. The first experimental support for the notion of dark matter [K42] came from the experimental finding that water looks in atto-second time scale from the point of view of neutron diffraction and electron scattering chemically like $H_{1.5}O$: as if one fourth of protons are dark [D104, D93, D119, D60]. Dark protons would be identifiable as fractional protons. Of course, also dark hydrogen atoms can be considered.

One can imagine also a second option. The model for [I1] [K51] leads to a rather concrete view about how magnetic body controls biological body and receives sensory input from it. The model relies on the idea that dark water molecule clusters and perhaps also dark exotically ionized super-nuclei formed as linear closed strings of dark protons [K42] perform this mimicry. Dark proton super-nuclei are ideal for mimicking the cyclotron frequencies of ordinary atoms condensed to dark magnetic flux quanta. Of course, also partially ionized hydrogen fractional ions could perform the cyclotron mimicry of molecules with the same accuracy.

One can consider the possibility fractional molecules/atoms correspond to exotic atoms formed by electrons bound to exotically ionized dark super-nuclei: the sizes of these nuclei are however above atomic size scale so that dark electrons would move in a harmonic oscillator potential rather than Coulombic potential and form states analogous to atomic nuclei. The prediction would be the existence of magic electron numbers [K42]. Amazingly, there is strong experimental evidence for the existence of this kind of many-electron states. Even more, these states are able to mimic the chemistry of ordinary atoms [D116, D53, D42]. The formation of hydrogen bonds between catalyst and substrate could be the correlate for the fusion of fractional hydrogen atoms.

If the fusion process gives rise 1/1-hydrogen, its spontaneous decay to ordinary hydrogen would liberate the difference of binding energies as metabolic energy helping to overcome the energy barrier for the reaction. The liberated energy would be rather large and correspond 3.4 eV UV photon even for $r = 2$ which suggests that it does not relate with standard metabolism. For larger values of r the liberated energy rapidly approaches to the ground state energy of hydrogen. Note that the binding energy of ordinary hydrogen atom in state $n = r$ has in the lowest order approximation same energy as the ground state of dark hydrogen atom for $\hbar/\hbar_0 = r$ so that one can consider the possibility of a resonant coupling of these states.

Fractional protons and electrons have effective charge $\pm ke/r$ so that the binding regions of catalysts and reacting molecules could carry effective fractional surface charge.

This might relate in an interesting manner to the problem of how poly-electrolytes can be stable (I am grateful for Dale Trenary for pointing me the problem and for interesting discussions). For instance, DNA carries a charge of -2 units per nucleotide due to the phosphate backbone. The models trying to explain the stability involve effective binding of counter ions to the polyelectrolyte so that the resulting system has a lower charge density. The simulations of DNA condensation by Stevens [I24] however predict that counter ion charge should satisfy $z > 2$ in the case of DNA. The problem is of course that protons with $z = 1$ are the natural counter ions. The positive surface charge defined by the fractional protons attached to the nucleotides of DNA strand could explain the stability.

The hydrogen atoms in hydrogen bonds as fractional hydrogen atoms and $H_{1.5}O$ formula for water

The simplest assumption is that the hydrogens associated with hydrogen bonds are actually associated with 1/1 type dark hydrogen atoms. This hypothesis has interesting implications and could explain the formula $H_{1.5}O$ for water in atto-second time scales suggested by neutron diffraction and electron scattering [D104, D93, D119, D60].

The formation of hydrogen bond would correspond to a fusion of name and conjugate name between $H_{k/r}$-O-H atom and its conjugate $H_{(r-k)/r}$-O-H atom. The resulting pairs would obey the chemical formula H_3-O_2. Hence the formation of hydrogen bonds would predict the $H_{1.5}O$ formula suggested by neutron diffraction and electron scattering in atto-second time scale. This holds true only if one has complete pairing by hydrogen bonds. A more plausible explanation is that just the presence of fractioanl hydrogens implies the effect. Furthermore, the fraction of dark protons can depend on temperature.

The roles of water and ordered water in catalysis

The new view about hydrogen bond allows to understand the role of water in biology at qualitative level. For instance, one can

1. tentatively identify "ordered water" as a phase in which all $H_{k/r}$ atoms and their conjugates have combined to $H_{1/1}$ atoms,
2. understand why (or perhaps it is better to say "predict that") water containing $H_{k/r}$ atoms acts as a catalytic poison so that the binding sites of catalysts and reactants must be isolated from water unless the water is ordered,
3. justify the belief that gel phase involving ordered water is necessary for biological information processing,
4. understand why hydration causes hydrolysis,
5. understand the instability of DNA against decay to RNA outside nucleus.

A more more detailed sketch looks like following.

1. Suppose that at least part of water molecules appear in form $H_{k/r}$-OH and $H_{(r-k)/r}$-O-H. These molecules and the molecule $H_{1/1}$-OH_2 formed in their fusion has much smaller binding energy than ordinary water molecule and is expected to be unstable against transition to H_3O. This would suggest that the feed of metabolic energy is needed to generate the dark hydrogen atoms.

   Fractional dark water molecules can join pairwise to form H-O-($H_{1/1}$)-O-H$\equiv$ H_3O_2 with $H_{1/1}$-atoms replacing hydrogen in hydrogen bond. Also $H_{k_1/r}$-O-$H_{k_2/r}$ molecules are possible and could form closed strings obeying the chemical formula $O_n(H_{1/1})_n$. Also open strings with H-O: s at ends are possible. This phase of water might allow identificaton as "ordered water" believed to be associated with gel phase and be crucial for quantal information processing inside cell. Liquid crystal phase of water could correspond to a bundle of open vertical segments H-$O_n(H_{1/1})_{n-2}$-H forming a 2-dimensional liquid (vertical freezing).
2. Exotic water molecules could spoil the action of both catalyst and reactant molecules by attaching to the "letters" in the name of catalyst or reactant so that the letters are not visible and catalyst and reactant cannot recognize each other anymore. Hence binding sites of catalyst and reactant must be isolated from water containing fractional water molecules. This is what Sidorova and Rau [I28] suggest on basis of comparison of specific and non-specific catalysts: non-specific catalysts contain water in an isolated binding volume whereas for specific catalysts this volume is empty. An alternative mechanism hindering water molecules to attach to "letters" is that water is "ordered water" with no fractional water molecules present.
3. DNA is known to be stable against decay to RNA via hydration inside the cell but not outside. Hydration could correspond to the joining of fractional water to sites of DNA transforming it to RNA. Inside nucleus this cannot occur if water is in ordered water phase permanently.

How the first self-replicators emerged?

The identification of the first self replicator can be seen as perhaps the most fascinating and challenging problem faced by the pre-biotic model builders. Self replicator is by definition an entity which catalyzes its own replication. The analogy with the self-referential statement appearing in Gödel's theorem obvious.

In TGD framework self replication would reduce to a spontaneous decay of $H_{1/1}$-atom to $H_{k/r}$- and $H_{(r-k)/r}$-atoms and their subsequent completion to $H_{1/1}$-atoms

The picture about emergence of self-replicators would be roughly following.

1. The first self-replicating entities would have been plasmoids [I23] generating $H_{1/1}$ atoms whose presence would have made possible the emergence of the first molecular self replicators. The generation of $H_{1/1}$ atoms requires metabolic energy feed. In the first approximation the decay of $H_{1,1}$ to fractional hydrogen atoms does not liberate nor require energy.
2. $H_{k/r}$ atoms would have replaced some ordinary H-atoms in some negatively charged molecules M_i (perhaps MXTP, $X = A, U, C, G$) leading to a spontaneous emergence of linear negatively charged polymers consisting of M_i. One can imagine a coding in which each X corresponds to fixed value of k or collection of the (2 hydrogen bonds or 3 hydrogen bonds depending on X). This would make the attachment of X and its conjugate to form a hydrogen bond a highly favored process.
3. $H_{k/r}$ atoms would have taken also the role of active binding sites. In ordered water conjugate molecules $M_{c,i}$ having $H_{(r-k)/r}$ atoms as labels would have had high probability to attach to the polymers made of M_i.
4. RNA molecules are good candidates for self-replicators in the presence of ordered water. The phase transition from ordinary to ordered water (which would have developed later to sol-gel phase transition) would have been an essential element of replication.

The role of water in chiral selection

In the latest New Scientist (when I am writing this) there was a news telling that chiral selection occurs in water but not in heavy water [C114]. The L form of amino-acid glutamate is more stable than R in ordinary but not so in heavy water so that water environment must be responsible for the chirality selection of bio-molecules. The proposed explanation for the finding, whose importance cannot be over-estimated, was following.

1. Water molecules have two forms: orto- and para, depending on whether the nuclear spins of protons are parallel or opposite. Deuterium nuclei are spinless so that heavy water has only single form. In thermal equilibrium the fraction of orto water is 3/4 and para water 1/4.
2. Ortho-water is magnetic and if L form of amino-acid is slightly more magnetic than R, chirality selection can be understood as result of the magnetic interaction with water.

One can of course wonder how extremely short ranged weak interactions could produce strong enough effect on the magnetic moment. The situation is not made easier by the fact that magnetic interaction energies are inherently very weak and deep below the thermal threshold.

It is interesting to find whether these findings could be explained by and allow a more detailed formulation of the TGD based model for water based on the notion of fractional hydrogen atom, the new view about hydrogen bond, and the notion of dark protonic strings forming atomic sized super-nuclei carrying exotic weak charges.

1. Dark matter brings in long ranged exotic weak interactions which can produce large parity breaking effects in atomic and even longer length scales. The long ranged parity breaking weak interactions of the dark protonic super nuclei assignable to amino-acids and water could explain the chiral selection.
2. The magnetic interaction energy is scaled up by r, so that magnetic interactions could indeed play a key role. Ordinary classical magnetic fields are in TGD framework always accompanied by Z^0 magnetic fields. If amino-acids possess exotic em charge implying also exotic weak charge, one can understand the chiral breaking as being induced by the Z^0 magnetic interaction of aminocids with the dark magnetic fields generated by water molecules or their clusters possessing a net magnetic moment. In heavy water these fields would be absent so that the experimental findings could be understood.
3. The experimental evidence that water behaves as $H_{1.5}O$ in atto-second time scales means that 1/4: th of protons of water are effectively dark. The notion of fractional hydrogen atom leads to a model of hydrogen bond predicting correctly $H_{1.5}O$ formula and the dropping of 1/4: th of protons at larger possibly dark space-time sheets. The model also predicts that the mass of $H - O - H_r - O - H \equiv 2H_{1.5}O$ hydrogen bonded pairs is very near to the mass of 2 water molecules since there are $r \simeq m_p/m_e$ electrons involved. The paired molecules have three protons and non-vanishing net nuclear spin and thus generate a magnetic field and

make hydrogen bonded water a magnetic system. The natural identification would be as dark magnetic field accompanied by Z^0 magnetic field responsible for the chiral selection.

In the case of $D-O-D_r-O-D$ mass would be by about one proton mass m_p lower than mass of two D_2O molecules so that this D-bonded heavy water would look like $D_{1.25}O$ as far as masses are considered and $D_{1.5}O$ as far neutron diffraction and electron scattering are considered. In this case no magnetic field is generated since the nuclear spin of D vanishes and no chiral breaking results. This picture explains the experimental findings. The model is not equivalent with the proposal of the experimentalists.

4. The model predicts that the protons liberated in the formation of hydrogen bonds drop to larger space-time sheets but does not specify their fate. A strong constraint comes from the requirement that the dropped particles have exotic weak charges acting as sources of the geometrically unavoidable classical Z^0 magnetic field at dark space-time sheets causing the large parity breaking. This constraint is satisfied if the protons form super-nuclei (scaled up variants of nuclei) consisting of protonic strings connected by color bonds involving exotic quark and antiquark at its ends and some of these bonds are charged (of type $u\overline{d}$ or $d\overline{u}$: this could also generate the em charge needed to make the protonic string stable.

12.4 TGD Based Model For Qualia And Sensory Receptors

The identification of quantum number increments in quantum jump for a subsystem representing sub-self and the capacitor model of sensory receptor are already more than decade old ideas.

The concrete realization of this vision is based on several ideas that I have developed during last five years.

1. The vision about dark matter as a hierarchy of phases partially labeled by the value of Planck constant led to the model of DNA as topological quantum computer [K4]. In this model magnetic flux tubes connecting DNA nucleotides with the lipids of the cell membrane define strands of the braids defining topological quantum computations. The braid strand corresponds to so called wormhole flux tube and has quark and antiquark at its ends. u and d quarks and their antiquarks code for four DNA nucleotides in this model.

2. Zero energy ontology assigns to elementary particles so called causal diamonds (CDs). For u and d quarks and electron these time scales are (6.5, .78, 100) ms respectively, and correspond to fundamental biorhythms. Electron time scale corresponds to 10 Hz fundamental biorhythm defining also the fundamental frequency of speech organs, .78 ms to kHz cortical synchrony [J10], and 160 Hz to cerebellar synchrony [J9]. Elementary particles therefore seem to be directly associated with neural activity, language, and presumably also hearing. One outcome was the modification of the earlier model of memetic code involving the notion of cognitive neutrino pair by replacing the sequence of cognitive neutrino pairs with that of quark sub-CDs within electron CD. Nerve pulses could induce the magnetization direction of quark coding for bit but there are also other possibilities. The detailed implications for the model of nerve pulse [K88] remain to be disentangled.

3. The understanding of the Negentropy Maximization Principle [K65] and the role of negentropic entanglement in living matter together with the vision about life as something in the intersection of real and p-adic worlds was a dramatic step forward. In particular, space-like and time-like negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) become basic aspects of conscious intelligence and are expected to be especially important for understanding the difference between speech and music.

4. One of the basic challenge has been to construct a quantitative model for cell membrane.

   (a) The first model was based on the assumption that long range weak forces however play a key role [K9]. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other whereas for the standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive or Boolean representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms - one of the key observations during last years- take this role. The essential element is that the energies of the Josephson photons are in visible range. This would explain bio-photons and even why the frequencies assignable to visual receptors. The problem is that Weinberg angle must be assumed to be much smaller in the near vacuum extremal phase than in standard model.

(b) Second model is based on Gerald Pollack's findings about fourth phase of water and exclusion zones [L24]. These zones inspire a model for pre-biotic cells. The outcome is a modification of the simplest model of Josephson junction. Besides resting potential also the difference between cyclotron energies between the two sides of the membrane plays a key role. This model allows to understand what happens in metabolism in terms of a quantum model replacing the thermodynamical model for cell membrane with its quantal "square root" inspired by Zero Energy Ontology. The model allows also to understand bio-photons as decay products of dark photons.

(c) The success of the latter model does not of course mean that the weak forces could not be important in cell membrane scale and the realistic model could be a hybrid of these two models. The inclusion of Z^0 contribution to the effective magnetic field could also to the fact that the endogenous magnetic field deduced from Blackman's experiments is $B_{end} = 2B_E/5$ rather than B_E (Earth's magnetic field).

12.4.1 A General Model Of Qualia And Sensory Receptor

The identification of sensory qualia in terms of quantum number increments and geometric qualia representing geometric and kinematic information in terms of moduli of CD, the assignment of sensory qualia with the membrane of sensory receptor, and capacitor model of qualia are basic ideas behind the model. The communication of sensory data to magnetic body using Josephson photons is also a key aspect of the model.

A general model of qualia

It is good to start by summarizing the general vision about sensory qualia and geometric qualia in TGD Universe.

1. The basic assumption is that sensory qualia correspond to increments of various quantum numbers in quantum jump. Standard model quantum numbers- color quantum numbers, electromagnetic charge and weak isospin, and spin are the most obvious candidates. Also cyclotron transitions changing the integer characterizing cyclotron state could corresponds to some kind of quale- perhaps "a feeling of existence". This could make sense for the qualia of the magnetic body.

2. Geometric qualia could correspond to the increments of zero modes characterizing the induced CP_2 Käjhler form of the partonic 2-surface and of the moduli characterizing the causal diamonds serving as geometric correlates of selves. This moduli space involves the position of CD and the relative position of tips as well as position in CP_2 and relative position of two CP_2 points assigned to the future and past boundaries of CD. There are good motivations for proposing that the relative positions are quantized. This gives as a special case the quantization of the scale of CD in powers of two. Position and orientation sense could would represent this kind of qualia. Also kinematical qualia like sensation of acceleration could correspond to geometric qualia in generalized 4-D sense. For instance, the sensation about motion could be coded by Lorentz boots of sub-CD representing mental image about the object.

3. One can in principle distinguish between qualia assignable to the biological body (sensory receptors in particular) and magnetic body. The basic question is whether sensory qualia can be assigned only with the sensory receptors or with sensory pathways or with both. Geometric qualia might be assignable to the magnetic body and could provide third person perspective as a geometric and kinematical map of the body and its state of motion represented using the moduli space assignable to causal diamonds (CD). This map could be provided also by the body in which case the magnetic body would only share various mental images. The simplest starting assumption consistent with neuro-science is that sensory qualia are assigned with the

cell membrane of sensory receptor and perhaps also with the neurons receiving data from it carried by Josephson radiation coding for the qualia and possibly partially regenerating them if the receiving neuron has same value of membrane potential as the sensory receptor when active. Note that during nerve pulse also this values of membrane potential is achieved for some time.

Could some sensory qualia correspond to the sensory qualia of the magnetic body?

Concerning the understanding of a detailed model for how sensory qualia are generated, the basic guideline comes from the notion of magnetic body and the idea that sensory data are communicated to the magnetic body as Josephson radiation associated with the cell membrane. This leaves two options: either the primary a sensory qualia are generated at the level of sensory receptor and the resulting mental images negentropically entangle with the "feeling of existence" type mental images at the magnetic body or they can be also generated at the level of the magnetic body by Josephson radiation -possibly as cyclotron transitions. The following arguments are to-be-or-not-to-be questions about whether the primary qualia must reside at the level of sensory receptors.

1. Cyclotron transitions for various cyclotron condensates of bosonic ions or Cooper pairs of fermionic ions or elementary particles are assigned with the motor actions of the magnetic body and Josephson frequencies with the communication of the sensory data. Therefore it would not be natural to assign qualia with cyclotron transitions. One the other hand, in zero energy ontology motor action can be regarded formally as a time reversed sensory perception, which suggests that cyclotron transitions correlated with the "feeling of existence" at magnetic body entangled with the sensory mental images. They could also code for the pitch of sound as will be found but this quale is strictly speaking also a geometric quale in the 4-D framework.
2. If Josephson radiation induces cyclotron transitions, the energy of Josephson radiation must correspond to that of cyclotron transition. This means very strong additional constraint not easy to satisfy except during nerve pulse when frequencies varying from about 10^{14} Hz down to kHz range are emitted the system remains Josephson contact. Cyclotron frequencies are also rather low in general, which requires that the value of $\hbar$ must be large in order to have cyclotron energy above the thermal threshold. This would however conform with the very beautiful dual interpretation of Josephson photons in terms of bio-photons and EEG. One expects that only high level qualia can correspond to a very large values of $\hbar$ needed.

   For the sake of completeness it should be noticed that one might do without large values of $\hbar$ if the carrier wave with frequency defined by the metabolic energy quantum assignable to the kicking and that the small modulation frequency corresponds to the cyclotron frequency. This would require that Josephson frequency corresponds to the frequency defined by the metabolic quantum. This is not consistent with the fact that very primitive organisms possess sensory systems.
3. If all primary qualia are assigned to the magnetic body, Josephson radiation must include also gluons and light counterparts of weak bosons are involved besides photons. This is quite a strong additional assumption and it will be found that the identification of sensory qualia in terms of quantum numbers of quark pair restricts them to the cell membrane. The coding of qualia by Josephson frequencies is however possible and makes it possible to regenerate them in nervous system. The successful model explaining the peak frequencies of photoreceptors in terms of ionic cyclotron frequencies supports this view and provides a realization for an old idea about spectroscopy of consciousness which I had already been ready to give up.

Capacitor model of sensory qualia

In capacitor model of sensory receptor the increments of quantum numbers are amplified as particles with given quantum numbers flow between the plates of capacitor like system and the second plate defines the sub-self responsible for the mental image. The generation of complementary qualia assignable to the two plates and bringing in mind complementary colors is predicted. The capacitor is at the verge of di-electric breakdown. The interior and exterior of the receptor cell are the most plausible candidates for the capacitor plates with lipid layers defining the analog of di-electric able to changes its properties. Josephson currents generating Josephson radiation could communicate the sensory percept to the magnetic body but would not generate genuine sensory qualia there (the pitch of sound would be interpreted as a geometric quale). The coding is possible if the basic qualia correspond in one-one manner to ionic Josephson currents. There are sensory receptors which themselves do not fire (this is the case for hair cells for hearing and tactile receptor cells) and in this case the neuron next to the receptor in the sensory pathway would take the role of the quantum critical system.

The notion of sensory capacitor can be generalized. In zero energy ontology the plates could be effectively replaced with positive and negative energy parts of zero energy state or with cyclotron Bose-Einstein condensates corresponding to two different energies. Plates could also correspond to a pair of space-time sheets labeled by different p-adic primes and the generation of quale would correspond in this case to a flow of particles between the space-time sheets or magnetic flux tubes connected by contacts defining Josephson junctions.

The TGD inspired model for photoreceptors [K88] relies crucially on the assumption that sensory neurons at least and probably all cell membranes correspond to nearly vacuum extremals with the value of Weinberg angle equal to $sin^2(\theta_W) = .0295$ and weak bosons having Compton length of order cell size and ordinary value of Planck constant. This also explains the large parity breaking effects in living matter. The almost vacuum extremal property conforms with the vision about cell membrane as a quantum critical system ideal for acting as a sensory receptor.

12.4.2 Detailed Model For The Qualia

The proposed vision about qualia requires a lot of new physics provided by TGD. What leads to a highly unique proposal is the intriguing coincidence of fundamental elementary particle time scales with basic time scales of biology and neuro science and the model of DNA as topological quantum computer [K4].

1. Zero energy ontology brings in the size scale of CD assignable to the field body of the elementary particle. Zero energy states with negentropic time-like entanglement between positive and negative energy parts of the state might provide a key piece of the puzzle. The negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) beween positive energy parts of the states associated with the sub-CD assignable to the cell membrane and sub-CD at the magnetic body is expected to be an important factor.

2. For the standard value of $\hbar$ the basic prediction would be 1 ms second time scale of d quark, 6.5 ms time scale of u quark, and.1 second time scale of electron as basic characterizes of sensory experience if one accept the most recent estimates $m(u) = 2$ MeV and $m(d) = 5$ MeV for the quark masses [C66]. These time scales correspond to 10 Hz, 160 Hz, and 1280 Hz frequencies, which all characterize neural activity (for the identification of 160 Hz frequency as cerebellar resonance frequency see [J9]). Hence quarks could be the most interesting particles as far as qualia are considered and the first working hypothesis would be that the fundamental quantum number increments correspond to those for quark-anti-quark pair. The identification in terms of quantum numbers of single quark is inconsistent with the model of color qualia.

3. The model of DNA as topological quantum computer led to the proposal that DNA nucleotides are connected to the lipids of the cell membrane by magnetic flux tubes having quark and antiquark at its ends such that the u and d quarks and their antiquarks code for the four nucleotides. The outer lipid layer was also assumed to be connected by flux tubes to the nucleotide in some other cell or in cell itself.

4. The model for DNA as topological quantum computer did not completely specify whether the flux tubes are ordinary flux tubes or wormhole flux tubes with possibly opposite signs of energy assigned with the members of the flux tube pair. Although it is not necessary, one could assume that the quantum numbers of the two parallel flux tubes cancel each other so that wormhole flux tube would be characterized by quantum numbers of quark pairs at its ends. It is not even necessary to assume that the net quantum numbers of the flux tubes vanish. Color confinement however suggests that the color quantum at the opposite ends of the flux tube are of opposite sign.

(a) The absence of a flux tube between lipid layers was interpreted as an isolation from external world during the topological quantum computation. The emergence of the flux tube connection means halting of topological quantum computation. The flux tube connection with the external world corresponds to sensory perception at the level of DNA nucleotide in consistency with the idea that DNA plays the role of the brain of cell [K92]. The total color quantum numbers at the ends of the flux tubes were assumed to sum up to zero. This means that the fusion of the flux tubes ending to the interior and exterior cell membrane to single one creates a flux tube state not localized inside cell and that the interior of cell carries net quantum numbers. The attractive interpretation is that this process represents the generation of quale of single nucleotide.

(b) The formation of the flux tube connection between lipid layers would involve the transformation of both quark-antiquark pairs to an intermediate state. There would be no kinematic constraints on the process nor to the mass scales of quarks. A possible mechanism for the separation of the two quark-antiquark pairs associated with the lipids from the system is double reconnection of flux tubes which leads to a situation in which the quark-antiquark pairs associated with the lipid layers are connected by short flux loops and separated to a disjoint state and there is a long wormhole flux tube connecting the nucleotides possibly belonging to different cells.

(c) The state of two quark pairs need not have vanishing quantum numbers and one possibility is that the quantum numbers of this state code for qualia. If the total numbers of flux tubes are vanishing also the net quantum numbers of the resulting long flux tube connecting two different cells provide equivalent coding. A stronger condition is that this state has vanishing net quantum numbers and in this case the ends of the long flux tube would carry opposite quantum numbers. The end of flux tube at DNA nucleotide would characterize the quale.

5. Two identification of primary qualia are therefore possible.

   (a) If the flux tubes have vanishing net quantum numbers, the primary sensory quale can be assigned to single receptor cell and the flow of the quantum numbers corresponds to the extension of the system with vanishing net quantum numbers in two-cell system.

   (b) If the net quantum numbers of the flux tube need not vanish, the resulting two cell system carries non-vanishing quantum numbers as the pair of quark-antiquark pairs removes net quantum numbers out of the system.

6. If the net quantum numbers for the flux tubes vanish always, the specialization of the sensory receptor membrane to produce a specific quale would correspond to an assignment of specific quantum numbers at the DNA ends of the wormhole flux tubes attached to the lipid layers of the cell membrane. The simplest possibility that one can imagine is that the outer lipid layer is connected to the conjugate DNA nucleotide inside same cell nucleus. This option would however assign vanishing net quantum number increments to the cell as whole and is therefore unacceptable.

7. The formation of a temporary flux tube connection with another cell is necessary during the generation of quale and the question is what kind of cell is in question. The connection of the receptor to cells along the sensory pathway are expected to be present along the entire sensory pathway from DNA nucleotide to a nucleotide in the conjugate strand of second neuron to DNA nucleotide of the third neutron.... If Josephson photons are able to regenerate the quale in second neuron this would make it possible to replicate the quale along entire sensory pathway. The problem is that Josephson radiation has polarization orthogonal to axons and must propagate along the axon whereas the flux tube connection must be orthogonal to axon. Hence the temporary flux tube connection is most naturally between receptor cells and would mean horizontal integration of receptor cells to a larger structure. A holistic process in directions parallel and orthogonal to the sensory pathway would be in question. Of course, the flux tube could be also curved and connect the receptor to the next neuron along the sensory pathway.

8. The specialization of the neuron to sensory receptor would require in the framework of positive energy ontology that -as far as qualia assignable to the electro-weak quantum numbers are considered - all DNA nucleotides are identical by the corresponds of nucleotides with quarks

and antiquarks. This cannot be the case. In zero energy ontology and for wormhole flux tubes it is however enough to assume that the net electroweak quantum numbers for the quark antiquark pairs assignable to the DNA wormhole contact are same for all nucleotides. This condition is easy to satisfy. It must be however emphasized that there is no reason to require that all nucleotides involved generate same quale and at the level of neurons sensory maps assigning different qualia to different nucleotides and lipids allowing DNA to sensorily perceive the external world are possible.

The model should be consistent with the assignment of the fundamental bio-rhythms with the CDs of electron and quarks.

1. Quark color should be free in long enough scales and cellular length scales are required at least. The QCD in question should therefore have long enough confinement length scales. The first possibility is provided by almost vacuum extremals with a long confinement scale also at the flux tubes. Large $\hbar$ for the cell membrane space-time sheet seems to be unavoidable and suggests that color is free in much longer length scale than cell length scale.
2. Since the length of the flux tubes connecting DNA and cell membrane is roughly 1 micrometer and by a factor of order 10^7 longer than the d quark Compton length, it seems that the value of Planck constant must be of this order for the flux tubes. This however scales up the time scale of d quark CD by a factor of 10^{14} to about 10^4 years! The millisecond and 160 ms time scales are much more attractive. This forces to ask what happens to the quark-anti-quark pairs at the ends of the tubes.
3. The only possibility seems to be that the reconnection process involves a phase transition in which the closed flux tube structure containing the two quark pairs assignable to the wormhole contacts at lipid layers is formed and leaks to the page of the Big Book with pages partially labeled by the values of Planck constant. This page would correspond to the standard value of Planck constant so that the corresponding d quark CDs would have a duration of millisecond. The reconnection leading to the ordinary situation would take place after millisecond time scale. The standard physics interpretation would be as a quantum fluctuation having this duration. This sequence of quark sub-CDs could define what might be called memetic codon representation of the nerve pulse sequence.
4. One can also consider the possibility is that near vacuum extremals give rise to a copy of hadron physics for which the quarks associated with the flux tubes are light. The Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$ define excellent p-adic time scales for quarks and light variants of weak gauge bosons. Quark mass 5 MeV would with $k = 120$ would be replaced with $k = 163$ (167) one would have mass 1.77 eV (.44 eV). Small scaling of both masses gives 2 eV and.5 eV which correspond to basic metabolic quanta in TGD framework. For quark mass of 2 MeV with $k = 123$ $k = 163$ (167) one would give masses.8 eV (.05 eV). The latter scale correspond to Josephson energy assignable with the membrane potential in the ordinary phase.

   In this case a phase transition transforming almost vacuum extremal to ordinary one takes place. What this would mean that the vacuum extremal property would hold true below much shorter p-adic length scale. In zero energy ontology the scaling up of quark masses is in principle possible. This option looks however too artificial.

12.4.3 Overall View About Qualia

This picture leads to the following overall view about qualia. There are two options depending on whether single quark-antiquark pair or two of them labels the qualia. In the following only the simpler option with single quark-antiquark pair is discussed.

1. All possible pairings of spin and electroweak isospin (or em charge) define 16 basic combinations if one assumes color singletness. If arbitrary color is allowed, there is a nine-fold increase of quantum numbers decomposable to color singlet and octet qualia and further into 3×15 qualia with vanishing increments of color quantum numbers and 6×16 qualia with non-vanishing increments of color quantum numbers. The qualia with vanishing increments for electroweak quantum numbers could correspond to visual colors. If electroweak quantum

numbers of the quark-anti-quark pair vanish, one has 3×7 *resp.* 6×8 combinations of colorless *resp.* colored qualia.

2. There is a huge number of various combinations of these fundamental qualia if one assumes that each nucleotide defines its own quale and fundamental qualia would be analogous to constant functions and more general qualia to general functions having values in the space with $9 \times 16 - 1$ points. Only a very small fraction of all possible qualia could be realized in living matter unless the neurons in brain provide representations of body parts or of external world in terms of qualia assignable to lipid-nucleotide pairs. The passive DNA strand would be ideal in this respect.

3. The basic classification of qualia is as color qualia, electro-weak quale, and spin quale and products of these qualia. Also combinations of color qualiaandelectroweak and spin quale are possible and could define exotic sensory qualia perhaps not yet realized in the evolution. Synesthesia is usually explained in terms of sensory leakage between sensory pathways and this explanation makes sense also in TGD framework if there exists a feedback from the brain to the sensory organ. Synesthesia cannot however correspond to the product qualia: for "quantum synesthesia" cross association works in both directions and this distinguishes it from the ordinary synesthesia.

4. The idea about brain and genome as holograms encourages to ask whether neurons or equivalently DNA could correspond to sensory maps with individual lipids representing qualia combinations assignable to the points of the perceptive field. In this framework quantum synesthesia would correspond to the binding of qualia of single nucleotide (or lipid) of neuron cell membrane as a sensory representation of the external world. DNA is indeed a holographic representation of the body (gene expression of course restricts the representation to a part of organism). Perhaps it is this kind of representation also at the level of sensory experience so that all neurons could be little sensory copies of body parts as holographic quantum homunculi. In particular, in the associative areas of the cortex neurons would be quantum synesthetes experiencing the world in terms of composite qualia.

5. The number of flux tube connections generated by sensory input would code for the intensity of the quale. Josephson radiation would do the same at the level of communications to the magnetic body. Also the temporal pattern of the sequence of quale mental images matters. In the case of hearing this would code for the rhythmic aspects and pitch of the sound.

12.4.4 About Detailed Identification Of The Qualia

One can make also guesses about detailed correspondence between qualia and quantum number increments.

1. Visual colors would correspond to the increments of only color quantum numbers. Each biologically important ion would correspond to its own color increment in one-one correspondence with the three pairs of color-charged gluons and these would correspond to blue-yellow, red-green, and black white [K88]. Black-white vision would mean a restriction to the $SU(2)$ subgroup of color group. The model for the cell membrane as a nearly vacuum extremal assigns the peak frequencies corresponding to fundamental colors with biologically important ions. Josephson radiation could induce artificially the same color qualia in other neurons and this might provide an manner to communicate the qualia to the brain where they could be re-experienced at neuronal level. Some organisms are able to perceive also the polarization of light. This requires receptors sensitive to polarization. The spin of quark pair would naturally code for polarization quale.

2. Also tastes and odours define qualia with "colors". Certainly the increments of electroweak numbers are involved but since these qualia do not have any directional flavor, spin is probably not involved. This would give c 3×4 basic combinations are possible and can certainly explain the 5 or 6 basic tastes (counted as the number of different receptors). Whether there is a finite number of odours or not has been a subject of a continual debate and it might be that odours already correspond to a distribution of primary qualia for the receptor cell. That odours are coded by nerve pulse patterns for a group of neurons [J14] would conform with this picture.

3. Hearing seems to represent a rather colorless quale so that electroweak isospin suggests again itself. If we had a need to hear transversely polarized sound also spin would be involved. Cilia are involved also with hair cells acting as sensory receptors in the auditory system and vestibular system. In the case of hearing the receptor itself does not fire but induces a firing of the higher level neuron. The temporal pattern of qualia mental images could define the pitch of the sound whereas the intensity would correspond to the number of flux tube connections generated.

   The modulation of Josephson frequencies -rather than Josephson frequencies as such- would code for the pitch and the total intensity of the Josephson radiation for the intensity of the sound and in fact any quale. Pitch represents non-local information and the qualia sub-selves should be negentropically entangled in time direction. If not, the experience corresponds to a sequence of sound pulses with no well-defined pitch and responsible for the rhythmic aspects of music. Right brain sings-left brain talks metaphor would suggests that right and left brain have different kind of specializations already at the level of sensory receptors.

4. Somato-sensory system gives rise to tactile qualia like pain, touch, temperature, proprioception (body position). There are several kinds of receptors: nocireceptors, mechanoreceptors, thermoreceptors, etc... Many of these qualia have also emotional coloring and it might be that the character of entanglement involved (negentropic/entropic defines the emotional color of the quale. If this is the case, one might consider a pure quale of touch as something analogous to hearing quale. One can argue that directionality is basic aspect of some of these qualia -say sense of touch- so that spin could be involved besides electroweak quantum numbers. The distribution of these qualia for the receptor neuron might distinguish between different tactile qualia.

12.4.5 Recent TGD based view about qualia

The TGD inspired theory of qualia [K47] has evolved gradually and the recent view differs from the above described picture in some aspects.

1. The original vision was that qualiaandother aspects of consciousness experience are determined by the change of quantum state in the reduction: the increments of quantum numbers would determine qualia. I had not yet realized that repeated state function reduction (Zeno effect) realized in ZEO is central for consciousness. The objection was that qualia change randomly from reduction to reduction.

2. Later I ended up with the vision that the rates for the changes of quantum numbers would determine qualia: this idea was realized in terms of sensory capacitor model in which qualia would correspond to kind of generalized di-electric breakdown feeding to subsystem responsible for quale quantum numbers characterizing the quale. The Occamistic objection is that the model brings in an additional element not present in quantum measurement theory.

3. The view that emerged while writing the critics of IIT of Tononi is that qualia correspond to the quantum numbers measured in the state function reduction. That in ZEO the qualia remain the same for the entire sequence of repeated state function reductions is not a problem since qualia are associated with sub-self (sub-CD), which can have lifetime of say about .1 seconds! Only the generalization of standard quantum measurement theory is needed to reduce the qualia to fundamental physics. This for instance supports the conjecture that visual colors correspond to QCD color quantum numbers. This makes sense in TGD framework predicting a scaled variants of QCD type physics even in cellular length scales.

   This view implies that the model of sensory receptor based on the generalization of di-electric breakdown [K65] is wrong as such since the rate for the transfer of the quantum numbers would not define the quale. A possible modification of the model simple: the analog of di-electric breakdown generates Bose-Einstein condensate and the quantum numbers for the BE condensate give rise to qualia assignable to sub-self.

12.5 Could Cell Membrane Correspond To Almost Vacuum Extremal?

The question whether cell membrane or even cell could correspond almost vacuum extremal of Kähler action (in some cases) was the question which led to the realization that the frequencies of peak sensitivity for photoreceptors correspond to the Josephson frequencies of biologically important ions if one accepts that the value of the Weinberg angle equals to $sin^2(\theta_W) = .0295$ instead of the value .23 in the normal phase, in which the classical electromagnetic field is proportional to the induced Kähler form of CP_2 in a good approximation. Another implication made possible by the large value of Planck constant is the identification of Josephson photons as the counterparts of bio-photons one one hand and those of EEG photons on the other hand. These observation in turn led to a detailed model of sensory qualia and of sensory receptor. Therefore the core of this argument deserves to be represented also here although it has been discussed in [K88].

12.5.1 Cell Membrane As Almost Vacuum Extremal

Although the fundamental role of vacuum extremals for quantum criticality and life has been obvious from the beginning, it took a long time to realize how one could model living cell as this kind of system.

1. Classical electric fields are in a fundamental role in biochemistry and living biosystems are typically electrets containing regions of spontaneous electric polarization. Fröhlich [I21] proposed that oriented electric dipoles form macroscopic quantum systems with polarization density serving as a macroscopic order parameter. Several theories of consciousness share this hypothesis. Experimentally this hypothesis has not been verified.
2. TGD suggests much more profound role for the unique di-electric properties of the biosystems. The presence of strong electric dipole fields is a necessary prerequisite for cognition and life and could even force the emergence of life. Strong electric fields imply also the presence of the charged wormhole BE condensates: the surface density of the charged wormholes on the boundary is essentially equal to the normal component of the electric field so that wormholes are in some sense "square root" of the dipole condensate of Fröhlich! Wormholes make also possible pure vacuum polarization type dipole fields: in this case the magnitudes of the em field at the two space-time sheets involved are same whereas the directions of the fields are opposite. The splitting of wormhole contacts creates fermion pairs which might be interpreted as cognitive fermion pairs. Also microtubules carry strong longitudinal electric fields. This formulation emerged much before the identification of ordinary gauge bosons and their superpartners as wormhole contacts.

Cell membrane is the basic example about electret and one of the basic mysteries of cell biology is the resting potential of the living cell. Living cell membranes carry huge electric fields: something like 10^7 Volts per meter. For neuron resting potential corresponds to about.07 eV energy gained when unit charge travels through the membrane potential. In TGD framework it is not at all clear whether the presence of strong electromagnetic field necessitates the presence of strong Kähler field. The extremely strong electric field associated with the cell membrane is not easily understood in Maxwell's theory and almost vacuum extremal property could change the situation completely in TGD framework.

1. The configuration could be a small deformation of vacuum extremal so that the system would be highly critical as one indeed expects on basis of the general visiona about living matter as a quantum critical system. For vacuum extremals classical em and Z^0 fields would be proportional to each other. The second half of Maxwell's equations is not in general satisfied in TGD Universe and one cannot exclude the presence of vacuum charge densities in which case elementary particles as the sources of the field would not be necessarily. If one assumes that this is the case approximately, the presence of Z^0 charges creating the classical Z^0 fields is implied. Neutrinos are the most candidates for the carrier of Z^0 charge. Also nuclei could feed their weak gauge fluxes to almost non-vacuum extremals but not atomic electrons since this would lead to dramatic deviations from atomic physics. This would mean that weak bosons would be light in this phase and also Weinberg angle could have a non-standard value.

2. There are also space-time surfaces for CP_2 projection belongs to homologically non-trivial geodesic sphere. In this case classical Z^0 field can vanish [L3], [L3] and the vision has been that it is sensible to speak about two basic configurations.
   (a) Almost vacuum extremals (homologically trivial geodesic sphere).
   (b) Small deformations of non-vacuum extremals for which the gauge field has pure gauge Z^0 component (homologically non-trivial geodesic sphere).

   The latter space-time surfaces are excellent candidates for configurations identifiable as TGD counterparts of standard electroweak physics. Note however that the charged part of electroweak fields is present for them.

3. To see whether the latter configurations are really possible one must understand how the gauge fields are affected in the color rotation.
   (a) The action of color rotations in the holonomy algebra of CP_2 is non-trivial and corresponds to the action in $U(2)$ sub-group of $SU(3)$ mapped to $SU(2)_L \times U(1)$. Since the induced color gauge field is proportional to Kähler form, the holonomy is necessary Abelian so that also the representation of color rotations as a sub-group of electro-weak group must correspond to a local $U(1)$ sub-group local with respect to CP_2 point.
   (b) Kähler form remains certainly invariant under color group and the right handed part of Z^0 field reducing to $U(1)_R$ sub-algebra should experience a mere Abelian gauge transformation. Also the left handed part of weak fields should experience a local $U(1)_L$ gauge rotation acting on the neutral left handed part of Z^0 in the same manner as it acts on the right handed part. This is true if the $U(1)_L$ sub-group does not depend on point of CP_2 and corresponds to Z^0 charge. If only Z^0 part of the induced gauge field is non-vanishing as it can be for vacuum extremals then color rotations cannot change the situation. If Z^0 part vanishes and non-vacuum extremal is in question, then color rotation rotation of W components mixing them but acts as a pure $U(1)$ gauge transformation on the left handed component.
   (c) It might not be without importance that for any partonic 2-surface induced electro-weak gauge fields have always U(1) holonomy, which could allow to define what neutral part of induced electroweak gauge field means locally. This does not however hold true for the 4-D tangent space distribution. In any case, the cautious conclusion is that there are two phases corresponding to nearly vacuum extremals and small deformations of extremals corresponding to homologically non-trivial geodesic spheres for which the neutral part of the classical electro-weak gauge field reduces to photon field.

4. The unavoidable presence of long range Z^0 fields would explain large parity breaking in living matter, and the fact that neutrino Compton length is of the order of cell size would suggest the possibility that within neutrino Compton electro-weak gauge fields or even longer scales could behave like massless fields. The explanation would be in terms of the different ground state characterized also by a different value of Weinberg angle. For instance, of the p-adic temperature of weak bosons corresponds to $T_p = 1/2$, the mass scale would be multiplied by a factor $\sqrt{M_{89}}$ and Compton lengths of weak bosons would be around 10^{-4} meters corresponding to the size scale of a large neuron. If the value of Planck constant is also large then the Compton length increases to astrophysical scale.

5. From the equations for classical induced gauge fields in terms of Kähler form and classical Z^0 field [L3] , [L3]

$$\gamma = 3J - \frac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = sin^2(\theta_W) \tag{12.5.1}$$

   it follows that for the vacuum extremals the part of the classical electro-weak force proportional to the electromagnetic charge vanishes for $p = 0$ so that only the left-handed couplings to the weak gauge bosons remain. The absence of electroweak symmetry breaking and vanishing or at least smallness of p would make sense below the Compton length of dark weak bosons. If this picture makes sense it has also implications for astrophysics and cosmology since small deformations of vacuum extremals are assumed to define the interesting extremals. Dark matter hierarchy might explain the presence of unavoidable long ranged Z^0 fields as being due to dark matter with arbitrarily large values of Planck constant so that various elementary particle Compton lengths are very long.

6. The simplest option is that the dark matter -say quarks with Compton lengths of order cell size and Planck constant of order $10^7\hbar_0$ - are responsible for dark weak fields making almost vacuum extremal property possible. The condition that Josephson photons correspond to EEG frequencies implys $\hbar \sim 10^{13}\hbar_0$ and would mean the scaling of intermediate gauge boson Compton length to that corresponding to the size scale of a larger neuron. The quarks involved with with DNA as topological quantum computer model could be in question and membrane potential might be assignable to the magnetic flux tubes. The ordinary ionic currents through cell membrane -having no coupling to classical Z^0 fields and not acting as its sourse- would be accompanied by compensating currents of dark fermions taking care that the almost vacuum extremal property is preserved. The outcome would be large parity breaking effects in cell scale from the left handed couplings of dark quarks and leptons to the classical Z^0 field. The flow of Na^+ ions during nerve pulse could take along same dark flux tube as the flow of dark quarks and leptons. This near vacuum extremal property might be fundamental property of living matter at dark space-time sheets at least.

Could nuclei and neutrinos couple to light variants of weak gauge fields in the critical phase?

One of the hard-to-kill ideas of quantum TGD inspired model of quantum biology is that neutrinos might have something do with hearing and cognition. This proposal looks however unrealistic in the recent vision. I would be more than happy to get rid of bio-neutrinos but the following intriguing finding does not allow me to have this luxury.

1. Assume that the endogenous magnetic field $B_{end} = .2$ Gauss is associated with a nearly vacuum extremal and therefore accompanied by $B_Z = 2B_{end}/p$. Assume for definiteness $m_\nu = .3$ eV and $p = sin^2(\theta_W) = .23$. The neutrino cyclotron frequency is given by the following expression

$$f_\nu = \frac{m_e}{m_\nu}\frac{1}{2sin^2(\theta_W)}f_e \ .$$

From $f_e \simeq .57\times$ MHz and $p = sin^2(\theta_W) = .23$ one obtains $E_\nu = 1.7\times 10^{-2}$ eV, which is roughly one third to the Josephson frequency of electron assignable to cell membrane. Could Josephson frequency of cell membrane excite neutrino cyclotron transitions?

2. The model for photoreceptors to be discussed below forces to conlude that the value of Weinberg angle in the phase near vacuum extremal must be $p = .0295$ if one wants to reproduces the peak energies of photoreceptors as Josephson frequencies of basic biological ions. This would predict $E_\nu = .41$ eV, which is rather near to the metabolic energy quantum. The non-relativistic formula however fails in this case and one must use the relativistic formula giving

$$E = \sqrt{g_Z Q_Z B_Z 2\pi} \simeq .48 \ eV$$

giving the metabolic energy quantum. Does this mean that Z^0 cyclotron frequency for neutrino is related to the transfer of metabolic energy using Z^0 MEs in the phase near vacuum extremals.

3. Josephson frequency is proportional to $1/\hbar$, whereas neutrino cyclotron frequency does not depend on $\hbar$ at non-relativistic energies. For larger values of $\hbar$ the neutrino becomes relativistic so that the mass in the formula for cyclotron frequency must be replaced with energy. This gives

$$E = \sqrt{n}r^{1/2}\sqrt{g_Z Q_Z B_Z 2\pi} \simeq r^{1/2}\times .48 \ eV \ \ , \ \ r = \sqrt{\hbar/\hbar_0} \ .$$

Here n refers to the cyclotron harmonic.

These observations raise the question whether the three frequencies with maximum response assignable to the three different types of receptors of visible light in retina could correspond to the three cyclotron frequencies assignable to the three neutrinos with different mass scales? The first objection is that the dependence on mass disappears completely at the relativistic limit. The second objection is that the required value value of Planck constant is rather small and far from being enough to have electroweak boson Compton length of order cell size. One can of course ask whether the electroweak gauge bosons are actually massless inside almost vacuum extremals. If fermions -including neutrino- receive their masses from p-adic thermodynamics then massless electroweak gauge bosons would be consistent with massive fermions. Vacuum extremals are indeed analogous to the unstable extrema of Higgs potential at which the Higgs vacuum expecation vanishes so that this interpretation might make sense.

Ionic Josephson frequencies defined by the resting potential for nearly vacuum extremals

If cell membrane corresponds to an almost vacuum extremal, the membrane potential potential is replaced with an effective resting potential containing also the Z^0 contribution proportional to the ordinary resting potential. The surprising outcome is that one could understand the preferred frequencies for photo-receptors [J3] as Josephson frequencies for biologically important ions. Furthermore, most Josephson energies are in visible and UV range and the interpretation in terms of bio-photons is suggestive. If the value of Planck constant is large enough Josephson frequencies are in EEG frequency range so that bio-photons and EEG photons could be both related to Josephson photons with large $\hbar$.

1. One must assume that the interior of the cell corresponds to many fermion state -either a state filled with neutrinos up to Fermi energy or Bose-Einstein condensate of neutrino Cooper pairs creating a harmonic oscillator potential. The generalization of nuclear harmonic oscillator model so that it applies to multi-neutrino state looks natural.
2. For exact vacuum extremals elementary fermions couple only via left-handed isospin to the classical Z^0 field whereas the coupling to classical em field vanishes. Both K_+, Na_+, and Cl_- $A-Z=Z+1$ so that by p-n pairing inside nucleus they have the weak isospin of neuron (opposite to that of neutrino) whereas Ca_{++} nucleus has a vanishing weak isospin. This might relate to the very special role of Ca_{++} ions in biology. For instance, Ca_{++} defines an action potential lasting a time of order.1 seconds whereas Na_+ defines a pulse lasting for about 1 millisecond [J1]. These time scales might relate to the time scales of CDs associated with quarks and electron.
3. The basic question is whether only nuclei couple to the classical Z^0 field or whether also electrons do so. If not, then nuclei have a large effective vector coupling to em field coming from Z^0 coupling proportional to the nuclear charge increasing the value of effective membrane potential by a factor of order 100. If both electrons and nuclei couple to the classical Z^0 field, one ends up with difficulties with atomic physics. If only quarks couple to the Z^0 field and one has $Z^0=-2\gamma/p$ for vacuum extremals, and one uses average vectorial coupling $\langle I_L^3\rangle=\pm 1/4$ with + for proton and - for neutron, the resulting vector coupling is following

$$\begin{aligned} (\frac{Z-N}{4}-pZ)Z^0+q_{em}\gamma &= Q_{eff}\gamma \ , \\ Q_{eff} &= -\frac{Z-N}{2p}+2Z+q_{em} \ . \end{aligned} \tag{12.5.2}$$

Here γ denotes em gauge potential. For K^+, Cl^-, Na^+, Ca^{++} one has $Z=(19,17,11,20)$, $Z-N=(-1,-1,-1,0)$, and $q_{em}=(1,-1,1,2)$. **Table 12.1** below gives the values of Josephson energies for some values of resting potential for $p=.23$. Rather remarkably, they are in IR or visible range. This is basically due to the large value of weak isospin for nuclei.

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12.5.2 Are Photoreceptors Nearly Vacuum Extremals?

In Hodgkin-Huxley model ionic currents are Ohmian currents. If one accepts the idea that the cell membrane acts as a Josephson junction, there are also non-dissipative oscillatory Josephson

$E(Ion)/eV$	$V = -40\ mV$	$V = -60\ mV$	$V = -70\ mV$
Na^+	1.01	1.51	1.76
Cl^-	1.40	2.11	2.46
K^+	1.64	2.47	2.88
Ca^{++}	1.68	2.52	2.94

Table 12.1: Values of the Josephson energy of cell membrane for some values of the membrane voltage for $p = .23$. The value $V = -40$ mV corresponds to the resting potential for photoreceptors and $V = -70$ mV to the resting state of a typical neuron.

currents of ions present, which run also during flow equilibrium for the ionic parts of the currents. A more radical possibility is that the dominating parts of the ionic currents are oscillatory Josephson currents so that no metabolic energy would be needed to take care that density gradients for ions are preserved. Also in this case both nearly vacuum extremals and extremals with nearly vanishing Z^0 field can be considered. Since sensory receptors must be highly critical the natural question is whether they could correspond to nearly vacuum extremals. The quantitative success of the following model for photoreceptors supports this idea.

Photoreceptors can be classified to three kinds of cones responsible for color vision and rods responsible for black-white vision. The peak sensitivities of cones correspond to wavelengths (405, 535, 565) nm and energies (3.06, 2.32, 2.19) eV. The maximum absorption occurs in the wave length range 420-440 nm, 534-545 nm, 564-580 nm for cones responsible for color vision and 498 nm for rods responsible black-white vision [L73, J3]. The corresponding photon energies are (2.95, 2.32, 2.20) eV for color vision and to 2.49 eV for black-white vision. For frequency distribution the maxima are shifted from these since the maximum condition becomes $dI/d\lambda + 2I/\lambda = 0$, which means a shift to a larger value of λ, which is largest for smallest λ. Hence the energies for maximum absorbance are actually lower and the downwards shift is largest for the highest energy.

From **Table 12.1** it is clear that the energies of Josephson photons are in visible range for reasonable values of membrane voltages, which raises the question whether Josephson currents of nuclei in the classical em and Z^0 fields of the cell membrane could relate to vision.

Consider first the construction of the model.

1. Na$^+$ and Ca^{++} currents are known to present during the activation of the photoreceptors. Na^+ current defines the so called dark current [J3] reducing the membrane resting potential below its normal value and might relate to the sensation of darkness as eyes are closed. Hodgkin-Huxley model predicts that also K^+ current is present. Therefore the Josephson energies of these three ion currents are the most plausible correlates for the three colors.
2. One ends up with the model in the following manner. For Ca^{++} the Josephson frequency does not depend on p and requiring that this energy corresponds to the energy 2.32 eV of maximal sensitivity for cones sensitive to green light fixes the value of the membrane potential during hyper-polarization to $V = .055$ V, which is quite reasonable value. The value of the Weinberg angle parameter can be fixed from the condition that other peak energies are reproduced optimally. The result of $p = .0295$.

The predictions of the model come as follows summarized also by the **Table 12.2**.

1. The resting potential for photoreceptors is $V = -40$ mV [J4]. In this case all Josephson energies are below the range of visible frequencies for $p = .23$. Also for maximal hyper-polarization Na^+ Josephson energy is below the visible range for this value of Weinberg angle.
2. For $V = -40$ mV and $p = .0295$ required by the model the energies of Cl^- and K^+ Josephson photons correspond to red light. 2 eV for Cl^- corresponds to a basic metabolic quantum. For Na^+ and Ca^{++} the wave length is below the visible range. Na^+ Josephson energy is below visible range. This conforms with the interpretation of Na^+ current as a counterpart for the sensation of darkness.
3. For $V = -55$ mV - the threshold for the nerve pulse generation- and for $p = .0295$ the Josephson energies of Na^+, Ca^{++}, and K^+ a correspond to the peak energies for cones

Ion	Na^+	Cl^-	K^+	Ca^{++}
$E_J(.04\ \ mV, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065\ \ V, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40\ \ mV, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50\ \ mV, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55\ \ mV, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65\ \ mV, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70\ \ mV, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75\ \ mV, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80\ \ mV, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90\ \ mV, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95\ \ mV, p = .0295)/eV$	3.80	4.75	5.32	3.99
Color	R	G	B	W
E_{max}	2.19	2.32	3.06	2.49
energy-interval/eV	1.77-2.48	1.97-2.76	2.48-3.10	

Table 12.2: Table gives the prediction of the model of photoreceptor for the Josephson energies for typical values of the membrane potential. For comparison purposes the energies E_{max} corresponding to peak sensitivities of rods and cones, and absorption ranges for rods are also given. R, G, B, W refers to red, green, blue, white. The values of Weinberg angle parameter $p = sin^2(\theta_W)$ are assumed to be .23 and.0295. The latter value is forced by the fit of Josephson energies to the known peak energies if one allows that ions - rather than their Cooper pairs - are charge carriers.

sensitive to red, green, and blue respectively. Also Cl^- is in the blue region. Ca^{++} Josephson energy can be identified as the peak energy for rods. The increase of the hyper-polarization to $V = -59$ mV reproduces the energy of the maximal wave length response exactly. A possible interpretation is that around the criticality for the generation of the action potential ($V \simeq -55$ mV) the qualia would be generated most intensely since the Josephson currents would be strongest and induce Josephson radiation inducing the quale in other neurons of the visual pathway at the verge for the generation of action potential. This supports the earlier idea that visual pathways defines a neural window. Josephson radiation could be interpreted as giving rise to bio-photons (energy scale is correct) and to EEG photons (for large enough values of $\hbar$ the frequency scales is that of EEG).

4. In a very bright illumination the hyper-polarization is $V = -65$ mV [J4], which the normal value of resting potential. For this voltage Josephson energies are predicted to be in UV region except in case of Ca^{++}. This would suggests that only the quale "white" is generated at the level of sensory receptor: very intense light is indeed experienced as white.

The model reproduces basic facts about vision assuming that one accepts the small value of Weinberg angle, which is indeed a natural assumption since vacuum extremals are analogous to the unstable extrema of Higgs potential and should correspond to small Weinberg angle. It deserves to be noticed that neutrino Josephson energy is 2 eV for $V = -50$ mV, which correspond to color red. 2 eV energy defines an important metabolic quantum.

It interesting to try to interpret the resting potentials of various cells in this framework in terms of the Josephson frequencies of various ions.

1. The maximum value of the action potential is +40 mV so that Josephson frequencies are same as for the resting state of photoreceptor. Note that the time scale for nerve pulse is so slow as compared to the frequency of visible photons that one can consider that the neuronal membrane is in a state analogous to that of a photoreceptor.
2. For neurons the value of the resting potential is -70 mV. Na^+ and Ca^{++} Josephson energies 2.80 eV and 2.94 eV are in the visible range in this case and correspond to blue light. This does not mean that Ca^{++} Josephson currents are present and generate sensation of blue at

neuronal level: the quale possibly generated should depend on sensory pathway. During the hyper-polarization period with -75 mV the situation is not considerably different.

3. The value of the resting potential is -95 mV for skeletal muscle cells. In this case Ca^{++} Josephson frequency corresponds to 4 eV metabolic energy quantum as **Table 12.1** shows.
4. For smooth muscle cells the value of resting potential is -50 mV. In this case Na^+ Josephson frequency corresponds to 2 eV metabolic energy quantum.
5. For astroglia the value of the resting potential is -80/-90 mV for astroglia. For -80 mV the resting potential for Cl^- corresponds to 4 eV metabolic energy quantum. This suggests that glial cells could also provide metabolic energy as Josephson radiation to neurons.
6. For all other neurons except photo-receptors and red blood cells Josephson photons are in visible and UV range and the natural interpretation would be as bio-photons. The bio-photons detected outside body could represent sensory leakage. An interesting question is whether the IR Josephson frequencies could make possible some kind of IR vision.

To sum up, the basic criticism against the model is that the value of Weinberg angle must be by a factor of 1/10 smaller than the standard model value, and at this moment it is difficult to say anything about its value for nearly vacuum extremals.

A possible cure could be that the voltage is not same for different ions. This is possible since at microscopic level the Josephson junctions correspond to transmembrane proteins acting as channels and pumps. The membrane potential through receptor protein is different for color receptors. For this option one would have the correspondences
$Na^+ \leftrightarrow$ 2.19 eV (R) and $eV = 86.8$ eV,
$Cl^- \leftrightarrow$ 2.32 eV (G) and $eV = 65.8$ eV,
$K^+ \leftrightarrow$ 2.49 eV (W) and $eV = 60.2$ eV,
$Ca^{++} \leftrightarrow$ 3.06 eV (B) and $eV = 67.3$ meV.
For Na^+ the value of the membrane potential is suspiciously large.

It is interesting to look what happens when the model is generalized so that Josephson energy includes the difference of cyclotron energies at the two sides of the cell membrane and Weinberg angle has its standard model value.

1. Consider first *near to vacuum extremals*. In the formula for cyclotron frequencies in the effective magnetic field the factor Z/A in the formula of is replaced with

$$\frac{\frac{N-Z}{2p} + 2Z + q_{em}}{A} ,$$

   which is not far from unity so that the cyclotron frequency would be near to that for proton for all ions. Also neutral atoms would experience classical and magnetic Z^0 fields. Cyclotron frequency would be almost particle independent so that cyclotron contribution gives an almost constant shift to the generalized Josephson energy. When the difference of cyclotron energies vanishes, the model reduces to that discussed above.

   The weak independence of the cyclotron frequency on particle properties does not conform with the idea that EEG bands correspond to bosonic ions or Cooper pairs of fermionic ions.

2. For *far from vacuum extremals* the proportionality of cyclotron energy to h_{eff} and B_{end} allows easy reproduction the energies for which photon absorption is maximal if one allows the cyclotron energies to differ at the two sides of the membrane for sensory receptors.

A remark about decade later: The model just discussed neglects the fact that superconductivity requires that Cooper pairs of fermionic ions are present unless one assumes that the nuclei are bosonic counterparts of fermionic nuclei with same chemical properties - TGD inspired nuclear physics indeed predicts this kind of exotic nuclei [L4]. For Cooper pairs of Na^+, Cl^-, and K^+, $p = .23$ and $E_J = .04$ eV assignable to visual receptors the Josephson energies are doubled being $2.02, 2.80, 3.02$ eV. These energies could correspond to peak energies for visible photons. The assumption of ionic Cooper pairs is rather attractive since it would allow to avoid two questionable assumptions.

For electron the Josephson energy would be scaled by a factor $-1 + 1/2p$ to $E_J = 1.0859 \times eV_{rest}$ for $p = .2397$. For neutrino the energy would be given by $E_J = -0.0859 \times V_{rest}$: for $p = 1/4$

it would vanish by the vanishing of vectorial part of Z^0 charge. For proton the energy would be $E_J = (3 - 1/2p)V_{rest} = .914 \times V_{rest}$ and for neutron $E_J = V_{rest}/2p = 2.086 \times V_{rest}$.

12.6 Pollack's Findings About Fourth Phase Of Water And The Model Of Cell

The discovery of negatively charged exclusion zone formed in water bounded by gel phase has led Pollack to propose the notion of gel like fourth phase of water. In this article this notion is discussed in TGD framework. The proposal is that the fourth phase corresponds to negatively charged regions - exclusion zones - with size up to 100-200 microns generated when energy is fed into the water - say as radiation, in particular solar radiation. The stoichiometry of the exclusion zone is $H_{1.5}O$ and can be understood if every fourth proton is dark proton residing at the flux tubes of the magnetic body assignable to the exclusion zone and outside it.

This leads to a model for prebiotic cell as exclusion zone. Dark protons are proposed to form dark nuclei whose states can be grouped to groups corresponding to DNA, RNA, amino-acids, and tRNA and for which vertebrate genetic code is realized in a natural manner. The voltage associated with the system defines the analog of membrane potential, and serves as a source of metabolic energy as in the case of ordinary metabolism. The energy is liberated in a reverse phase transition in which dark protons transform to ordinary ones. Dark proton strings serve as analogs of basic biopolymers and one can imagine analog of bio-catalysis with enzymes replaced with their dark analogs. The recent discovery that metabolic cycles emerge spontaneously in absence of cell support this view.

One can find a biographical sketch [I2] (`http://tinyurl.com/ycqtuchp`) giving a list of publications containing items related to the notions of exclusion zone and fourth phase of water discussed in the talk.

12.6.1 Pollack's Findings

I list below some basic experimental findings about fourth gel like phase of water made in the laboratory led by Gerald Pollack [L24].

1. In water bounded by a gel a layer of thickness up to 100-200 microns is formed. All impurities in this layer are taken outside the layer. This motivates the term "exclusion zone". The layer consists of layers of molecular thickness and in these layers the stoichiometry is $\mathrm{H}_{1.5}\mathrm{O}$. The layer is negatively charged. The outside region carries compensating positive charge. This kind of blobs are formed in living matter. Also in the splitting of water producing Brown's gas negatively charged regions are reported to emerge [H19, H1].
2. The process requires energy and irradiation by visible light or thermal radiation generates the layer. Even the radiation on skin can induce the phase transition. For instance, the blood flow in narrow surface veins requires metabolic energy and irradiation forces the blood to flow.
3. The layer can serve as a battery: Pollack talks about a form of free energy deriving basically from solar radiation. The particles in the layer are taken to the outside region, and this makes possible disinfection and separation of salt from sea water. One can even understand how clouds are formed and mysteries related to the surface tension of water as being due the presence of the layer formed by $H_{1.5}O$.
4. In the splitting of water producing Brown's gas [H19, H1] having a natural identification as Pollack's fourth phase of water the needed energy can come from several alternative sources: cavitation, electric field, etc...

12.6.2 Dark Nuclei And Pollack's Findings

While listening the lecture of Pollack I realized that a model for dark water in term of dark proton sequences is enough to explain the properties of the exotic water according to experiments done in the laboratory of Pollack. There is no need to assume sequences of half-dark water molecules containing one dark proton each.

Model for the formation of exclusion zones

The data about formation of exclusion zones allows to construct a more detailed model for what might happen in the formation of exclusion zones.

1. The dark proton sequences with dark proton having size of order atomic nucleus would reside at the flux tubes of dark magnetic field which is dipole like field in the first approximation and defines the magnetic body of the negatively charged water blob. This explains the charge separation if the flux tubes have length considerably longer than the size scale of the blob which is given by size of small cell. In the model inspired by Moray B. King's lectures charge separation is poorly understood.
2. An interesting question is whether the magnetic body is created by the electronic currents or whether it consists of flux tubes carrying monopole flux: in the latter case no currents would be needed. This is obviously purely TGD based possibility and due to the topology of CP_2.
3. This means that in the model inspired by the lectures of Moray B. King discussed above, one just replaces the sequences of partially dark water molecules with sequences of dark protons at the magnetic body of the $H1.5O$ blob. The model for the proto-variants of photosynthesis and metabolism remain as such. Also now genetic code would be realized [K51, L4].
4. The transfer of impurities from the exclusion zone could be interpreted as a transfer of them to the magnetic flux tubes outside the exclusion zone as dark matter.

These primitive forms of photosynthesis and metabolism form could be key parts of their higher level chemical variants. Photosynthesis by irradiation would induce a phase transition generating dark magnetic flux tubes (or transforming ordinary flux tubes to dark ones) and the dark proton sequences at them. Metabolism would mean burning of the resulting blobs of dark water to ordinary water leading to the loss of charge separation. This process would be analogous to the catabolism of organic polymers liberating energy. Also organic polymers in living matter carry their metabolic energy as dark proton sequences: the layer could also prevent their hydration. That these molecules are typically negatively charged would conform with the idea that dark protons at magnetic flux tubes carry the metabolic energy.

The liberation of energy would involve increase of the p-adic prime characterizing the flux tubes and reduction of Planck constant so that the thickness of the flux tubes remains the same but the intensity of the magnetic field is reduced. The cyclotron energy of dark protons is liberated in coherent fashion and in good approximation the frequencies of the radiation corresponds to multiplies of cyclotron frequency: this prediction is consistent with that in the original model for the findings of Blackman and others [J7].

The phase transition generating dark magnetic flux tubes containing dark proton sequences would be the fundamental step transforming inanimate matter to living matter and the fundamental purpose of metabolism would be to make this possible.

Minimal metabolic energy consumption and the value of membrane potential

This picture raises a question relating to the possible problems with physiological temperature.

1. The Josephson radiation generated by cell membrane has photon energies coming as multiples of ZeV, where V is membrane potential about.06 V and $Z = 2$ is the charge of electron Cooper pair. This gives $E = .12$ eV.
2. There is a danger that thermal radiation masks Josephson radiation. The energy for photons at the maximum of the energy density of blackbody radiation as function of frequency is given as the maximum of function $x^3/(e^x - 1)$, $x = E/T$ given by $e^{-x} + x/3 - 1 = 0$. The maximum is given approximately by $x = 3$ and thus $E_{max} \simeq 3T$ (in units $c = 1, k_B = 1$). At physiological temperature $T = 310$ K (37 C) this gives .1 eV, which is slightly below Josephson energy: living matter seems to have minimized the value of Josephson energy - presumably to minimize metabolic costs. Note however that for the thermal energy density as function of *wavelength* the maximum is at $E \simeq 5T$ corresponding to 1.55 eV which is larger than Josephson energy. The situation is clearly critical.
3. One can ask whether also a local reduction of temperature around cell membrane in the fourth phase of water is needed.

"Electric expansion" of water giving rise to charge separation and presumably creating fourth phase of water is reported to occur [H19, H1].

(b) Could the electric expansion/phase transition to dark phase be adiabatic involving therefore no heat transfer between the expanding water and environment? If so, it would transform some thermal energy of expanding water to work and reduce its temperature. The formula for the adiabatic expansion of ideal gas with f degrees of freedom for particle ($f = 3$ if there are no other than translational degrees of freedom) is $(T/T_0) = (V/V_0)^{-\gamma}$, $\gamma = (f + 2)/f$. This gives some idea about how large reduction of temperature might be involved. If p-adic scaling for water volume by a power of two takes place, the reduction of temperature can be quite large and it does not look realistic.

(c) The electric expansion of water need not however involve the increase of Planck constant for water volume. Only the Planck constant for flux tubes must increase and would allow the formation of dark proton sequences and the generation of cyclotron Bose-Einstein condensates or their dark analog in which fermions (electrons in particular) effectively behave as bosons (the anti-symmetrization of wave function would occur in dark degrees of freedom corresponding to multi-sheeted covering formed in the process).

12.6.3 Fourth Phase Of Water And Pre-Biotic Life In TGD Universe

Metabolism and fourth phase of water

If the fourth phase of water defines pre-biotic life form then the phase transition generating fourth phase of water and its reversal are expected to be fundamental elements of the ordinary metabolism, which would have developed from the pre-biotic metabolism. The following arguments conforms with this expectation.

1. Cell interiors, in particular the interior of the inner mitochondrial membrane are negatively charged as the regions formed in Pollack's experiments. Furthermore, the citric acid cycle, (`http://tinyurl.com/y8ubjgnc`), which forms the basic element of both photosynthesis (`http://tinyurl.com/yauwzkho`) and cellular respiration `http://tinyurl.com/ybeefxmb`, involves electron transport chain (`http://tinyurl.com/yat3m4vk`) in which electron loses gradually its energy via production of NADP and proton at given step. Protons are pumped to the other side of the membrane and generates proton gradient serving as metabolic energy storage just like battery. The interpretation for the electron transport chain in terms of Pollack's experiment would be in terms of generation of dark protons at the other side of the membrane.
2. When ATP is generated from ADP three protons per ATP flow back along the channel formed by the ATP synthase molecule (`http://tinyurl.com/yd5ndcyk`) (perhaps Josephson junction) and rotate the shaft of a "motor" acting as a catalyst generating three ATP molecules per turn by phosphorylating ADP. The TGD based interpretation is that dark protons are transformed back to ordinary ones and possible negentropic entanglement is lost.
3. ATP is generated also in glycolysis (`http://tinyurl.com/ybzgdgve`), which is ten-step process occurring in cytosol so that membrane like structure need not be involved. Glycolysis involves also generation of two NADH molecules and protons. An open question (to me) is whether the protons are transferred through an endoplasmic reticulum or from a region of ordered water (fourth phase of water) to its exterior so that it would contribute to potential gradient and could go to magnetic flux tubes as dark proton. This would be natural since glycolysis is realized for nearly all organisms and electron transport chain is preceded by glycolysis and uses as input the output of glycolysis (two pyruvate molecules (`http://tinyurl.com/y8v7aq9s`)).
4. Biopolymers - including DNA and ATP - are typically negatively charged. They could thus be surrounded by fourth phase of water and neutralizing protons would reside at the magnetic bodies. This kind of picture would conform with the idea that the fourth phase (as also magnetic body) is fractal like. In phosphorylation the metabolic energy stored to a potential difference is transferred to shorter length scales (from cell membrane scale to molecular scale).

In glycolysis (`http://tinyurl.com/ybzgdgve`) the net reaction $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2(g)+ 6H_2O(l)+heat$ takes place. The Gibbs free energy change is $\Delta G = -2880$ kJ per mole of $C_6H_{12}O_6$

and is negative so that the process takes place spontaneously. Single glucose molecule is theoretized to produce $N = 38$ ATP molecules in optimal situation but there are various energy losses involved and the actual value is estimated to be 29-30. From $Joule = 6.84 \times 10^{18}$ eV and $mol = 6.02 \times 10^{23}$ and for $N = 38$ one would obtain the energy yield.86 eV per single ATP. The nominal value that I have used.5 eV. This is roughly 5 to 8 times higher than $E = ZeV, Z = 2$, which varies in the range.1-.16 eV so that the metabolic energy gain cannot be solely due to the electrostatic energy which would actually give only a small contribution.

In the thermodynamical approach to metabolism the additional contribution would be due to the difference of the chemical potential μ for cell exterior and interior, which is added to the membrane potential as effective potential energy. The discrepancy is however rather large and this forces the question the feasibility of the model. This forces to reconsider the model of osmosis in the light of Pollack's findings.

Pollack's findings in relation to osmosis and model for cell membrane and EEG

Osmosis (`http://tinyurl.com/yc5dbtzv`) has remained to me poorly understood phenomenon. Osmosis means that solvent molecules move through a semipermeable membrane to another side of the membrane if the concentration of solute is higher at that side. Solute can be water or more general liquid, supercritical liquid, and even gas.

Osmosis is not diffusion: it can occur also towards a higher concentration of water. Water molecules are not attracted by solute molecules. A force is required and the Wikipedia explanation is that solute molecules approaching pores from outside experience repulsion and gain momentum which is transferred to the water molecules.

The findings of Pollack inspire the question whether the formation of exclusion zone could relate to osmosis and be understood in terms of the fourth phase of water using genuine quantal description.

In the thermodynamical model for ionic concentrations one adds to the membrane resting potential a contribution from the difference of chemical potentials μ_i at the two sides of the membrane. Chemical potentials for the ions parametrize the properties of the cell membrane reducing basically to the properties of the channels and pumps (free diffusion and membrane potential do not entirely determine the outcome).

If the transfer of ions - now protons - through cell membrane is quantal process and through Josephson junctions defined by transmembrane proteins, then the thermodynamical model can at best be a phenomenological parameterization of the situation. One should find the quantum counterpart of thermodynamical description, and here the identification of quantum TGD as square root of thermodynamics in Zero Energy Ontology (ZEO) suggests itself. In this approach thermodynamical distributions are replaced by probability amplitudes at single particle level such that their moduli squared give Boltzmann weights.

1. Simplest Josephson junction model for cell membrane

The first guess is that quantum description is achieved by a generalization of the Josephson junction model allowing different values of Planck constant at magnetic flux tubes carrying dark matter.

1. Josephson junctions correspond microscopically to transmembrane proteins defining channels and pumps. In rougher description entire cell membrane is described as Josephson junction.
2. The magnetic field strength at flux tube can differ at the opposite side of the membrane and even the values of h_{eff} could in principle be different. The earlier modelling attempts suggest that $h_{eff}/h = n = 2^k A$, where A is the atomic weight of ion, is a starting assumption deserving testing. This would mean that each ion resides at its own flux tubes.

   The phase transitions changing the value of h_{eff} could induce ionic flows through cell membrane, say that occurring during nerve pulse since the energy difference defining the ratio of square roots of Boltzmann weights at the two sides of the membrane would change. Also the change of the local value of the magnetic field could do the same.

Consider first the simplest model taking into account only membrane potential.

1. The simplest model for Josephson junction defined by the transmembrane protein is as a two state system (Ψ_1, Ψ_2) obeying Schrödinger equation.

$$i\hbar_1 \frac{\partial \Psi_1}{\partial t} = ZeV\Psi_1 + k_1\Psi_2 \ ,$$

$$i\hbar_2 \frac{\partial \Psi_2}{\partial t} = k_2\Psi_2 \ .$$

   One can use the decomposition $\Psi_i = R_i exp(i\Phi(t)$ to express the equations in a more concrete form. The basic condition is that the total probability defined as sum of moduli squared equals to one: $R_1^2 + R_2^2 = 1$. This is guaranteed if the hermiticity condition $k_1/\hbar_1 = \overline{k_2}\hbar_2$ holds true. Equations reduce to those for an ordinary Josephson junction except that the frequency for the oscillating Josephson current is scaled down by $1/h_{eff}$.

2. One can solve for R_2 assuming $\Phi_1 = eVt/\hbar_{eff}$. This gives

$$R_2(t) = sin(\Phi_0) + \frac{k_1}{\hbar_1} sin(\frac{eVt}{\hbar_1}) \ .$$

   R_2 oscillates around $sin(\Phi_0)$ and the concentration difference is coded by $\Phi 0$ taking the role of chemical potential as a phenomenological parameter.

3. The counterparts of Boltzmann weights would be apart from a phase factor square roots of ordinary Boltzmann weights defined by the exponent of Coulomb energy:

$$R = sin(\phi_0) = exp(\frac{ZeV(t)}{2T}) \ .$$

   Temperature would appear as a parameter in single particle wave function and the interpretation would be that thermodynamical distribution is replaced by its square root in quantum theory. In ZEO density matrix is replaced by its hermitian square root multiplied by density matrix.

2. The counterpart of chemical potential in TGD description

This model is not as such physically realistic since the counterpart of chemical potential is lacking. The most straightforward generalization of the thermodynamical model is obtained by the addition of an ion dependent chemical potential term to the membrane potential: $ZeV \rightarrow ZeV + \mu_I$. This would however require a concrete physical interpretation.

1. The most obvious possibility is that also the chemical potential actually correspond to an interaction energy - most naturally the cyclotron energy $E_c = \hbar_{eff} ZeB_{end}/m$ of ion - in this case proton - at the magnetic flux tube. Cyclotron energy is proportional to h_{eff} and can be rather large as assumed in the model for the effects of ELF em fields on brain.

2. This model would predict the dependence of the effective chemical potential on the mass and charge of ion for a fixed value of on h_{eff} and B_{end}. The scales of ionic chemical potential and ion concentrations would also depend on value of h_{eff}.

3. The model would provide a different interpretation for the energy scale of bio-photons, which is in visible range rather than infrared as suggested by the value of membrane potential.

   The earlier proposal [K47] was that cell membrane can be in near vacuum extremal configuration in which classical Z^0 field contributes to the membrane potential and gives a large contribution for ions. The problematic aspect of the model was the necessity to assume Weinberg angle in this phase to have much smaller value than usually. This difficulty could be perhaps avoided by noticing that the membrane potentials can differ for color receptors so that the earlier assignment of specific ions to color receptors could make sense for ordinary value of Weingerg angle. Second problem is that for proton the Z^0 contribution is negligible in good approximation so that this model does not explain the high value of the metabolic energy currency.

4. The simplest model the communications to magnetic body rely on Josephson radiation whose fundamental frequency f_J is at resonance identical with the cyclotron frequency $f_c(MB)$ at particular part of the flux tube of the magnetic body: $(f_c(MB) = f_J$. $f_c(MB)$ corresponds

to EEG frequency in the case of brain and biophotons are produced from dark EEG photons as ordinary photons in phase transition reducing $h_{eff} = n \times h$ to h.

In the modified model the sum $f_c + f_{J,n}$ ($f_{J,n} = E_J/n \times h$) of h_{eff}-independent cyclotron frequency and Josephson frequency proportional to $1/h_{eff}$ equals to cyclotron frequency $f_c(MB)$ at "personal" magnetic body varying slowly along the flux tube: $f_c + f_{J,n} = f_c(MB)$. If also the variation of f_J assignable to the action potential is included, the total variation of membrane potential gives rise to a frequency band with width roughly

$$\frac{\Delta f}{f} \simeq \frac{2f_{J,n}}{f_c + f_{J,n}} = \frac{2f_{J,1}}{nf_c + f_{J,1}} \quad .$$

If dark photons correspond to biophotons the energy is of cyclotron photon is in visible and UV range one has $nf_c = E_{bio}$ and

$$\frac{\Delta f}{f} \simeq \frac{2ZeV}{E_{bio} + ZeV} \quad .$$

The prediction is scale invariant and same for all ions and also electron unless E_{bio} depends on ion. For $eV = .05$ eV, $Z = 1$, and $E_{bio} = 2$ eV ($f \simeq 5 \times 10^{14}$ Hz) one has $\Delta f/f \sim .1$ giving 10 per cent width for EEG bands assumed in the simpler model.

If this vision is on the correct track, the fundamental description of osmosis would be in terms of a phase transition to the fourth phase of water involving generation of dark matter transferred to the magnetic flux tubes. For instance, the swelling of cell by an in-flow of water in presence of higher concentration inside cell could be interpreted as a phase transition extending exclusion zone as a process accompanied by a phase transition increasing the value of h_{eff} so that the lengths of the flux tube portions inside the cell increase and the size of the exclusion zone increases. In general case the phase transitions changing h_{eff} and B_{end} by power of two factor are possible. This description should bring magnetic body as part of bio-chemistry and allow understanding of both equilibriumion distributions, generation of nerve pulse, and basic metabolic processes leading to the generation of ATP.

One can also model sensory receptors and try to understand the maximal sensitivity of color receptors to specific wavelengths in this framework. The new degrees of freedom make this task easy if one is only interested in reproducing these frequencies. More difficult challenge is to understand the color receptors from the first principles. It is also possible to combine the new view with the assumption that sensory receptor cells are near to vacuum extremals. This would add a cyclotron contribution to the generalized Josephson frequency depending only weakly on particle and being non-vanishing also for em neutral particles.

Why would charge separation generate large h_{eff}?

The basic question is whether and how the separation of electron and proton charges generates large h_{eff}? A possible mechanism emerged from a model [K104] explaining anomalously large gravimagnetic effect claimed by Tajmar *et al* [E30, E45] to explain the well-established anomaly related to the mass of Cooper pairs in rotating super-conduction. The mass is too large by fraction of order 10^{-4} and the proposal is that gravimagnetism changes slightly the effective Thomson magnetic field associated with the rotating super-conductor leading to wrong value of Cooper pairs mass when only ordinary Thomson field is assumed to be present. The needed gravimagnetic field is however gigantic: 28 orders larger than that predicted by GRT. Gravimagnetic field is proportional h_{eff}^2 in TGD and if one uses h_{gr} for electron-Earth system one obtains correct order of magnitude.

Nottale's finding that planetary orbits seem to correspond to Bohr orbits in gravitational potential with gigantic value of gravitational Planck constant is the basic input leading to the model of gravimagnetic anomaly.

1. By Equivalence Principle h_{gr} has the general form $h_{gr} = GMm/v_0$, where M and m are the interacting masses and v_0 is a parameter with dimensions of velocity. For 4 inner planets one has $v_0/c \simeq 2^{-11}$.

2. The notion of h_{gr} generalizes to that for other interactions. For instance, in electromagnetic case the formation of strong em fields implying charge separation leads to systems in which $h_{em} = Z_1Z_2e^2/v_0$ is large. Pollack's exclusion zone and its complement define this kind of systems and is identified as prebiotic life form.
3. Since the natural expansion parameter of perturbative expansion is the $g^2/4\pi\hbar$, one can say that transition to dark matter phase make the situation perturbative. Mother Nature is theoretician friendly.

h_{em} might be large in the exclusion zones (EZ) appearing in the water bounded by gel and their variants could play central role in living matter.

1. EZ carries very large negative charge with positive charge outside the exclusion zone.
2. TGD interpretation is in terms of $H_{1.5}O$ phase of water formed when every 4: th proton is transferred to magnetic body as dark particle with large value of h_{eff}. The proposal is that primitive life form is in question.
3. The pair formed by EZ and its complement could have large value of $h_{eff} = h_{em} = Z^2e^2/v_0$.
4. The velocity parameter v_0 should correspond to some natural rotation velocity. What comes in mind is that complement refers to Earth and v_0 is the rotation velocity at the surface of Earth. The prediction for h_{eff} would be of order $h_{em}/h = 4\pi\alpha Z^2 \times .645 \times 10^6 \simeq 5.9 \times 10^4 Z^2$.
5. Cell membrane involves also large charge separation due to very strong electric field over the cell membrane. Also now dark phases with large h_{em} or h_{gr} could be formed.

I have proposed that metabolic machinery generates large h_{eff} phase somehow. $h_{eff} = h_{em}$ hypothesis allows to develop this hypothesis in more detail.

1. I have speculated earlier [K58] that the rotating shaft of a molecular motor associated with ATP synthase plays a key role in generating dark matter phase. What comes in mind is that charge separation takes place associating exclusion zone with the shaft and the rotational velocity v_0 of the shaft appears in the formula for h_{em}. Of course, some numerical constant not far from unity could be present. The electric field over the mitochondrial membrane generates charge separation. One can imagine several identifications for the product of charges. The charge Z associated with the complement would be naturally associated with single dark flux tube containing dark nucleon consisting of dark protons. For instance, the charge associated with the exclusion zone could be the charge of the electronic Cooper pair giving $h_{em} = 2e \times Z/v_0$.
2. The value of v_0/c is expected to be of order 10^{-14} from the angular rotation rate of ADP synthase about few hundred revolutions per second. The order of magnitude for h_{em} could be same as for h_{gr} associated with Earth-particle system.

$h_{eff}(ATPsynthase) = h_{gr}(2e, Earth)$ would make possible reconnection of electromagnetic flux tubes with gravimagnetic flux tubes [K86].

Which came first: metabolism or cell membrane?

One of the basic questions of biology is whether metabolism preceded basic biopolymers or vice versa. RNA world scenario assumes that RNA and perhaps also genetic code was first.

1. The above view suggests that both approaches are correct to some degree in TGD Universe. Both metabolism and genetic code realized in terms of dark proton sequences would have emerged simultaneously and bio-chemistry self-organized around them. Dark proton sequences defining analogs of amino-acid sequences could have defined analogs of protein catalysts and played a key role in the evolution of the metabolic pathways from the primitive pathways involving only the phase transition between ordinary water and fourth phase of water.
2. There is very interesting article (see `http://tinyurl.com/ycdhd4fd`) [?]eporting that complex metabolic pathways are generated spontaneously in laboratory environments mimicking hot thermal vents. Glycolysis and pentose phosphate pathway were detected. The proposal is that these pathways are catalyzed by metals rather than protein catalysts.

3. In standard biology these findings would mean that these metabolic pathways emerged before basic biopolymers and that genetic code is not needed to code for the metabolic pathways during this period. In TGD framework dark genetic code [K51, L4] would be there, and could code for the dark pathways. Dark proton strings in one-one correspondence with the amino-acid sequences could be responsible for catalysts appearing in the pathways. Only later these catalysts would have transformed to their chemical counterparts and might be accompanied by their dark templates. One cannot even exclude the possibility that the chemical realization of the DNA-amino-acid correspondence involves its dark analog in an essential manner.

12.6.4 Could Pollack effect make cell membrane a self-loading battery?

The so called Clarendon dry pile is 175 years old battery still working. The current is very weak (nano Ampere) but the working of the battery is claimed to be not well-understood. The TGD inspired model for cold fusion leads to the proposal that Pollack effect is part of electrolysis. This inspires the idea that Pollack effect and possibly also the associated cold fusion could make Clarendon dry pile a self-loading battery. Cell membrane can be regarded as the analog of self-loading battery, and in TGD framework also as a generalised Josephson junction. Hence one can ask whether also cell membrane could be seen as a self-loading battery utilizing Pollack's mechanism. This would also allow to understand why hyperpolarization stabilizes the membrane potential and why depolarization generates nerve pulse.

Clarendon pile: 175 years old battery still working

Elemer Rosinger had a Facebook link to an article telling about Clarendon dry pile, a very long-lived battery providing energy for an electric clock (see `http://tinyurl.com/zeut69y`, `http://tinyurl.com/jhrww2a`, and `http://tinyurl.com/gvbrhra`). This clock known also as Oxford bell has been ringing for 175 years now and the article suggests that the longevity of the battery is not really understood. The bell is not actually ringing so loud that human ear could hear it but one can see the motion of the small metal sphere between the oppositely charged electrodes of the battery in the video.

The function principle of the clock is simple. The gravitational field of earth is also present. When the sphere touches the negative electrode, it receives a bunch of electrons and gives the bunch away as it touches positive electrode so that a current consisting of these bunches is running between electrons. The average current during the oscillation period of 2 seconds is nanoampere so that nanocoulomb of charge is transferred during each period (Coulomb corresponds to a 6.242×10^{18} elementary charges (electrons)).

The dry pile was discovered by priest and physicist Giuseppe Zamboni at 1812 (see `http://tinyurl.com/jkvtj6f`). The pile consists of 2,000 pairs of pairs of discs of tin foil glued to paper impregnated with Zinc sulphate and coated on the other side with manganese dioxide: 2,000 thin batteries in series. The operation of battery gradually leads to the oxidation of Zinc and the loss of magnase dioxide but the process takes place very slowly. One might actually wonder whether it takes place too slowly so that some other source of energy than the electrostatic energy of the battery would be keep the clock running. Karpen pile is analogous battery discover by Vasily Karpen (see `http://tinyurl.com/jpzcs32`). It has now worked for 50 years.

Cold fusion is associated with electrolysis. Could the functioning of this mystery clock involve cold fusion taken seriously even by American Physical Society thanks to the work of the group of prof. Holmlid. Electrolytes have of course been "understood" for aeons. Ionization leads to charge separation and current flows in the resulting voltage. With a feeling of deep shame I must confess that I cannot understand how the ionization is possible in standard physics. This of course might be just my immense stupidity - every second year physics student would immediately tell that this is "trivial" - so trivial that he would not even bother to explain why. The electric field between the electrodes is immensely weak in the scale of molecules. How can it induce the ionisation? Could ordinary electrolytes involve new physics involving cold fusion liberating energy? These are the questions which pop up in my stupid mind. Stubborn as I am in my delusions, I have proposed what this new physics might be with inspiration coming from strange experimental findings of Gerald Pollack, cold fusion, and my own view about dark matter has phases of ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant. Continuing with my weird delusions I dare ask: Could cold fusion provide the energy for the "miracle" battery?

What batteries are?

To understand what might be involved one must first learn some basic concepts. I am trying to do the same.

1. Battery (see `http://tinyurl.com/8xqsnab`) consistes of two distinct electrochemical cells (see `http://tinyurl.com/jq8ljmo`). Cell consists of electrode and electrolyte. The electrodes are called anode and catode. By definition electron current along external wire flows to catode and leaves anode.

2. There are also ionic currents flowing inside the battery. In absence of the ionic currents the electrodes of the battery lose their charge. In the loading the electrodes get their charges. In the ideal situation the ionic current is same as electron current and the battery does not lose its charging. Chemical reactions are however taking place near and at the electrodes and in their reversals take place during charging. Chemical changes are not completely reversible so that the lifetime of the battery is finite.

   The ionic current can be rather complex: the carriers of the positive charge from anode can even change during the charge transfer: what matters that negative charge from catode is transferred to anode in some manner and this charge logistics can involve several steps. Near the catode the currents of positive ions (cations) and electrons from the anode combine to form neutral molecules. The negative current carriers from catode to the anode are called anions.

3. The charge of the clectrochemical cell is in the electrolyte near the surface of the electrode rather than inside it as one might first think and the chemical processes involve neutralization of ion and the transfer of neutral outcome to or from the electrode.

4. Catode - or better, the electrochemical cell containing the catode - can have both signs of charge. For positive charge one has a battery liberating energy as the electron current connecting the negative and positive poles goes through the load, such as LED. For negative charge current flows only if there is external energy feed: this is loading of the battery. External voltage source and thus energy is needed to drive the negative charges and positive charges to the electrodes. The chemical reactions involved can be rather complex and proceed in reverse direction during the loading process. Travel phone battery is a familiar example.

   During charging the roles of the anode and catode are changed: understanding this helps considerably.

Could dark cold fusion make possible self-loading batteries?

Could cold fusion help to understand why the Clarendon dry pile is so long lived?

1. The battery is series of very many simpler batteries. The mechanism should reduce to the level of single building brick. This is assumed in the following.

2. The charge of the battery tends to be reduced unless the ionic and electronic currents are identical. Also chemical changes occur. The mechanism involved should oppose the reduction of the charging by creating positive charge to the catode and negative charge to the anode or induce additional voltage between the electrodes of the battery inducing its loading. The energy feed involved might also change the direction of the basic chemical reactions as in the ordinary loading by raising the temperature at catode or anode.

3. Could be formation of Pollack's exclusion zones (EZs) in the elecrolytic cell containing the anode help to achieve this? EZs carry a high electronic charge. According to TGD based model protons are transformed to dark protons at magnetic flux tubes. If the positive dark charge at the flux tubes is transferred to the electrolytic cell containing catode and transformed to ordinary charge, it would increase the positive charge of the catode. The effect would be analogous to the loading of battery. The energy liberated in the process would compensate for the loss of charge energy due to electronic and ionic currents.

4. In the ordinary loading of the battery the voltage between batteries induces the reversal of the chemical processes occurring in the battery. This is due to the external energy feed. Could the energy feed from dark cold fusion induce similar effects now? For instance, could the energy liberated at the catode as positively charged dark nuclei transform to ordinary ones raise the temperature and in this manner feed the energy needed to change the direction of the chemical reactions.

Cell membrane as self-loading battery and how nerve pulse is generated?

This model might have an interesting application to the physics of cell membrane.

1. Cell membrane consisting of two lipid layers defines the analog of a battery. Cell interior plus inner lipid layer (anode) and cell exterior plus outer lipid layer (catode) are analogs of electrolyte cells.

   What has been troubling me for two decades is how this battery manages to load itself. Metabolic energy is certainly needed and ADP-ATP mechanism is essential element. I do not however understand how the membrane manages to keep its voltage.

   Second mystery is why it is hyperpolarization rather than polarization, which tends to stabilize the membrane potential in the sense that the probability for the spontaneous generation of nerve pulse is reduced. Neither do I understand why depolarization (reduction of the membrane voltage) leads to a generation of nerve pulse involving rapid change of the sign of the membrane voltage and the flow of various ionic currents between the interior and exterior of the cell.

2. In the TGD inspired model for nerve pulse cell interior and cell exterior or at least their regions near to lipid layers are regarded as super-conductors forming a generalized Josephson junction. For the ordinary Josephson junction the Coulombic energy due to the membrane voltage defines Josephson energy. Now Josephson energy is replaced by the ordinary Josephson energy plus the difference of cyclotron energies of the ion at the two sides of the membrane. Also ordinary Josephson radiation can be generated. The Josephson currents are assumed to run along magnetic flux tubes connecting cell interior and exterior. This assumption receives support from the strange finding that the small quantal currents associated with the membrane remain essentially the same when the membrane is replaced with polymer membrane.

3. The model for Clarendon dry pile suggests an explanation for the self-loading ability. The electrolytic cell containing the anode corresponds to the negatively charged cell interior, where Pollack's EZs would be generated spontaneously and the feed of protonic charge to the outside of the membrane would be along flux tubes as dark protons to minimize dissipation. Also ions would flow along them. The dark protons driven to the outside of the membrane transform to ordinary ones or remain dark and flow spontaneously back and provide the energy needed to add phosphate to ADP to get ATP.

4. The system could be quantum critical in the sense that a small reduction of the membrane potential induces nerve pulse. Why the ability to generate Pollack's EZs in the interior would be lost for a few milliseconds during nerve pulse? The hint comes from the fact that Pollack's EZs can be generated by feeding infrared radiation to a water bounded by gel. Also the ordinary Josephson radiation generated by cell membrane Josephson junction has energy in infrared range!

   Could the ordinary Josephson radiation generate EZs by inducing the ionization of almost ionized hydrogen bonded pairs of water molecules. The hydrogen bonded pairs must be very near to the ionization energy so that ordinary Josephson energy of about .06 eV assignable to the membrane voltage is enough to induce the ionization followed by the formation of $H_{3/2}O$. The resulting EZ would consist of layers with the effective stoichiometry $H_{3/2}O$.

   As the membrane voltage is reduced, Josephson energy would not be anymore enough to induce the ionization of hydrogen bonded pair of water molecules, EZs are not generated, and the battery voltage is rapidly reduced: nerve pulse is created. In the case of hyperpolarization the energy excees the energy needed for ionization and the situation becomes more stable.

5. This model could also allow to understand the effect of anesthetes [K84] [L34]. Anesthetes could basically induce hyperpolarization so that Josephson photons would continually generate

Pollack's EZ:s and creating of dark particles at the magnetic flux tubes. This need not mean that consciousness is lost at the cell level. Only sensory and motor actions are prevented because nerve pulses are not possible. This prevents formation of sensory and motor mental images at our level of hierarchy.

Meyer-Overton correlation states that the effectiveness of the anesthete correlates with its solubility to the lipid membrane. This is the case if the presence of anesthete in the membrane induces hyperpolarization so that the energies of the photons of Josephson radiation would be higher than needed for the generation of EZs accompanied by magnetic flux tubes along which ionic Josephson currents would flow between cell interior and exterior. For these quantal currents evidence exists [K88]. In the case of battery these dark ions would flow from the cell containing anode to that containing catode. For depolarization the energy of Josephson photons would be too low to allow the kicking off protons from hydrogen bonded pairs of water molecules so that EZs would not be created and self-loading would stop and nerve pulse would be generated.

12.7 Could Photosensitive Emulsions Make Dark Matter Visible?

The article "Possible detection of tachyon monopoles in photographic emulsions" by Keith Fredericks [H14] describes in detail (`http://tinyurl.com/ybjk94f9`) very interesting observations by him and also by many other researchers about strange tracks in photographic emulsions induced by various (probably) non-biological mechanisms and also by the exposure to human hands (touching by fingertips) as in the experiments of Fredericks. That the photographic emulsion itself consists of organic matter (say gelatin) might be of significance.

12.7.1 The Findings

The tracks have width between 5 μm-110 μm (horizontal) and 5 μm-460 μm (vertical). Even tracks of length up to at least 6.9 cm have been found. Tracks begin at some point and end abruptly. A given track can have both random and almost linear portions, regular periodic structures (figs 11 and 12), tracks can appear in swarms (**Fig.** 24), bundles (**Fig.** 25), and correlated pairs (**Fig.** 16), tracks can also split and recombine (**Fig.** 32) (here and below "**Fig.**" refers to a figure of the article at `http://tinyurl.com/ybjk94f9`).

Tracks differ from tracks of known particles: the constant width of track implies that electrons are not in question. No delta rays (fast electrons caused by secondary ionization appearing as branches in the track) characteristic for ions are present. Unlike alpha particle tracks the tracks are not straight. In magnetic fields tracks have parabolic portions whereas ordinary charged particle move along spiral. The magnetic field needed to cause spiral structure for baryons should be by two orders of magnitude higher than in the experiments.

For particle physicist all these features - for instance constant width - strongly suggest pre-existing structures becoming visible for some reason. The pre-existing structure could of course correspond to something completely standard structures present in the emulsion. If one is ready to accept that biology involves new physics, it could be something more interesting.

Also evidence for cold fusion is reported by the group of Urutskoev [H9]. There is evidence for cold fusion in living matter [C33, C150]: the fact that the emulsion contains gelatin might relate to this. In [L4] a dark matter based mechanism of cold fusion allowing protons to overcome the Coulomb wall is discussed. Either dark protons or dark nuclei with much larger quantum size than usually would make this possible and protons could end up to the dark nuclei along dark flux tubes. In TGD inspired biology dark protons (large h_{eff}) with scaled up Compton length of order atomic size are proposed to play key role since their states allow interpretation in terms of vertebrate genetic code [L4, K25].

12.7.2 The Importance Of Belief System

These structures could be something quite standard or not. This readiness to consider non-standard explanations depends on belief system.

1. In the belief system of standard physics these pre-existing structures would be organic material consisting of ordinary matter so that no new physics is involved. Probably it is easy to kill this hypothesis. If this can be done, the situation becomes really interesting.
2. In my own belief system they *could* correspond to dark matter structures made visible by some mechanism. The presence of human hands could induce this phenomenon in the experiments of Fredericks. If so we might be already considering remote interactions involving dark photons and magnetic flux tubes, whose images "tracks" would be.
3. The first guess is that these structures are in the emulsion. This need not be the case! They could be structures outside- say in human hands - sending dark photon beam absorbed by the small photosensitive crystals in the emulsion. A photograph of dark matter (say in the hands of sender) would be formed! One possibility is that tracks represent a photograph of the dark matter at the flux tubes of the magnetic body of the emulsion. This would be a variant for what Gariaev perhaps managed to achieve with camera: taking a photo of dark matter [K1] !
4. Unfortunately belief system becomes important also in second manner. The reductionistic belief system tells that the tracks must be something trivial. There cannot be new physics in scale of cell as we have read in text books. Therefore these tracks are not studied by professionals who could very easily find whether there is something really interesting involved.

Dark matter in TGD based belief system corresponds to a hierarchy of phases of ordinary matter with an effective value h_{eff} of Planck constant coming as integer multiple of ordinary Planck constant. This makes possible macroscopic quantum phases consisting of dark matter. The flux tubes could carry magnetic monopole flux but the magnetic charge would be topological (made possible by the non-trivial second homology of CP_2 factor of the 8-D embedding space containing space-times as surfaces) rather than Dirac type magnetic charge.

The TGD inspired identification of tracks could be as images of magnetic flux tubes or bundles of them containing dark matter defining one of the basic new physics elements in TGD based quantum biology. One can imagine two options for the identification of the tracks as "tracks".

1. The primary structures are in the photo-sensive emulsion.
2. The structures in photograph are photographs of dark matter in external world, say structures in human hands or human body or of dark matter at some magnetic body, say at the flux tubes of the magnetic body of the emulsion.

The fact that the tracks have been observed in experimental arrangements not involving exposure to human hands, indeed suggests that tracks represent photographs about parts of the magnetic body assignable to the emulsion. For this option the external source would serve only as the source of possibly dark photons.

This would imply a close analogy with the experiments of Peter Gariaev's group interpreted in TGD framework as photographing of the magnetic body of DNA sample [K1]. Also here one has an external source of light: the light would be transformed to dark photons in DNA sample, scatter from the dark charged particles at the flux tubes of the magnetic body of DNA sample, and return back transforming to ordinary light and generating the image in the photosensitive emulsion.

12.7.3 Why Not Tachyonic Monopoles?

The identification of the tracks as orbits of particles proposed by author and also by other experimentalists is to my opinion problematic for the reasons which I have already explained. The article of Fredericks lists further details which do not conform with the particle interpretation. A further proposal is that the particles are tachyonic magnetic monopoles. One motivation for the monopole hypothesis is the (unsuccessful) attempt to explain the parabolic shape of the tracks in external magnetic field.

To my view the interpretation as a tachyonic monopole - a notion introduced by Recami and Mignani [H22] (`http://tinyurl.com/yajz68tt`) - adopted in the article is theoretically problematic. Of course, if the tracks are actually pre-existing structures made visible by some mechanism, there is no need to postulate super-luminal propagation. To see the problem, one can start from a general formula relating energy, momentum and mass. One has

$$E^2 = p^2 + m^2 \ . \qquad (12.7.1)$$

When m is imaginary as for tachyon so that one can write $m = iM$, one obtains

$$E^2 = p^2 - M^2 \ . \qquad (12.7.2)$$

If E and p are assumed to be real as is done usually the condition $E \geq 0$ and more generally the reality of E gives $p \geq M$. Tachyon cannot therefore be at rest and one cannot assign to it kinetic energy since tachyon at rest would have imaginary energy.

This has two implications.

1. The identification as tachyon and the conclusion $p \ll M$ from experiments (see figure 34 for the relation between E, p and m in various cases) is not consistent with $p \geq M$.

2. Recami and Mignani assign a kinetic energy to tachyon (formula 14). Unfortunately, this formula does not make sense if one accepts that E and p are real since one cannot assign to tachyon kinetic energy: the analogy of kinetic energy would be "kinetic momentum" defined as the difference of the actual momentum and minimal momentum $p = M$ ($p_{kin} = \sqrt{E^2 + M^2} - M \simeq E - M - M^2/2E$). As Fredericks notices, the behavior is not actually consistent with a motion of magnetic monopole in magnetic field. Parabolic orbits are in plane orthogonal to magnetic field rather than containing its direction vector (`http://tinyurl.com/ybjk94f9`)!

12.7.4 Interpretation As Dark Matter Structures Becoming Visible In Presence Of Living Matter

As such the observations are extremely interesting. I cannot however believe that the tracks represent particles. To my opinion tachyonic monopole interpretation fails because it does not make sense to talk about kinetic energy of tachyon.

To me the complex structures of tracks very strongly suggest pre-existing structures becoming visible for some reason. Looking the shape of tracks brings to my mind linear structure such as protein molecules. They contain regular helical portions and denatured portions. Now the longitudinal scale is of course much longer. The transversal scale is that for cells. This is perhaps not too surprising since organic materials such as gelatin are involved. The flux tubes could carry magnetic monopole fluxes and in purely formal sense would thus be analogous to magnetic monopoles with space-like momentum in their direction - that is tachyonic monopoles. They would be however actually ordinary systems with non-tachyonic momentum.

The particles possibly causing the tracks cannot be electrically charged since in this case they would not have managed to reach the emulsion. There seems however to be an interaction with magnetic fields since the tracks are parabola. Urutskoev *et al* [H9] propose that tracks are caused by magnetic monopoles. Unfortunately, the predicted parabolic orbit would be in the plane containing the magnetic field lines: the situation is completely analogous to the parabolic motion of projectile in the Earth's gravitational field.

"Tracks" as photographs of magnetic flux tubes?

Consider first the identification of "tracks" (for convenience I will drop the quotation marks in the sequel) as images of magnetic flux tubes.

1. The hypothesis that tracks are photographs of flux tubes explains the "track-ness". In the Earth's magnetic field the thickness of flux tubes is by flux quantization of the same order of magnitude as the thickness of thickest tracks observed for single flux quantum. Flux tube hypothesis seems to be also consistent with the other strange properties of the "tracks". In particular, the composition to random and smoothly curved portion would conform with the idea that also linear molecules are formed around templates defined by magnetic flux tubes.

2. The tracks have been observed to be created in several situations and it is not at all clear whether the exposure to hands in the experiments of Fredericks is absolutely necessary. TGD suggests that the analog of dielectric breakdown associated with nerve pulses (the electric field at cell membrane is two times higher than the electric field inducing di-electric breakdown in air) replaces the strong electric fields causing di-electric breakdown used in the experiments of Urutskoev [H9]. Dark magnetic flux tubes can accompany any kind of matter so that tracks could be also images about the dark magnetic body of an external object rather than that of emulsion. In principle, one cannot exclude the possibility that the presence of the experimenter is decisive in all cases. If so, this would be a new kind of experimenter effect.
3. To what could the abrupt ending of the track correspond in this picture? Magnetic flux tubes cannot end but they can go to another space-time sheet through wormhole contact and apparently disappear. This would indeed take place for the closed flux tubes representing elementary particles and carrying magnetic monopole flux. The flux tubes could quite generally carry a multiple of magnetic monopole flux. They would have rather large scale as compared to the CP_2 scale of 10^4 Planck lengths.

1. Explanation for parabolic portions of tracks

The presence of parabolic tracks in the plane orthogonal to the external static magnetic fields is very interesting feature to be explained. Parabolic character could be simply due to the simplest non-linear fit to the shape of the flux tube: it is however argued that parabolic character is exact. One should understand why the flux tube is orthogonal to the external magnetic field or magnetic field generated by the emulsion? Could this reflect the geometry of the experimental arrangement?

In TGD framework one can consider a very natural possibility that a constant electric field orthogonal to the external magnetic field is present.

1. In standard physics the presence of the electric field might be excluded easily. In TGD framework simplest space-time sheets representing constant Kähler magnetic fields allow a simple deformation to sheets containing orthogonal electric field. A simple situation (not necessarily a preferred extremal of Kähler action) corresponds to a space-time sheet $X^4 \subset M^4 \times S^2$, S^2 a geodesic sphere of CP_2. Using spherical coordinates $(u = cos(\Theta), \Phi)$ for S^2 and Cartesian coordinates (t, z, x, y) for M^4, one has $(u = f(x), \Phi = \omega t + ky)$ $(c = 1)$. The non-vanishing components of magnetic and electric fields are apart from a coefficient of proportionality of order unity given by $E_x \equiv J_{0x} = \partial_x u \times \omega$ and $B^z \equiv J_{xy} = \partial_x u \times k$ with $E_x/B_z = \omega/k$. Electric and magnetic fields are orthogonal and the value of the ω/k ratio fixes the electric field strength in terms of the magnetic field strength. In fact, the mere assumption that the CP_2 projection is 2-dimensional implies that electric and magnetic parts of various induced gauge fields are orthogonal.
2. This field would be represented by a space-time sheet at which the flux tubes of the external magnetic are topologically condensed (glued by wormhole contacts). The charged particles inside the flux tube would experience the presence of this electric field as a constant force trying to force them out from the flux tube. If the flux tube adopts a parabolic shape of the orbit of individual charged particle, the electric force is parallel to the flux tube and one has equilibrium situation. *All* charged particles inside flux tube must move with the same velocity at given point of flux tube: this conforms with super-conductivity implying the existence of global order parameter. Note that the dark charged particles inside flux tube would not directly interact with the emulsion or with air so that they can reach the emulsion easily.
3. For non-relativistic motion the equation for the parabolic orbit is $y = x^2/L$, where the length $L = 2mv^2/qE$ characterizes the size scale of the parabola. Parametrizing E in terms of voltage and length L as $E = V_e/L$ one has $eV_c/mc^2 = 2(v/c)^2$. For electron rest energy $m_ec^2 = .5$ MeV and $v/c = 10^{-3}$ one would have $V_c = 1$ V. For proton the electric field would be by a factor 2^{11} stronger for the same orbit parameters.

   For a given electric field the parameters of the parabola allow to distinguish between flux tubes carrying different charged particles since the kinetic energies from the are expected to be different. I have indeed proposed that magnetic flux tubes could serve as a kind of filter allowing to distill ions with different masses at their own magnetic flux tubes: the equilibrium condition would make the flux tubes filters. The cyclotron energy scale $E_c = \hbar_{eff} ZeB/m$ would give a rough guess for the order of magnitude of kinetic energy of the particle: cyclotron energy scale is proportional to h_{eff} so that quite high energies can be considered. eV as a typical atomic energy scale and also as the energy scale of bio-photons (interpreted as decay products of dark photons [K13]) is the first guess for the energy scale.

4. It should be easy to check whether the emulsion is accompanied by electric field and also to deduce bounds for its values. Living matter is electret and one could imagine that gelatin contains some kind of remnants of bio-electric fields - perhaps as dark variants.

2. The decrease of the track thickness with the increase of distance

Urutskoev *et al* [H9] have reported the decrease of the track thickness with the increase of the source distance. Does this mean that the flux tubes photographed are near the source and the reduction of track thickness with distance is an optical effect similar to that for ordinary photographs?

If the flux tubes belong to the magnetic body of emulsion, this explanation fails. It is however easy to invent plausible explanation also in this case. based on a simple model for the quantization of the magnetic flux.

1. The reconnection for flux tubes of the source and emulsion can take place only for flux tubes with same magnetic field strength and by flux conservation same transversal area S. Note that conservation of magnetic flux implies $B \times S = constant$ so that increasing the thickness of flux tube decreases the strength of the magnetic field.

2. If the flux tubes have a fractal structure with flux tubes containing bundles of flux tubes (bundle structure has been observed for the tracks), one can argue that the weaker the magnetic field, the smaller the number of flux tubes in the typical bundle and the smaller the radius of the bundle if the flux tubes inside bundle have constant density. For dipole field the weakening of the average field with distance could mean that flux tube bundles split to smaller bundles. A "temporary" splitting of at track to a bundle of widely separated tracks has been observed for tracks and would mean reduction of the average magnetic field strength.

3. If the number of grains corresponds to the number of flux tubes within a bundle, the number of flux tubes in the bundle would be thousands. The average size of the grain suggests a diameter of order .34 μ m for the flux tubes. If the magnetic length $L_B = \sqrt{h/eB}$ equals to $L_B = .17$ μm (scaling rule: 1 Tesla corresponds to $L_B = 64$ nm), the magnetic field strength would be 354 Gauss (the Earth's magnetic field has nominal value of.5 Gauss). The external magnetic field of 20 Gauss used by Urutskoev *et al* defines a good candidate for the flux tube radius. For this field single flux tube would correspond to 18-19 crystals.

If this model is on correct track, these photographs could among other things provide means for the detailed study of the quantized dynamics of magnetic fields based on decomposition to flux tubes consisting of flux tubes consisting of...

What could be the source of dark photons?

Photographic emulsion would work as usually by detecting photons. What is clear that the photons must be dark when they scatter from the magnetic flux tubes of the magnetic body of the emulsion. There are however several options for how the dark photons are produced.

1. Ordinary photons from the source could hit the emulsion, transform to dark photons and propagate to the magnetic flux tubes, reflect back, transform to ordinary photons, and interact with the micro-crystals of the emulsion and generate the visible track as the image of the flux tube. Emulsion would take the role possessed by DNA sample in Gariaev's experiments and the external source would take the role of lamps used to generate visible light [K1].

2. Dark photons could also originate from the source. They could arrive along the flux tubes of its magnetic body. In the experimental situations considered these would reconnect with the flux tubes of the magnetic body of the emulsion and scatter from dark matter at them. After this the photons would propagate to the emulsion and transform to ordinary photons and give rise to the image. Reconnection of the flux tubes is the basic mechanism of attention in

TGD inspired theory of consciousness and in TGD inspired biology, and also used to explain various findings of Persinger *et al* [K25].

3. The emission of dark photons is expected to take place in critical systems in which large values of effective Planck constant h_{eff} making possible long range correlations can be present. The situations studied (glow discharge plasma processes, exploding wires and foils, low energy discharges in water, super-compression of solid targets using electron beams) indeed seem to be critical. Only the search of monopoles of solar origin at the north pole represents a situation in which criticality is not present in obvious manner (the measurement method might involve criticality to guarantee maximal sensitivity). This kind of situations would generate time varying magnetic fields, whose flux tubes could reconnect with the magnetic flux tubes assignable to the photographic emulsion. This in turn would make possible for dark photons to propagate from source to the emulsion. In some experiments also static magnetic fields are present.

4. What is interesting that the "cold currents" reported already by Tesla in his experiments involving di-electric breakdowns at surfaces of wires of coils could correspond to dark currents propagating along the magnetic flux tubes [L18] [L18]. Most of these experiments correspond to critical situations making possible the manifestation of otherwise hidden new physics. Whether one can see these manifestations of course depends on whether one believes on the reductionistic Bible or not.

Chapter 13

Super-Conductivity in Many-Sheeted Space-Time

13.1 Introduction

In this chapter various TGD based ideas related to high T_c super-conductivity are discussed studied.

1. Supra currents and Josephson currents provide excellent tools of bio-control allowing large space-time sheets to control the smaller space-time sheets. The predicted hierarchy of dark matter phases characterized by a large value of $\hbar$ and thus possessing scaled up Compton and de Broglie wavelengths allows to have quantum control of short scales by long scales utilizing de-coherence phase transition. Quantum criticality is the basic property of TGD Universe and quantum critical super-conductivity is therefore especially natural in TGD framework. The competing phases could be ordinary and large $\hbar$ phases and supra currents would flow along the boundary between the two phases.
2. It is possible to make a tentative identification of the quantum correlates of the sensory qualia quantum number increments associated with the quantum phase transitions of various macroscopic quantum systems [K47] and various kind of Bose-Einstein condensates and super-conductors are the most relevant ones in this respect.
3. The state basis for the fermionic Fock space spanned by N creation operators can be regarded as a Boolean algebra consisting of statements about N basic statements. Hence fermionic degreees of freedom could correspond to the Boolean mind whereas bosonic degrees of freedom would correspond to sensory experiencing and emotions. The integer valued magnetic quantum numbers (a purely TGD based effect) associated with the defect regions of super conductors of type I provide a very robust information storage mechanism and in defect regions fermionic Fock basis is natural. Hence not only fermionic super-conductors but also their defects are biologically interesting [K49, K87].

13.1.1 General Ideas About Super-Conductivity In Many-Sheeted Space-Time

The notion of many-sheeted space-time alone provides a strong motivation for developing TGD based view about superconductivity and I have developed various ideas about high T_c super-conductivity [D79] in parallel with ideas about living matter as a macroscopic quantum system. A further motivation and a hope for more quantitative modelling comes from the discovery of various non-orthodox super-conductors including high T_c superconductors [A11]. [D79, D8]. heavy fermion super-conductors and ferromagnetic superconductors [D78, D55, D37]. The standard BCS theory does not work for these super-conductors and the mechanism for the formation of Cooper pairs is not understood. There is experimental evidence that quantum criticality [D127] is a key feature of many non-orthodox super-conductors. TGD provides a conceptual framework and bundle of ideas making it possible to develop models for non-orthodox superconductors.

Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form. The hypothesis that Planck constants in CD (causal diamond defined as the intersection of the future and past directed light-cones of M^4) and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant [K43, K42] adds further content to the notion of quantum criticality.

After several alternatives I ended with the conjecture that the value of $\hbar$ is in the general case given by $\hbar = n \times \hbar_0$. Integer n characterizes a sub-algebra of super-symplectic algebra or related algebra with conformal structure characterized by the property that conformal weights are n-multiples of those of the full algebra. The sub-algebra is isomorphic with the full algebra so that a fractal hierarchy of sub-algebras is obtained. One obtains an infinite hierarchy of conformal gauge symmetry breaking hierarchies defined by the sequences of integers n_i dividing n_{i+1}.

The identification in terms of hierarchies of inclusions of hyper-finite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

The only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value of $\alpha_K = g_K^2/4\pi\hbar$ should be analogous to critical temperature and determined by quantum criticality requirement. There are two possible interpretations for the hierarchy of Planck constants.

1. The actual value of $\hbar$ is always its standard value and value of $\alpha_K = g_K 2/4\pi\hbar$ is always its maximal value $\alpha_K(n = 1$ but there are n space-time sheets contributing the same value of Kähler action effectively scaling up the value of $\hbar_0$ to $n\hbar_0$ scaling down the value of $\alpha_K(1)$ to $\alpha_K(1)/n$. The n sheets would belong to n different conformal gauge equivalence classes of space-time surfaces connecting fixed 3-surfaces at opposite boundaries of CD. This interpretation is analogous to the introduction of the singular covering space of embedding space.

   One can of course ask whether all values $0 < m \leq n$ for the number of "actualized" sheets are possible. A possible interpretation would be in terms of charge fractionization.

2. One could also speak of genuine hierarchy of Planck constants $\hbar = n\hbar_0$ predicting a genuine hierarchy of Kähler coupling strengths $\alpha_K(n) = \alpha_K(n = 1)/n$. In thermodynamical analogy zero temperature is an accumulation of critical temperatures behaving like $1/n$. Intriguingly, in p-adic thermodynamics p-adic temperature is quantized for purely number theoretical reasons as $1/n$ multiples of the maximal p-adic temperature. Note that Kähler function is the analog of free energy. In this interpretation the n sheets are identified.

Phases with different values n behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality for the phase transition changing the value of n to its multiple or divisor. In large $\hbar(CD)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

Number theoretic complexity argument favors the hypothesis that the integers n corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, might be favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale.

Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, α_K does not seem to depend on p-adic prime whereas gravitational constant is proportional to L_p^2. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime M_{127} so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution [L82].

$\hbar(CD)$ appears in the commutation and anti-commutation relations of various superconformal algebras. Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of Planck constants coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD thus predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and each other [**?**] and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [**?**, K103, K42]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical superconductivity.

Cusp catastrophe serves as a metaphor for criticality. In the case of high T_c superconductivity temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labeled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

Many-sheeted space-time concept and ideas about macroscopic quantum phases

Many-sheeted space-time leads to obvious ideas concerning the realization of macroscopic quantum phases.

1. The dropping of particles to larger space-time sheets is a highly attractive mechanism of super-conductivity. If space-time sheets are thermally isolated, the larger space-time sheets could be at extremely low temperature and super-conducting.

2. The possibility of large $\hbar$ phases allows to give up the assumption that space-time sheets characterized by different p-adic length scales are thermally isolated. The scaled up versions of a given space-time sheet corresponding to a hierarchy of values of $\hbar$ are possible such that the scale of kinetic energy and magnetic interaction energy remain same for all these space-time sheets. For the scaled up variants of space-time sheet the critical temperature for superconductivity could be higher than room temperature.

3. The idea that wormhole contacts can form macroscopic quantum phases and that the interaction of ordinary charge carriers with the wormhole contacts feeding their gauge fluxes to larger space-time sheets could be responsible for the formation of Cooper pairs, have been around for a decade [K124]. The rather recent realization that wormhole contacts can be actually regarded as space-time correlates for Higgs particles suggests also a new view about the photon massivation in super-conductivity.

4. Quantum classical correspondence has turned out be a very powerful idea generator. For instance, one can ask what are the space-time correlates for various notions of condensed matter such as phonons, BCS Cooper pairs, holes, etc...

13.1.2 TGD Inspired Model For High T_c Superconductivity

The TGD inspired model for high T_c super-conductivity relies on the notions of quantum criticality, dynamical quantized Planck constant requiring a generalization of the 8-D embedding space to a book like structure, and many-sheeted space-time. In particular, the notion of magnetic flux tube as a carrier of supra current of central concept.

With a sufficient amount of twisting and weaving these basic ideas one ends up to concrete models for high T_c superconductors as quantum critical superconductors consistent with the qualitative facts that I am personally aware. The following minimal model looks the most realistic option found hitherto.

1. The general idea is that magnetic flux tubes are carriers of supra currents. In anti-ferromagnetic phases these flux tube structures form small closed loops so that the system behaves as an insulator. Some mechanism leading to a formation of long flux tubes must exist. Doping creates holes located around stripes, which become positively charged and attract electrons to the flux tubes.
2. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of $h_{eff} = nh$, $S = 0$ Cooper pairs with even $L \geq 2$ are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign, $S = 1$ Cooper pairs with odd $L \geq 1$ are favored.
3. The higher critical temperature T_{c1} corresponds to a formation local configurations of parallel spins assigned to the holes of stripes giving rise to a local dipole fields with size scale of the order of the length of the stripe. Conducting electrons form Cooper pairs at the magnetic flux tube structures associated with these dipole fields. The presence of magnetic field favors Cooper pairs with spin $S = 1$. It took long time to realize that pairs of large h_{eff} magnetic flux tubes with fluxes in opposite directions are ideal for carrying Cooper pairs with members of the pair at the different flux tubes. Large spin interaction energy with magnetic field proportional to $h_{eff} = nh$ stablizes the pair.
4. Stripes can be seen as 1-D metals with de-localized electrons. The interaction responsible for the energy gap corresponds to the transversal oscillations of the magnetic flux tubes inducing oscillations of the nuclei of the stripe. These transverse phonons have spin and their exchange is a good candidate for the interaction giving rise to a mass gap. This could explain the claimed BCS type aspects of high T_c super-conductivity. Another interpretation is as spin density waves now known to be important for high temperature superconductivity.
5. Above T_c supra currents are possible only in the length scale of the flux tubes of the dipoles which is of the order of stripe length. The reconnections between neighboring flux tube structures induced by the transverse fluctuations give rise to longer flux tubes structures making possible finite conductivity. These occur with certain temperature dependent probability $p(T, L)$ depending on temperature and distance L between the stripes. By criticality $p(T, L)$ depends on the dimensionless variable $x = TL/\hbar$ only: $p = p(x)$. At critical temperature T_c transverse fluctuations have large amplitude and makes $p(x_c)$ so large that very long flux tubes are created and supra currents can run. The phenomenon is completely analogous to percolation [D13].
6. The critical temperature $T_c = x_c\hbar/L$ is predicted to be proportional to $\hbar$ and inversely proportional to L (, which is indeed to be the case). If flux tubes correspond to a large value of $\hbar$, one can understand the high value of T_c. Both Cooper pairs and magnetic flux tube structures represent dark matter in TGD sense.
7. The model allows to interpret the characteristic spectral lines in terms of the excitation energy of the transversal fluctuations and gap energy of the Cooper pair. The observed 50 meV threshold for the onset of photon absorption suggests that below T_c also $S = 0$ Cooper pairs are possible and have gap energy about 9 meV whereas $S = 1$ Cooper pairs would have gap energy about 27 meV. The flux tube model indeed predicts that $S = 0$ Cooper pairs become stable

below T_c since they cannot anymore transform to $S = 1$ pairs. Their presence could explain the BCS type aspects of high T_c super-conductivity. The estimate for $\hbar/\hbar_0 = r$ from critical temperature T_{c1} is about $r = 3$ contrary to the original expectations inspired by the model of of living system as a super-conductor suggesting much higher value. An unexpected prediction is that coherence length is actually r times longer than the coherence length predicted by conventional theory so that type I super-conductor could be in question with stripes serving as duals for the defects of type I super-conductor in nearly critical magnetic field replaced now by ferromagnetic phase.

8. TGD suggests preferred values for $r = \hbar/\hbar_0$ and the applications to bio-systems favor powers of $r = 2^{11}$. $r = 2^{11}$ predicts that electron Compton length is of order atomic size scale. Bio-superconductivity could involve electrons with $r = 2^{22}$ having size characterized by the thickness of the lipid layer of cell membrane.

At qualitative level the model explains various strange features of high T_c superconductors. One can understand the high value of T_c and ambivalent character of high T_c super conductors, the existence of pseudogap and scalings laws for observables above T_c, the role of stripes and doping and the existence of a critical doping, etc...

The model explains the observed ferromagnetic super-conductivity at quantum criticality [D78]. Since long flux tubes already exist, the overcritical transverse of fluctuations of the magnetic flux tubes inducing reconnections are now not responsible for the propagation of the super currents now. The should however provide the binding mechanism of $S = 1, L = 2$ Cooper pairs via the coupling of the fluctuations to excitation in the direction of flux tubes. I have considered effectively one-dimensional phonons in the direction of flux tubes as a candidates for this excitation. Spin density waves looks however a more realistic possibility. Also a modulated ferromagnetic phase consisting of stripes of opposite magnetization direction allows superconductivity [D78] and could be understood in terms of $S = 0$ Cooper pairs with electrons of the pair located at the neighboring stripes (flux tubes in TGD model.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

13.2 General TGD Based View About Super-Conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [D106]. These unorthodox super-conductors carry various attributes such as cuprate, organic, dichalcogenide, heavy fermion, bismute oxide, ruthenate, antiferromagnetic and ferromagnetic. Mario Rabinowitz has proposed a simple phenomenological theory of super-fluidity and super-conductivity which helps non-specialist to get a rough quantitative overall view about super-conductivity [D106].

13.2.1 Basic Phenomenology Of Super-Conductivity

The following provides the first attempt by a non-professional to form an overall view about super-conductivity.

Basic phenomenology of super-conductivity

The transition to super-conductivity occurs at critical temperature T_c and involves a complete loss of electrical resistance. Super-conductors expel magnetic fields (Meissner effect) and when the external magnetic field exceeds a critical value H_c super-conductivity is lost either completely or partially. In the transition to super-conductivity specific heat has singularity. For long time magnetism and super-conductivity were regarded as mutually exclusive phenomena but the discovery of ferromagnetic super-conductors [D78, D37] has demonstrated that reality is much more subtle.

The BCS theory developed by Bardeen, Cooper, and Schrieffer in 1957 provides a satisfactory model for low T_c super-conductivity in terms of Cooper pairs. The interactions of electrons with the crystal lattice induce electron-electron interaction binding electrons to Cooper pairs at sufficiently low temperatures. The electrons of Cooper pair are at the top of Fermi sphere (otherwise they cannot interact to form bound states) and have opposite center of mass momenta and spins. The binding creates energy gap E_g determining the critical temperature T_c. The singularity of the specific heat in the transition to super-conductivity can be understood as being due to the loss of thermally excitable degrees of freedom at critical temperature so that heat capacity is reduced exponentially. BCS theory has been successful in explaining the properties of low temperature super conductors but the high temperature super-conductors discovered in 1986 and other non-orthodox superconductors discovered later remain a challenge for theorists.

The reasons why magnetic fields tend to destroy super-conductivity is easy to understand. Lorentz force induces opposite forces to the electrons of Cooper pair since the momenta are opposite. Magnetic field tends also to turn the spins in the same direction. The super-conductivity is destroyed in fields for which the interaction energy of magnetic moment of electron with field is of the same order of magnitude as gap energy $E_g \sim T_c$: $e\hbar H_c/2m \sim T_c$.

If spins are parallel, the situation changes since only Lorentz force tends to destroy the Cooper pair. In high T_c super-conductors this is indeed the case: electrons are in spin triplet state ($S = 1$) and the net orbital angular momentum of Cooper pair is $L = 2$. The fact that orbital state is not $L = 0$ state makes high T_c super-conductors much more fragile to the destructive effect of impurities than conventional super-conductors (due to the magnetic exchange force between electrons responsible for magnetism). Also the Cooper pairs of ^3He superfluid are in spin triplet state but have $S = 0$.

The observation that spin triplet Cooper pairs might be possible in ferro-magnets stimulates the question whether ferromagnetism and super-conductivity might tolerate each other after all, and the answer is affirmative [D37]. The article [D78] provides an enjoyable summary of experimental discoveries.

Basic parameters of super-conductors from universality?

Super conductors are characterized by certain basic parameters such as critical temperature T_c and critical magnetic field H_c, densities n_c and n of Cooper pairs and conduction electrons, gap energy E_g, correlation length ξ and magnetic penetration length λ. The super-conductors are highly complex systems and calculation of these parameters from BCS theory is either difficult or impossible.

It has been suggested [D106] that these parameters might be more or less universal so that they would not depend on the specific properties of the interaction responsible for the formation of Cooper pairs. The motivation comes from the fact that the properties of ordinary Bose-Einstein condensates do not depend on the details of interactions. This raises the hope that these parameters might be expressible in terms of some basic parameters such as T_c and the density of conduction electrons allowing to deduce Fermi energy E_F and Fermi momentum k_F if Fermi surface is sphere. In [D106] formulas for the basic parameters are indeed suggested based on this of argumentation assuming that Cooper pairs form a Bose-Einstein condensate.

1. The most important parameters are critical temperature T_c and critical magnetic field H_c in principle expressible in terms of gap energy. In [D106] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

$$\lambda \geq 2d = 2(\frac{n_c}{g})^{-1/D} \tag{13.2.1}$$

guaranteeing the quantum overlap of Cooper pairs. Here n_c is the density of Bose-Einstein condensate of Cooper pairs and g is the number of spin states and D the dimension of the condensate. This condition follows also from the requirement that the number of particles per energy level is larger than one (Bose-Einstein condensation).

Identifying this expression with the de Broglie wavelength $\lambda = \hbar/\sqrt{2mE}$ at thermal energy $E = (D/2)T_c$, where D is the number of degrees of freedom, one obtains

$$T_c \leq \frac{h^2}{4Dm}(\frac{n_c}{g})^{2/D} \ . \tag{13.2.2}$$

m denotes the effective mass of super current carrier and for electron it can be even 100 times the bare mass of electron. The reason is that the electron moves is somewhat like a person trying to move in a dense crowd of people, and is accompanied by a cloud of charge carriers increasing its effective inertia. In this equation one can consider the possibility that Planck constant is not the ordinary one. This obviously increases the critical temperature unless n_c is scaled down in same proportion in the phase transition to large $\hbar$ phase.

2. The density of n_c Cooper pairs can be estimated as the number of fermions in Fermi shell at E_F having width Δk deducible from kT_c. For $D = 3$-dimensional spherical Fermi surface one has

$$\begin{aligned} n_c &= \frac{1}{2}\frac{4\pi k_F^2 \Delta k}{\frac{4}{3}\pi k_F^3} n \ , \\ kT_c &= E_F - E(k_F - \Delta k) \simeq \frac{h^2 k_F \Delta k}{m} \ . \end{aligned} \tag{13.2.3}$$

Analogous expressions can be deduced in $D = 2$- and $D = 1$-dimensional cases and one has

$$n_c(D) = \frac{D}{2}\frac{T_c}{E_F} n(D) \ . \tag{13.2.4}$$

The dimensionless coefficient is expressible solely in terms of n and effective mass m. In [D106] it is demonstrated that the inequality 13.2.2 replaced with equality when combined with 13.2.4 gives a satisfactory fit for 16 super-conductors used as a sample.

Note that the Planck constant appearing in E_F and T_c in Eq. 13.2.4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations 13.2.2 and 13.2.4 are consistent within orders of magnitudes. For $D = 2$, which corresponds to high T_c superconductivity, the substitution of n_c from Eq. 13.2.4 to Eq. 13.2.2 gives a consistency condition from which n_c disappears completely. The condition reads as

$$n\lambda_F^2 = \pi = 4g \ .$$

Obviously the equation is not completely consistent.

3. The magnetic penetration length λ is expressible in terms of density n_c of Cooper pairs as

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} \ . \tag{13.2.5}$$

The ratio $\kappa \equiv \frac{\lambda}{\xi}$ determines the type of the super conductor. For $\kappa < \frac{1}{\sqrt{2}}$ one has type I super conductor with defects having negative surface energy. For $\kappa \geq \frac{1}{\sqrt{2}}$ one has type II super conductor and defects have positive surface energy. Super-conductors of type I this results in complex stripe like flux patterns maximizing their area near criticality. The super-conductors of type II have $\kappa > 1/\sqrt{2}$ and the surface energy is positive so that the flux penetrates as flux quanta minimizing their area at lower critical value H_{c_1} of magnetic field and completely at higher critical value H_{c_2} of magnetic field. The flux quanta contain a core of size ξ carrying quantized magnetic flux.

4. Quantum coherence length ξ can be roughly interpreted as the size of the Cooper pair or as the size of the region where it is sensible to speak about the phase of wave function of Cooper pair. For larger separations the phases of wave functions are un-correlated. The values of ξ vary in the range $10^3 - 10^4$ Angstrom for low T_c super-conductors and in the range $5 - 20$ Angstrom for high T_c super-conductors (assuming that they correspond to ordinary $\hbar$!) the ratio of these coherence lengths varies in the range $[50 - 2000]$, with upper bound corresponding to $n_F = 2^{11}$ for $\hbar$. This would give range $1 - 2$ microns for the coherence lengths of high T_c super-conductors with lowest values of coherence lengths corresponding to the highest values of coherence lengths for low temperatures super conductors.

Uncertainty Principle $\delta E \delta t = \hbar/2$ using $\delta E = E_g \equiv 2\Delta$, $\delta t = \xi/v_F$, gives an order of magnitude estimate for ξ differing only by a numerical factor from the result of a rigorous calculation given by

$$\xi = \frac{4\hbar v_F}{E_g} . \tag{13.2.6}$$

E_g is apart from a numerical constant equal to T_c: $E_g = nT_c$. Using the expression for v_F and T_c in terms of the density of electrons, one can express also ξ in terms of density of electrons.

For instance, BCS theory predicts $n = 3.52$ for metallic super-conductors and $n = 8$ holds true for cuprates [D106]. For cuprates one obtains $\xi = 2n^{-1/3}$ [D106]. This expression can be criticized since cuprates are Mott insulators and it is not at all clear whether a description as Fermi gas makes sense. The fact that high T_c super-conductivity involves breakdown of anti-ferromagnetic order might justify the use of Fermi gas description for conducting holes resulting in the doping.

For large $\hbar$ the value of ξ would scale up dramatically if deduced theoretically from experimental data using this kind of expression. If the estimates for ξ are deduced from v_F and T_c purely calculationally as seems to be the case, the actual coherence lengths would be scaled up by a factor $\hbar/\hbar_0 = n_F$ if high T_c super-conductors correspond to large $\hbar$ phase. As also found that this would also allow to understand the high critical temperature.

13.2.2 Universality Of The Parameters In TGD Framework

Universality idea conforms with quantum criticality of TGD Universe. The possibility to express everything in terms of density of critical temperature coding for the dynamics of Cooper pair formation and the density charge carriers would make it also easy to understand how p-adic scalings and transitions to large $\hbar$ phase affect the basic parameters. The possible problem is that the replacement of inequality of Eq. 13.2.2 with equality need not be sensible for large $\hbar$ phases. It will be found that in many-sheeted space-time T_c does not directly correspond to the gap energy and the universality of the critical temperature follows from the p-adic length scale hypothesis.

The effect of p-adic scaling on the parameters of super-conductors

p-Adic fractality expresses as $n \propto 1/L^3(k)$ would allow to deduce the behavior of the various parameters as function of the p-adic length scale and naïve scaling laws would result. For instance, E_g and T_c would scale as $1/L^2(k)$ if one assumes that the density n of particles at larger space-time sheets scales p-adically as $1/L^3(k)$. The basic implication would be that the density of Cooper pairs and thus also T_c would be reduced very rapidly as a function of the p-adic length scale. Without thermal isolation between these space-time sheets and hight temperature space-time sheets there would not be much hopes about high T_c super-conductivity.

In the scaling of Planck constant basic length scales scale up and the overlap criterion for super-conductivity becomes easy to satisfy unless the density of electrons is reduced too dramatically. As found, also the critical temperature scales up so that there are excellent hopes of obtain high T_c super-conductor in this manner. The claimed short correlation lengths are not a problem since they are calculational quantities.

It is of interest to study the behavior of the various parameters in the transition to the possibly existing large $\hbar$ variant of super-conducting electrons. Also small scalings of $\hbar$ are possible and the considerations to follow generalize trivially to this case. Under what conditions the behavior of the various parameters in the transition to large $\hbar$ phase is dictated by simple scaling laws?

1. *Scaling of T_c and E_g*

T_c and E_g remain invariant if E_g corresponds to a purely classical interaction energy remaining invariant under the scaling of $\hbar$. This is not the case for BCS super-conductors for which the gap energy E_g has the following expression.

$$\begin{aligned} E_g &= \hbar\omega_c exp(-1/X) \ , \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \\ \omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} \ . \end{aligned} \tag{13.2.7}$$

Here ω_c is the width of energy region near E_F for which "phonon" exchange interaction is effective. n_n denotes the density of nuclei and c_s denotes sound velocity.

$N(E_F)$ is the total number of electrons at the super-conducting space-time sheet. U_0 would be the parameter characterizing the interaction strength of of electrons of Cooper pair and should not depend on $\hbar$. For a structure of size $L \sim 1\ \mu$ m one would have $X \sim n_a 10^{12}\frac{U_0}{E_F}$, n_a being the number of exotic electrons per atom, so that rather weak interaction energy U_0 can give rise to $E_g \sim \omega_c$.

The expression of ω_c reduces to Debye frequency ω_D in BCS theory of ordinary super conductivity. If c_s is proportional to thermal velocity $\sqrt{T_c/m}$ at criticality and if n_n remains invariant in the scaling of $\hbar$, Debye energy scales up as $\hbar$. This can imply that $E_g > E_F$ condition making scaling non-sensible unless one has $E_g \ll E_F$ holding true for low T_c super-conductors. This kind of situation would *not* require large $\hbar$ phase for electrons. What would be needed that nuclei and phonon space-time sheets correspond to large $\hbar$ phase.

What one can hope is that E_g scales as $\hbar$ so that high T_c superconductor would result and the scaled up T_c would be above room temperature for $T_c > .15$ K. If electron is in ordinary phase X is automatically invariant in the scaling of $\hbar$. If not, the invariance reduces to the invariance of U_0 and E_F under the scaling of $\hbar$. If n scales like $1/\hbar^D$, E_F and thus X remain invariant. U_0 as a simplified parameterization for the interaction potential expressible as a tree level Feynman diagram is expected to be in a good approximation independent of $\hbar$.

It will be found that in high T_c super-conductors, which seem to be quantum critical, a high T_c variant of phonon mediated superconductivity and exotic superconductivity could be competing. This would suggest that the phonon mediated superconductivity corresponds to a large $\hbar$ phase for nuclei scaling ω_D and T_c by a factor $r = \hbar/\hbar_0$.

Since the total number $N(E_F)$ of electrons at larger space-time sheet behaves as $N(E_F) \propto E_F^{D/2}$, where D is the effective dimension of the system, the quantity $1/X \propto E_F/n(E_F)$ appearing in the expressions of the gap energy behaves as $1/X \propto E_F^{-D/2+1}$. This means that at the limit of vanishing electron density $D = 3$ gap energy goes exponentially to zero, for $D = 2$ it is constant, and for $D = 1$ it goes zero at the limit of small electron number so that the formula for gap energy reduces to $E_g \simeq \omega_c$. These observations suggests that the super-conductivity in question should be 2- or 1-dimensional phenomenon as in case of magnetic walls and flux tubes.

2. Scaling of ξ and λ

If n_c for high T_c super-conductor scales as $1/\hbar^D$ one would have $\lambda \propto \hbar^{D/2}$. High T_c property however suggests that the scaling is weaker. ξ would scale as $\hbar$ for given v_F and T_c. For $D = 2$ case the this would suggest that high T_c super-conductors are of type I rather than type II as they would be for ordinary $\hbar$. This conforms with the quantum criticality which would be counterpart of critical behavior of super-conductors of type I in nearly critical magnetic field.

3. Scaling of H_c and B

The critical magnetization is given by

$$H_c(T) = \frac{\Phi_0}{\sqrt{8}\pi\xi(T)\lambda(T)} \ , \tag{13.2.8}$$

where Φ_0 is the flux quantum of magnetic field proportional to $\hbar$. For $D = 2$ and $n_c \propto \hbar^{-2}$ $H_c(T)$ would not depend on the value of $\hbar$. For the more physical dependence $n_c \propto \hbar^{-2+\epsilon}$ one would have $H_c(T) \propto \hbar^{-\epsilon}$. Hence the strength of the critical magnetization would be reduced by a factor $2^{-11\epsilon}$ in the transition to the large $\hbar$ phase with $n_F = 2^{-11}$.

Magnetic flux quantization condition is replaced by

$$\int 2eBdS = n\hbar 2\pi \quad . \tag{13.2.9}$$

B denotes the magnetic field inside super-conductor different from its value outside the super-conductor. By the quantization of flux for the non-super-conducting core of radius ξ in the case of super-conductors of type II $eB = \hbar/\xi^2$ holds true so that B would become very strong since the thickness of flux tube would remain unchanged in the scaling.

13.2.3 Quantum Criticality And Super-Conductivity

The notion of quantum criticality has been already discussed in introduction. An interesting prediction of the quantum criticality of entire Universe also gives naturally rise to a hierarchy of macroscopic quantum phases since the quantum fluctuations at criticality at a given level can give rise to higher level macroscopic quantum phases at the next level. A metaphor for this is a fractal cusp catastrophe for which the lines corresponding to the boundaries of cusp region reveal new cusp catastrophes corresponding to quantum critical systems characterized by an increasing length scale of quantum fluctuations.

Dark matter hierarchy could correspond to this kind of hierarchy of phases and long ranged quantum slow fluctuations would correspond to space-time sheets with increasing values of $\hbar$ and size. Evolution as the emergence of modules from which higher structures serving as modules at the next level would correspond to this hierarchy. Mandelbrot fractal with inversion analogous to a transformation permuting the interior and exterior of sphere with zooming revealing new worlds in Mandelbrot fractal replaced with its inverse would be a good metaphor for what quantum criticality would mean in TGD framework.

How the quantum criticality of superconductors relates to TGD quantum criticality

There is empirical support that super-conductivity in high T_c super-conductors and ferromagnetic systems [D78, D55] is made possible by quantum criticality [D127]. In the experimental situation quantum criticality means that at sufficiently low temperatures quantum rather than thermal fluctuations are able to induce phase transitions. Quantum criticality manifests itself as fractality and simple scaling laws for various physical observables like resistance in a finite temperature range and also above the critical temperature. This distinguishes sharply between quantum critical super conductivity from BCS type super-conductivity. Quantum critical super-conductivity also exists in a finite temperature range and involves the competition between two phases.

The absolute quantum criticality of the TGD Universe maps to the quantum criticality of subsystems, which is broken by finite temperature effects bringing dissipation and freezing of quantum fluctuations above length and time scales determined by the temperature so that scaling laws hold true only in a finite temperature range.

Reader has probably already asked what quantum criticality precisely means. What are the phases which compete? An interesting hypothesis is that quantum criticality actually corresponds to criticality with respect to the phase transition changing the value of Planck constant so that the competing phases would correspond to different values of $\hbar$. In the case of high T_c super-conductors (anti-ferromagnets) the fluctuations can be assigned to the magnetic flux tubes of the dipole field patterns generated by rows of holes with same spin direction assignable to the stripes. Below T_c fluctuations induce reconnections of the flux tubes and a formation of very long flux tubes and make possible for the supra currents to flow in long length scales below T_c. Percolation type phenomenon is in question. The fluctuations of the flux tubes below $T_{c1} > T_c$ induce transversal phonons generating the energy gap for $S = 1$ Cooper pairs. $S = 0$ Cooper pairs are predicted to stabilize below T_c.

Scaling up of de Broglie wave lengths and criterion for quantum overlap

Compton lengths and de Broglie wavelengths are scaled up by an integer n, whose preferred values correspond to $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes. In particular, $n_F = 2^{k11}$ seem to be favored in living matter. The scaling up means that the overlap condition $\lambda \geq 2d$ for the formation of Bose-Einstein condensate can be satisfied and the formation of Cooper pairs becomes possible. Thus a hierarchy of large $\hbar$ super-conductivities would be associated with to the dark variants of ordinary particles having essentially same masses as the ordinary particles.

Unless one assumes fractionization, the invariance of $E_F \propto \hbar_{eff}^2 n^{2/3}$ in $\hbar$ increasing transition would require that the density of Cooper pairs in large $\hbar$ phase is scaled down by an appropriate factor. This means that supra current intensities, which are certainly measurable quantities, are also scaled down. Of course, it could happen that E_F is scaled up and this would conform with the scaling of the gap energy.

Quantum critical super-conductors in TGD framework

For quantum critical super-conductivity in heavy fermions systems, a small variation of pressure near quantum criticality can destroy ferromagnetic (anti-ferromagnetic) order so that Curie (Neel) temperature goes to zero. The prevailing spin fluctuation theory [D33] assumes that these transitions are induced by long ranged and slow spin fluctuations at critical pressure P_c. These fluctuations make and break Cooper pairs so that the idea of super-conductivity restricted around critical point is indeed conceivable.

Heavy fermion systems, such as cerium-indium alloy $CeIn_3$ are very sensitive to pressures and a tiny variation of density can drastically modify the low temperature properties of the systems. Also other systems of this kind, such as $CeCu_2Ge_2$, $CeIn_3$, $CePd_2Si_2$ are known [D78, D37]. In these cases super-conductivity appears around anti-ferromagnetic quantum critical point.

The last experimental breakthrough in quantum critical super-conductivity was made in Grenoble [D55]. URhGe alloy becomes super-conducting at $T_c = .280$ K, loses its super-conductivity at $H_c = 2$ Tesla, and becomes again super-conducting at $H_c = 12$ Tesla and loses its super-conductivity again at $H = 13$ Tesla. The interpretation is in terms of a phase transition changing the magnetic order inducing the long range spin fluctuations.

TGD based models of atomic nucleus [K103] and condensed matter [K42] assume that weak gauge bosons with Compton length of order atomic radius play an essential role in the nuclear and condensed matter physics. The assumption that condensed matter nuclei possess anomalous weak charges explains the repulsive core of potential in van der Waals equation and the very low compressibility of condensed matter phase as well as various anomalous properties of water phase, provide a mechanism of cold fusion and sono-fusion, etc. [K42, K40]. The pressure sensitivity of these systems would directly reflect the physics of exotic quarks and electro-weak gauge bosons. A possible mechanism behind the phase transition to super-conductivity could be the scaling up of the sizes of the space-time sheets of nuclei.

Also the electrons of Cooper pair (and only these) could make a transition to large $\hbar$ phase. This transition would induce quantum overlap having geometric overlap as a space-time correlate. The formation of flux tubes between neighboring atoms would be part of the mechanism. For instance, the criticality condition $4n^2\alpha = 1$ for BE condensate of n Cooper pairs would give $n = 6$ for the size of a higher level quantum unit possibly formed formed from Cooper pairs. If one does not assume invariance of energies obtained by fractionization of principal quantum number, this transition has dramatic effects on the spectrum of atomic binding energies scaling as $1/\hbar^2$ and practically universal spectrum of atomic energies would result [K40] not depending much on nuclear charge. It seems that this prediction is non-physical.

Quantum critical super-conductors resemble superconductors of type I with $\lambda \ll \xi$ for which defects near thermodynamical criticality are complex structures looking locally like stripes of thickness λ. These structures are however dynamical in super-conducting phase. Quite generally, long range quantum fluctuations due to the presence of two competing phases would manifest as complex dynamical structures consisting of stripes and their boundaries. These patterns are dynamical rather than static as in the case of ordinary spin glass phase so that quantum spin glass or 4-D spin glass is a more appropriate term. The breaking of classical non-determinism for vacuum extremals indeed makes possible space-time correlates for quantum non-determinism and this makes TGD Universe a 4-dimensional quantum spin glass.

Could quantum criticality make possible new kinds of high T_c super-conductors?

The transition to large $\hbar = r\hbar_0$ phase increases various length scales by r and makes possible long range correlations even at high temperatures. Hence the question is whether large $\hbar$ phase could correspond to ordinary high T_c super-conductivity. If this were the case in the case of ordinary high T_c super-conductors, the actual value of coherence length ξ would vary in the range $5-20$ Angstrom scaled up by a factor r. For effectively D-dimensional super-conductor The density of Cooper pairs would be scaled down by an immensely small factor $1/r^D$ from its value deduced from Fermi energy.

Large $\hbar$ phase for some nuclei might be involved and make possible large space-time sheets of size at least of order of ξ at which conduction electrons forming Cooper pairs would topologically condense like quarks around hadronic space-time sheets (in [K42] a model of water as a partially dark matter with one fourth of hydrogen ions in large $\hbar$ phase is developed).

Consider for a moment the science fictive possibility that super conducting electrons for some quantum critical super-conductors to be discovered or already discovered correspond to large $\hbar$ phase with $\hbar = r\hbar_0$ keeping in mind that this affects only quantum corrections in perturbative approach but not the lowest order classical predictions of quantum theory. For $r \simeq n2^{k11}$ with $(n,k) = (1,1)$ the size of magnetic body would be $L(149) = 5$ nm, the thickness of the lipid layer of cell membrane. For $(n,k) = (1,2)$ the size would be $L(171) = 10$ μm, cell size. If the density of Cooper pairs is of same order of magnitude as in case of ordinary super conductors, the critical temperature is scaled up by 2^{k11}. Already for $k = 1$ the critical temperature of 1 K would be scaled up to $4n^2 \times 10^6$ K if n_c is not changed. This assumption is not consistent with the assumption that Fermi energy remains non-relativistic. For $n = 1$ $T_c = 400$ K would be achieved for $n_c \rightarrow 10^{-6}n_c$, which looks rather reasonable since Fermi energy transforms as $E_F \rightarrow 8 \times 10^3 E_F$ and remains non-relativistic. H_c would scale down as $1/\hbar$ and for $H_c = .1$ Tesla the scaled down critical field would be $H_c = .5 \times 10^{-4}$ Tesla, which corresponds to the nominal value of the Earth's magnetic field.

Quantum critical super-conductors become especially interesting if one accepts the identification of living matter as ordinary matter quantum controlled by macroscopically quantum coherent dark matter. One of the basic hypothesis of TGD inspired theory of living matter is that the magnetic flux tubes of the Earth's magnetic field carry a super-conducting phase and the spin triplet Cooper pairs of electrons in large $\hbar$ phase might realize this dream. That the value of Earth's magnetic field is near to its critical value could have also biological implications.

13.2.4 Space-Time Description Of The Mechanisms OfSuper-Conductivity

The application of ideas about dark matter to nuclear physics and condensed matter suggests that dark color and weak forces should be an essential element of the chemistry and condensed matter physics. The continual discovery of new super-conductors, in particular of quantum critical superconductors, suggests that super-conductivity is not well understood. Hence super-conductivity provides an obvious test for these ideas. In particular, the idea that wormhole contacts regarded as parton pairs living at two space-time sheets simultaneously, provides an attractive universal mechanism for the formation of Cooper pairs and is not so far-fetched as it might sound first.

Leading questions

It is good to begin with a series of leading questions. The first group of questions is inspired by experimental facts about super-conductors combined with TGD context.

1. The work of Rabinowitch [D106] suggests that that the basic parameters of super-conductors might be rather universal and depend on T_c and conduction electron density only and be to a high degree independent of the mechanism of super-conductivity. This is in a sharp contrast to the complexity of even BCS model with its somewhat misty description of the phonon exchange mechanism.
   Questions: Could there exist a simple universal description of various kinds of super-conductivities?

2. The new super-conductors possess relatively complex chemistry and lattice structure.
Questions: Could it be that complex chemistry and lattice structure makes possible something very simple describable in terms of quantum criticality. Could it be that the transversal oscillations magnetic flux tubes allow to understand the formation of Cooper pairs at T_{c1} and their reconnections generating very long flux tubes the emergence of supra currents at T_c?

3. The effective masses of electrons in ferromagnetic super-conductors are in the range of 10-100 electron masses [D78] and this forces to question the idea that ordinary Cooper pairs are current carriers.
Questions: Can one consider the possibility that the p-adic length scale of say electron can vary so that the actual mass of electron could be large in condensed matter systems? For quarks and neutrinos this seems to be the case [K61, K71]. Could it be that the Gaussian Mersennes $(1+i)^k-1$, $k = 151, 157, 163, 167$ spanning the p-adic lengthscale range 10 nm-2.5 μm very relevant from the point of view of biology correspond to p-adic length especially relevant for super-conductivity?

Second group of questions is inspired by quantum classical correspondence.

1. Quantum classical correspondence in its strongest form requires that bound state formation involves the generation of flux tubes between bound particles. The weaker form of the principle requires that the particles are topologically condensed at same space-time sheet. In the case of Cooper pairs in ordinary superconductors the length of join along boundaries bonds between electrons should be of order 10^3-10^4 Angstroms. This looks rather strange and it seems that the latter option is more sensible.
Questions: Could quantum classical correspondence help to identify the mechanism giving rise to Cooper pairs?

2. Quantum classical correspondence forces to ask for the space-time correlates for the existing quantum description of phonons.
Questions: Can one assign space-time sheets with phonons or should one identify them as oscillations of say space-time sheets at which atoms are condensed? Or should the microscopic description of phonons in atomic length scales rely on the oscillations of wormhole contacts connecting atomic space-time sheets to these larger space-time sheets? The identification of phonons as wormhole contacts would be completely analogous to the similar identification of gauge bosons except that phonons would appear at higher levels of the hierarchy of space-time sheets and would be emergent in this sense. As a matter fact, even gauge bosons as pairs of fermion and anti-fermion are emergent structures in TGD framework and this plays fundamental role in the construction of QFT limit of TGD in which bosonic part of action is generated radiatively so that all coupling constants follow as predictions [**?**]. Could Bose-Einstein condensates of wormhole contacts be relevant for the description of super-conductors or more general macroscopic quantum phases?

The third group of questions is inspired by the new physics predicted or by TGD.

1. TGD predicts a hierarchy of macroscopic quantum phases with large Planck constant.
Questions: Could large values of Planck constant make possible exotic electronic super-conductivities? Could even nuclei possess large $\hbar$ (super-fluidity)?

2. TGD predicts that classical color force and its quantal counterpart are present in all length scales.
Questions: Could color force, say color magnetic force which play some role in the formation of Cooper pair. The simplest model of pair is as a space-time sheet with size of order ξ so that the electrons could be "outside" the background space-time. Could the Coulomb interaction energy of electrons with positively charged wormhole throats carrying parton numbers and feeding em gauge flux to the large space-time sheet be responsible for the gap energy? Could wormhole throats carry also quark quantum numbers. In the case of single electron condensed to single space-time sheet the em flux could be indeed fed by a pair of $u\overline{u}$ and $\overline{d}d$ type wormhole contacts to a larger space-time sheet. Could the wormhole contacts have a net color? Could the electron space-time sheets of the Cooper pair be connected by long color flux tubes to give color singlets so that dark color force would be ultimately responsible for the stability of Cooper pair?

3. Suppose that one takes seriously the ideas about the possibility of dark weak interactions with the Compton scale of weak bosons scaled up to say atomic length scale so that weak bosons are effectively massless below this length scale [K42].
   Questions: Could the dark weak length scale which is of order atomic size replace lattice constant in the expression of sound velocity? What is the space-time correlate for sound velocity?

Photon massivation, coherent states of Cooper pairs, and wormhole contacts

The existence of wormhole contacts is one of the most stunning predictions of TGD. First I realized that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts. Then came the idea that Higgs particle could be identified as a wormhole contact. It was soon followed by the identification all bosonic states as wormhole contacts [K61]. Finally I understood that this applies also to their super-symmetric partners, which can be also fermion [**?**]. Fermions and their super-partners would in turn correspond to wormhole throats resulting in the topological condensation of small deformations of CP_2 type vacuum extremals with Euclidian signature of metric to the background space-time sheet. This framework opens the doors for more concrete models of also super-conductivity involving the effective massivation of photons as one important aspect in the case of ordinary super-conductors.

There are two types of wormhole contacts. Those of first type correspond to elementary bosons. Wormhole contacts of second kind are generated in the topological condensation of space-time sheets carrying matter and form a hierarchy. Classical radiation fields realized in TGD framework as oscillations of space-time sheets would generate wormhole contacts as the oscillating space-time sheet develops contacts with parallel space-time sheets (recall that the distance between space-time sheets is of order CP_2 size). This realizes the correspondence between fields and quanta geometrically. Phonons could also correspond to wormhole contacts of this kind since they mediate acoustic oscillations between space-time sheets and the description of the phonon mediated interaction between electrons in terms of wormhole contacts might be useful also in the case of super-conductivity. Bose-Einstein condensates of wormhole contacts might be highly relevant for the formation of macroscopic quantum phases. The formation of a coherent state of wormhole contacts would be the counterpart for the vacuum expectation value of Higgs.

The notions of coherent states of Cooper pairs and of charged Higgs challenge the conservation of electromagnetic charge. The following argument however suggests that coherent states of wormhole contacts form only a part of the description of ordinary super-conductivity. The basic observation is that wormhole contacts with vanishing fermion number define space-time correlates for Higgs type particle with fermion and anti-fermion numbers at light-like throats of the contact.

The ideas that a genuine Higgs type photon massivation is involved with super-conductivity and that coherent states of Cooper pairs really make sense are somewhat questionable since the conservation of charge and fermion number is lost for coherent states. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. These interpretational problems can be resolved elegantly in zero energy ontology [K28] in which the total conserved quantum numbers of quantum state are vanishing. In this picture the energy, fermion number, and total charge of any positive energy state are compensated by opposite quantum numbers of the negative energy state in geometric future. This makes possible to speak about superpositions of Cooper pairs and charged Higgs bosons separately in positive energy sector.

If this picture is taken seriously, super-conductivity can be seen as providing a direct support for both the hierarchy of scaled variants of standard model physics and for the zero energy ontology.

Space-time correlate for quantum critical superconductivity

The explicit model for high T_c super-conductivity relies on quantum criticality involving long ranged quantum fluctuations inducing reconnection of flux tubes of local (color) magnetic fields associated with parallel spins associated with stripes to form long flux tubes serving as wires along which Cooper pairs flow. Essentially [D13] [D13] type phenomenon would be in question. The role of the doping by holes is to make room for Cooper pairs to propagate by the reconnection mechanism: otherwise Fermi statistics would prevent the propagation. Too much doping reduces the number of current carriers, too little doping leaves too little room so that there exists some optimal doping. In the case of high T_c super-conductors quantum criticality corresponds to a quite wide temperature range, which provides support for the quantum criticality of TGD Universe. The probability $p(T)$ for the formation of reconnections is what matters and exceeds the critical value at T_c.

13.2.5 Super-Conductivity At Magnetic Flux Tubes

Super-conductivity at the magnetic flux tubes of magnetic flux quanta is one the basic hypothesis of the TGD based model of living matter. There is also evidence for magnetically mediated super-conductivity in extremely pure samples [D57]. The magnetic coupling was only observed at lattice densities close to the critical density at which long-range magnetic order is suppressed. Quantum criticality that long flux tubes serve as pathways along which Cooper pairs can propagate. In anti-ferromagnetic phase these pathways are short-circuited to closed flux tubes of local magnetic fields.

Almost the same model as in the case of high T_c and quantum critical super-conductivity applies to the magnetic flux tubes. Now the flux quantum contains BE condensate of exotic Cooper pairs interacting with wormhole contacts feeding the gauge flux of Cooper pairs from the magnetic flux quantum to a larger space-time sheet. The interaction of spin 1 Cooper pairs with the magnetic field of flux quantum orients their spins in the same direction. Large value of $\hbar$ guarantees thermal stability even in the case that different space-time sheets are not thermally isolated.

The understanding of gap energy is not obvious. The transversal oscillations of magnetic flux tubes generated by spin flips of electrons define the most plausible candidate for the counterpart of phonons. In this framework phonon like states identified as wormhole contacts would be created by the oscillations of flux tubes and would be a secondary phenomenon.

Large values of $\hbar$ allow to consider not only the Cooper pairs of electrons but also of protons and fermionic ions. Since the critical temperature for the formation of Cooper pairs is inversely proportional to the mass of the charge carrier, the replacement of electron with proton or ion would require a scaling of $\hbar$. If T_{c1} is proportional to $\hbar^2$, this requires scaling by $(m_p/m_e)^{1/2}$. For $T_{c1} \propto \hbar$ scaling by $m_p/m_e \simeq 2^{11}$ is required. This inspired idea that powers of 2^{11} could define favored values of $\hbar/\hbar_0$. This hypothesis is however rather ad hoc and turned out to be too restrictive.

Besides Cooper pairs also Bose-Einstein condensates of bosonic ions are possible in large $\hbar$ phase and would give rise to super-conductivity. TGD inspired nuclear physics predicts the existence of exotic bosonic counterparts of fermionic nuclei with given (A, Z) [L4], [L4].

Superconductors at the flux quanta of the Earth's magnetic field

Magnetic flux tubes and magnetic walls are the most natural candidates for super-conducting structures with spin triplet Cooper pairs. Indeed, experimental evidence relating to the interaction of ELF em radiation with living matter suggests that bio-super-conductors are effectively 1- or 2-dimensional. $D \leq 2$-dimensionality is guaranteed by the presence of the flux tubes or flux walls of, say, the magnetic field of Earth in which charge carries form bound states and the system is equivalent with a harmonic oscillator in transversal degrees of freedom.

The effect of Earth's magnetic field is completely negligible at the atomic space-time sheets and cannot make super conductor 1-dimensional. At cellular sized space-time sheets magnetic field makes possible transversal the confinement of the electron Cooper pairs in harmonic oscillator states but does not explain energy gap which should be at the top of 1-D Fermi surface. The critical temperature extremely low for ordinary value of $\hbar$ and either thermal isolation between space-time sheets or large value of $\hbar$ can save the situation.

An essential element of the picture is that topological quantization of the magnetic flux tubes occurs. In fact, the flux tubes of Earth's magnetic field have thickness of order cell size from the quantization of magnetic flux. The observations about the effects of ELF em fields on bio-matter [J8] suggest that similar mechanism is at work also for ions and in fact give very strong support for bio-super conductivity based on the proposed mechanism.

Energy gaps for superconducting magnetic flux tubes and walls

Besides the formation of Cooper pairs also the Bose-Einstein condensation of charge carriers to the ground state is needed in order to have a supra current. The stability of Bose-Einstein condensate requires an energy gap $E_{g,BE}$ which must be larger than the temperature at the magnetic flux tube.

Several energies must be considered in order to understand $E_{g,BE}$.

1. The Coulombic binding energy of Cooper pairs with the wormhole contacts feeding the em flux from magnetic flux tube to a larger space-time sheet defines an energy gap which is expected to be of order $E_{g,BE} = \alpha/L(k)$ giving $E_g \sim 10^{-3}$ eV for $L(167) = 2.5$ μm giving a rough estimate for the thickness of the magnetic flux tube of the Earth's magnetic field $B = .5 \times 10^{-4}$ Tesla.
2. In longitudinal degrees of freedom of the flux tube Cooper pairs can be described as particles in a one-dimensional box and the gap is characterized by the length L of the magnetic flux tube and the value of $\hbar$. In longitudinal degrees of freedom the difference between $n = 2$ and $n = 1$ states is given by $E_0(k_2) = 3h^2/4m_eL^2(k_2)$. Translational energy gap $E_g = 3E_0(k_2) = 3h^2/4m_eL^2(k_2)$ is smaller than the effective energy gap $E_0(k_1) - E_0(k_2) = h^2/4m_eL^2(k_1) - h^2/4m_eL^2(k_2)$ for $k_1 > k_2 + 2$ and identical with it for $k_1 = k_2 + 2$. For $L(k_2 = 151)$ the zero point kinetic energy is given by $E_0(151) = 20.8$ meV so that $E_{g,BE}$ corresponds roughly to a temperature of 180 K. For magnetic walls the corresponding temperature would be scaled by a factor of two to 360 K and is above room temperature.
3. Second troublesome energy gap relates to the interaction energy with the magnetic field. The magnetic interaction energy E_m of Cooper pair with the magnetic field consists of cyclotron term $E_c = n\hbar eB/m_e$ and spin-interaction term which is present only for spin triplet case and is given by $E_s = \pm\hbar eB/m_e$ depending on the orientation of the net spin with magnetic field. In the magnetic field $B_{end} = 2B_E/5 = .2$ Gauss ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field) explaining the effects of ELF em fields on vertebrate brain, this energy scale is $\sim 10^{-9}$ eV for $\hbar_0$ and $\sim 1.6 \times 10^{-5}$ eV for $\hbar = 2^{14} \times \hbar_0$.

The smallness of translational and magnetic energy gaps in the case of Cooper pairs at Earth's magnetic field could be seen as a serious obstacle.

1. Thermal isolation between different space-time sheets provides one possible resolution of the problem. The stability of the Bose-Einstein condensation is guaranteed by the thermal isolation of space-time if the temperature at the magnetic flux tube is below E_m. This can be achieved in all length scales if the temperature scales as the zero point kinetic energy in transversal degrees of freedom since it scales in the same manner as magnetic interaction energy.
2. The transition to large $\hbar$ phase could provide a more elegant way out of the difficulty. The criterion for a sequence of transitions to a large $\hbar$ phase could be easily satisfied if there is a large number of charge Cooper pairs at the magnetic flux tube. Kinetic energy gap remains invariant if the length of the flux tube scales as $\hbar$. If the magnetic flux is quantized as a multiple of $\hbar$ and flux tube thickness scales as $\hbar^2$, B must scale as $1/\hbar$ so that also magnetic energy remains invariant under the scaling. This would allow to have stability without assuming low temperature at magnetic flux tubes.

13.3 TGD Based Model For High T_c Super Conductors

High T_c superconductors are quantum critical and involve in an essential magnetic structures, they provide an attractive application of the general vision for the model of super-conductivity based on magnetic flux tubes.

13.3.1 Some Properties Of High T_c Super Conductors

Quite generally, high T_c super-conductors are cuprates with CuO layers carrying the supra current. The highest known critical temperature for high T_c superconductors is 164 K and is achieved under huge pressure of 3.1×10^5 atm for LaBaCuO. High T_c super-conductors are known to be super conductors of type II.

This is however a theoretical deduction following from the assumption that the value of Planck constant is ordinary. For $\hbar = 2^{14}\hbar_0$ (say) ξ would be scaled up accordingly and type I super-conductor would be in question. These super-conductors are characterized by very complex patterns of penetrating magnetic field near criticality since the surface area of the magnetic defects is maximized. For high T_c super-conductors the ferromagnetic phase could be regarded as an analogous to defect and would indeed have very complex structure. Since quantum criticality would be in question the stripe structure would fluctuate with time too in accordance with 4-D spin glass character.

The mechanism of high T_c super conductivity is still poorly understood [D88, D90].

1. It is agreed that electronic Cooper pairs are charge carriers. It is widely accepted that electrons are in relative d-wave state rather than in s-wave (see [D76] and the references mentioned in [D88]). Cooper pairs are believed to be in spin triplet state and electrons combine to form $L = 2$ angular momentum state. The usual phonon exchange mechanism does not generate the attractive interaction between the members of the Cooper pair having spin. There is also a considerable evidence for BCS type Cooper pairs and two kinds of Cooper pairs could be present.

2. High T_c super conductors have spin glass like character [D85]. High T_c superconductors have anomalous properties also above T_c suggesting quantum criticality implying fractal scaling of various observable quantities such as resistivity. At high temperatures cuprates are anti-ferromagnets and Mott insulators meaning freezing of the electrons. Superconductivity and conductivity are believed to occur along dynamical stripes which are antiferromagnetic defects.

3. These findings encourage to consider the interpretation in terms of quantum criticality in which some new form of super conductivity which is not based on quasiparticles is involved. This super-conductivity would be assignable with the quantum fluctuations destroying antiferromagnetic order and replacing it with magnetically disordered phase possibly allowing phonon induced super-conductivity.

4. The doping of the super-conductor with electron holes is essential for high T_c superconductivity, and there is a critical doping fraction $p = .14$ at which T_c is highest. The interpretation is that holes make possible for the Cooper pairs to propagate. There is considerable evidence that holes gather on one-dimensional stripes with thickness of order few atom sizes and lengths in the range 1-10 nm [D90], which are fluctuating in time scale of 10^{-12} seconds. These stripes are also present in non-superconducting state but in this case they do not fluctuate appreciably. The most plausible TGD based interpretation is in terms of fluctuations of magnetic flux tubes allowing for the formation of long connected flux tubes making super-conductivity possible. The fact that the fluctuations would be oscillations analogous to acoustic wave and might explain the BCS type aspects of high T_c super-conductivity.

5. T_c is inversely proportional to the distance L between the stripes. A possible interpretation would be that full super-conductivity requires de-localization of electrons also with respect to stripes so that T_c would be proportional to the hopping probability of electron between neighboring stripes expected to be proportional to $1/L$ [D90].

From free fermion gas to Fermi liquids to quantum critical systems

The article of Jan Zaanen [D89] gives an excellent non-technical discussion of various features of high T_c super-conductors distinguishing them from BCS super-conductors. After having constructed a color flux tube model of Cooper pairs I found it especially amusing to learn that the analogy of high T_c super-conductivity as a quantum critical phenomenon involving formation of dynamical stripes to QCD in the vicinity of the transition to the confined phase leading to the generation of string like hadronic objects was emphasized also by Zaanen.

BCS super-conductor behaves in a good approximation like quantum gas of non-interacting electrons. This approximation works well for long ranged interactions and the reason is Fermi statistics plus the fact that Fermi energy is much larger than Coulomb interaction energy at atomic length scales.

For strongly interacting fermions the description as Fermi liquid (a notion introduced by Landau) has been dominating phenomenological approach. ^{3}He provides a basic example of Fermi liquid and already here a paradox is encountered since low temperature collective physics is that of Fermi gas without interactions with effective masses of atoms about 6 times heavier than those of real atoms whereas short distance physics is that of a classical fluid at high temperatures meaning a highly correlated collective behavior.

It should be noticed that many-sheeted space-time provides a possible explanation of the paradox. Space-time sheets containing join along boundaries blocks of ^3He atoms behave like gas whereas the ^3He atoms inside these blocks form a liquid. An interesting question is whether the ^3He atoms combine to form larger units with same spin as ^3He atom or whether the increase of effective mass by a factor of order six means that $\hbar$ as a unit of spin is increased by this factor forcing the basic units to consist of Bose-Einstein condensate of 3 Cooper pairs.

High T_c super conductors are neither Fermi gases nor Fermi liquids. Cuprate superconductors correspond at high temperatures to doped Mott insulators for which Coulomb interactions dominate meaning that electrons are localized and frozen. Electron spin can however move and the system can be regarded as an anti-ferromagnet. CuO planes are separated by highly oxidic layers and become super-conducting when doped. The charge transfer between the two kinds of layers is what controls the degree of doping. Doping induces somehow a de-localization of charge carriers accompanied by a local melting of anti-ferromagnet.

Collective behavior emerges for high enough doping. Highest T_c results with 15 per cent doping by holes. Current flows along electron stripes. Stripes themselves are dynamical and this is essential for both conductivity and superconductivity. For completely static stripes superconductivity disappears and quasi-insulating electron crystal results.

Dynamical stripes appear in mesoscopic time and length scales corresponding to 1-10 nm length scale and picosecond time scale. The stripes are in a well-defined sense dual to the magnetized stripe like structures in type I super-conductor near criticality, which suggests analog of type I super-conductivity. The stripes are anti-ferromagnetic defects at which neighboring spins fail to be antiparallel. It has been found that stripes are a very general phenomenon appearing in insulators, metals, and super-conducting compounds [D35].

Quantum criticality is present also above T_c

Also the physics of Mott insulators above T_c reflects quantum criticality. Typically scaling laws hold true for observables. In particular, resistivity increases linearly rather than transforming from T^2 behavior to constant as would be implied by quasi-particles as current carriers. The appearance of so called pseudo-gap [D103] at $T_{c1} > T_c$ conforms with this interpretation. In particular, the pseudo-gap is non-vanishing already at T_{c_1} and stays constant rather than starting from zero as for quasi-particles.

Results from optical measurements and neutron scattering

Optical measurements and neutron scattering have provided especially valuable microscopic information about high T_c superconductors allowing to fix the details of TGD based quantitative model.

Optical measurements of copper oxides in non-super-conducting state have demonstrated that optical conductivity $\sigma(\omega)$ is surprisingly featureless as a function of photon frequency. Below the critical temperature there is however a sharp absorption onset at energy of about 50 meV [D64]. The origin of this special feature has been a longstanding puzzle. It has been proposed that this absorption onset corresponds to a direct generation of an electron-hole pair. Momentum conservation implies that the threshold for this process is $E_g + E$, where E is the energy of the "gluon" which binds electrons of Cooper pair together. In the case of ordinary super-conductivity E would be phonon energy.

Soon after measurements, it was proposed that in absence of lattice excitations photon must generate two electron-hole pairs such that electrons possess opposite momenta [D64]. Hence the energy of the photon would be $2E_g$. Calculations however predicted soft rather than sharp onset of absorption since pairs of electron-hole pairs have continuous energy spectrum. There is something wrong with this picture.

Second peculiar characteristic [D67, D59, D48] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor. This scattering occurs only below the critical temperature, in spin-flip channel and for a favored momentum exchange $(\pi/a, \pi/a))$, where a denotes the size of the lattice cube [D67, D59, D48]. The transferred energy is concentrated in a remarkably narrow range around E_w rather than forming a continuum.

In [D29] is is suggested that e-e resonance with spin one gives rise to this excitation. This resonance is assumed to play the same role as phonon in the ordinary super conductivity and e-e resonance is treated like phonon. It is found that one can understand the dependence of the second derivative of the photon conductivity $\sigma(\omega)$ on frequency and that consistency with neutron scattering data is achieved. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV. This would suggest that the energy of the excitations generating the binding between the members of the Cooper pair is indeed 41 meV, that two electron-hole pairs and excitation of the super conductor are generated in photon absorption above threshold, and that the gap energy of the Cooper pair is 27 meV. Of course, the theory of Carbotte *et al* does not force the "gluon" to be triplet excitation of electron pair. Also other possibilities can be considered. What comes in mind are spin flip waves of the spin lattice associated with stripe behaving as spin 1 waves.

In TGD framework more exotic options become possible. The transversal fluctuations of stripes- or rather of the magnetic flux tubes associated with the stripes- could define spin 1 excitations analogous to the excitations of a string like objects. Gauge bosons are identified as wormhole contacts in quantum TGD and massive gauge boson like state containing electron-positron pair or quark-antiquark pair could be considered.

13.3.2 TGD Inspired Vision About High T_c Superconductivity

The following general view about high T_c super-conductivity as quantum critical phenomenon suggests itself. It must be emphasized that this option is one of the many that one can imagine and distinguished only by the fact that it is the minimal option.

The interpretation of critical temperatures

The two critical temperatures T_c and $T_{c_1} > T_c$ are interpreted as critical temperatures. The recent observation that there exists a spectroscopic signature of high T_c super-conductivity, which prevails up to T_{c_1} [D19], supports the interpretation that Cooper pairs exist already below T_{c1} but that for some reason they cannot form a coherent super-conducting state.

One can imagine several alternative TGD based models but for the minimal option is the following one.

1. T_{c_1} would be the temperature for the formation of two-phase system consisting of ordinary electrons and of Cooper pairs with a large value of Planck constant explaining the high critical temperature.
2. Magnetic flux tubes are assumed to be carriers of supra currents. These flux tubes are very short in in anti-ferromagnetic phase. The holes form stripes making them positively charged so that they attract electrons. If the spins of holes tend to form parallel sequences along stripes, they generate dipole magnetic fields in scales of order stripe length at least. The corresponding magnetic flux tubes are assumed to be carriers of electrons and Cooper pairs. The flux tube structures would be closed so that the supra currents associated with these flux tubes would be trapped in closed loops above T_c.
3. Below T_{c1} transversal fluctuations of the flux tubes structures occur and can induce reconnections giving rise to longer flux tubes. Reconnection can occur in two ways. Recall that upwards going outer flux tubes of the dipole field turn downwards and eventually fuse with the dipole core. If the two dipoles have opposite directions the outer flux tube of the first (second) dipole can reconnect with the inward going part of the flux tube of second (first) dipole. If the dipoles have same direction, the outer flux tubes of the dipoles reconnect with each other. Same applies to the inwards going parts of the flux tubes and the dipoles fuse to a single deformed dipole if all flux tubes reconnect. This alternative looks more plausible.

The reconnection process is in general only partial since dipole field consists of several flux tubes.

4. The reconnections for the flux tubes of neighboring almost dipole fields occur with some probability $p(T)$ and make possible finite conductivity. At T_c the system the fluctuations of the flux tubes become large and also $p(T, L)$, where L is the distance between stripes, becomes large and the reconnection leads to a formation of long flux tubes of length of order coherence length at least and macroscopic supra currents can flow. One also expects that the reconnection occurs for practically all flux tubes of the dipole field. Essentially a percolation type phenomenon [D13] would be in question. Scaling invariance suggests $p_c(T, L) = p_c(TL/\hbar)$, where L is the distance between stripes, and would predict the observed $T_c \propto \hbar/L$ behavior. Large value of $\hbar$ would explain the high value of T_c.

This model relates in an interesting manner to the vision of Zaanen [D92] expressed in terms of the highway metaphor visualizing stripes as quantum highways along which Cooper pairs can move. In antiferromagnetic phase the traffic is completely jammed. The doping inducing electron holes allows to circumvent traffic jam due to the Fermi statistics generates stripes along which the traffic flows in the sense of ordinary conductivity. In TGD framework highways are replaced with flux tubes and the topology of the network of highways fluctuates due to the possibility of reconnections. At quantum criticality the reconnections create long flux tubes making possible the flow of supra currents.

The interpretation of fluctuating stripes in terms of 1-D phonons

In TGD framework the phase transition to high T_c super-conductivity would have as a correlate fluctuating stripes to which supra currents are assigned. Note that the fluctuations occur also for $T > T_c$ but their amplitude is smaller. Stripes would be parallel to the dark magnetic flux tubes along which dark electron current flows above T_c. The fluctuations of magnetic flux tubes whose amplitude increases as T_c is approached induce transverse oscillations of the atoms of stripes representing 1-D transverse phonons.

The transverse fluctuations of stripes have naturally spin one character in accordance with the experimental facts. They allow identification as the excitations having 41 meV energy and would propagate in the preferred diagonal direction $(\pi/a, \pi/a)$. Dark Cooper pairs would have a gap energy of 27 meV. Neutron scattering resonance could be understood as a generation of these 1-D phonons and photon absorption a creation of this kind of phonon and breaking of dark Cooper pair. The transverse oscillations could give rise to the gap energy of the Cooper pair below T_{c1} and for the formation of long flux tubes below T_c but one can consider also other mechanisms based on the new physics predicted by TGD.

Various lattice effects such as superconductivity-induced phonon shifts and broadenings, possible isotope effects in T_c (questionable), the penetration depth, infrared and photoemission spectra have been observed in the cuprates [D8]. A possible interpretation is that ordinary phonons are replaced by 1-D phonons defined by the transversal excitations of stripes but do not give rise to the binding of the electrons of the Cooper pair but to reconnection of flux tubes. An alternative proposal which seems to gain experimental support is that spin waves appearing near antiferromagnetic phase transitions replace phonons.

More precise view about high T_c superconductivity taking into account recent experimental results

There are more recent results allowing to formulate more precisely the idea about transition to high T_c super-conductivity as a percolation type phenomenon. Let us first summarize the recent picture about high T_c superconductors.

1. 2-dimensional phenomenon is in question. Supra current flows along preferred lattice planes and type II super-conductivity in question. Proper sizes of Cooper pairs (coherence lengths) are ξ =1-3 nm. Magnetic length λ is longer than $\xi/\sqrt{2}$.

2. Mechanism for the formation of Cooper pairs is the same water bed effect as in the case of ordinary superconductivity. Phonons are only replaced with spin-density waves for electrons with periodicity in general not that of the underlying lattice. Spin density waves relate closely

to the underlying antiferromagnetic order. Spin density waves appear near phase transition to antiferromagnetism.

3. The relative orbital angular mentum of Cooper pair is L=2 ($x^2 - y^2$ wave), and vanishes at origin unlike for ordinary s wave SCs. The spin of the Cooper pair vanishes.

Consider now the translation of this picture to TGD language. Basic notions are following.

1. Magnetic flux tubes and possibly also dark electrons forming Cooper pairs.
2. The appearence of spin waves means sequences of electrons with opposite spins. The magnetic field associated with them can form closed flux tube containing both spins. Assume that spins-are orthogonal to the lattice plane in which supracurrent flows. Assume that the flux tube branches associated with electron with given spin branches so that it is shared with both neighboring electrons.
3. Electrons of opposite spins at the two portions of the closed flux tube have magnetic interaction energy. The total energy is minimal when the spins are in opposite directions. Thus the closed flux tube tends to favor formation of Cooper pairs.
4. Since magnetic interaction energy is proportional to $h_{eff} = n \times h$, it is expected stabilize the Cooper pairs at high temperatures. For ordinary super-conducti- vity magnetic fields tends to de-stabilize the pairs by trying to force the spins of spin singlet pair to the same direction.
5. This does not yet give super-conductivity. The closed flux tubes associated with paired spins can however reconnect so that longer flux closed flux tubes are formed. If this occurs for entire sequences, one obtains two flux tubes containing electrons with opposite spins forming Cooper pairs: this would be the "highway" and percolation would corresponds to this process. The pairs would form supracurrents in longer scales.
6. The phase phase transitions generating the reconnections could be percolation type phase transition.

This picture might apply also in TGD based model of bio-superconductivity.

1. The stability of dark Cooper pairs assume to reside at magnetic flux tubes is a problem also now. Fermi statistics favors opposite spins but this means that magnetic field tends to spit the pairs if the members of the pair are at the same flux tube.
2. If the members of the pair are at different flux tubes, the situation changes. One can have $L = 1$ and $S = 1$ with parallel spins (ferromagnetism like situation) or $L = 2$ and $S = 0$ state (anti-ferromagnetism like situation). $L > 0$ is necessary since electrons must reside at separate flux tubes.

Nematics and high T_c superconductors

Waterloo physicists discover new properties of superconductivity is the title of article (see http://tinyurl.com/jfz3l45) popularizing the work of David Hawthorn, Canada Research Chair Michel Gingras, doctoral student Andrew Achkar and post-doctoral student Zhihao Hao published in Science [D49] (see http://tinyurl.com/zycahrx). There is a dose of hype involved. As a matter of fact, it has been known for years that electrons flow along stripes, kind of highways in high T_c superconductors.

This effect is known as nematicity and means that electron orbitals break lattice symmetries and align themselves like a series of rods. Nematicity in long length scales occurs a temperatures below the critical point for super-conductivity. In the above mentioned work cuprate CuO_2 is studied. For non-optimal doping the critical temperature for transition to macroscopic superconductivity is below the maximal critical temperature. Long length scale nematicity is observed in these phases.

In the article by Rosenthal *et al* [D66] (see http://tinyurl.com/h34347f) it is however reported that nematicity is in fact preserved above critical temperature as a local order -at least up to the upper critical temperature, which is not easy to understand in the BCS theory of superconductivity. One can say that the stripes are short and short-lived so that genuine superconductivity cannot take place.

These two observations lend further support for the TGD inspired model of high T_c superconductivity and bio-superconductivity. It is known that antiferromagnetism is essential for the phase transition to superconductivity but Maxwellian view about electromagnetism and standard quantum theory do not make it easy to understand how. Magnetic flux tube is the first basic new notion provided by TGD. Flux tubes carry dark electrons with scaled up Planck constant $h_{eff} = n \times h$: this is second new notion. This implies scaling up of quantal length scales and in this manner makes also super-conductivity possible.

Magnetic flux tubes in antiferromagnetic materials form short loops. At the upper critical point they however reconnect with some probability to form loops with look locally like parallel flux tubes carrying magnetic fields in opposite directions. The probability of reverse phase transition is so large than there is a competion. The members of Cooper pairs are at parallel flux tubes and have opposite spins so that the net spin of pair vanishes: $S = 0$. At the first critical temperature the average length and lifetime of flux tube highways are too short for macroscopic super-conductivity. At lower critical temperature all flux tubes re-connect permanently average length of pathways becomes long enough.

This phase transition is mathematically analogous to percolation in which water seeping through sand layer wets it completely. The competion between the phases between these two temperatures corresponds to quantum criticality in which phase transitions $h_{eff}/h = n_1 \leftrightarrow n_2$ take place in both directions ($n_1 = 1$ is the most plausible first guess). Earlier I did not fully realize that Zero Energy Ontology provides an elegant description for the situation [L49] [?]. The reason was that I thought that quantum criticality occurs at single critical temperature rather than temperature interval. Nematicity is indeed detected locally below upper critical temperature and in long length scales below lower critical temperature.

Explanation for the spectral signatures of high T_c superconductor

The model should explain various spectral signatures of high T_c super-conductors. It seems that this is possible at qualitative level at least.

1. Below the critical temperature there is a sharp absorption onset at energy of about $E_a = 50$ meV.
2. Second characteristic [D67, D59, D48] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor also visible only below the critical temperature.
3. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV for the energy gap.

$E_g = 27$ meV has a natural interpretation as energy gap of spin 1 Cooper pair. $E_w = 41$ meV can be assigned to the transversal oscillations of magnetic flux tubes inducing 1-D transversal photons which possibly give rise to the energy gap. $E_a = 50$ meV can be understood if also $S = 0$ Cooper pair for which electrons of the pair reside dominantly at the "outer" dipole flux tube and inner dipole core. The presence of this pair might explain the BCS type aspects of high T_c super-conductivity. This identification would predict the gap energy of $S = 0$ Cooper pair to be $E_g(S = 0) = 9$ meV. Since the critical absorption onset is observed only below T_c these Cooper pairs would become thermally stable at T_c and the formation of long flux tubes should somehow stabilize them. For very long flux tubes the distance of a point of "outer" flux tube from the nearby point "inner" flux tube becomes very long along dipole flux tube. Hence the transformation of $S = 0$ pairs to $S = 1$ pairs is not possible anymore and $S = 0$ pairs are stabilized.

Model for Cooper pairs

The TGD inspired model for Cooper pairs of high T_c super-conductor involves several new physics aspects: large $\hbar$ phases, the notion of magnetic flux tubes. One can also consider the possibility that color force predicted by TGD to be present in all length scales is present.

1. One can consider two options for the topological quantization of the dipole field. It could decompose to a flux tube pattern with a discrete rotational symmetry Z_n around dipole axis or to flux sheets identified as walls of finite thickness invariant under rotations around dipole

axis. Besides this there is also inner the flux tube corresponding to the dipole core. For the flux sheet option one can speak about eigenstates of L_z. For flux tube option the representations of Z_n define the counterparts of the angular momentum eigenstates with a cutoff in L_z analogous to a momentum cutoff in lattice. The discretized counterparts of spherical harmonics make sense. The counterparts of the relative angular momentum eigenstates for Cooper pair must be defined in terms of tensor products of these rather than using spherical harmonics assignable with the relative coordinate $r_1 - r_2$. The reconnection mechanism makes sense only for the flux tube option so that it is the only possibility in the recent context.

2. Exotic Cooper pair is modeled as a pair of large $\hbar$ electrons with zoomed up size at space-time representing the dipole field pattern associated with a sequence of holes with same spin. If the members of the pair are at diametrically opposite flux tubes or at the "inner" flux tube (dipole core) magnetic fluxes flow in same direction for electrons and spin 1 Cooper pair is favored. If they reside at the "inner" flux tube and outer flux tube, spin zero state is favored. This raises the question whether also $S = 0$ variant of the Cooper pair could be present.

3. Large $\hbar$ is needed to explain high critical temperature. By the general argument the transition to large $\hbar$ phase occurs in order to reduce the value of the gauge coupling strength - now fine structure constant- and thus guarantee the convergence of the perturbation theory. The generation or positive net charge along stripes indeed means strong electromagnetic interactions at stripe.

Color force in condensed matter length scales is a new physics aspect which cannot be excluded in the case that transverse oscillations of flux tubes do not bind the electrons to form a Cooper pair. Classically color forces accompany any non-vacuum extremal of Kähler action since a non-vanishing induced Kähler field is accompanied by a classical color gauge field with Abelian holonomy. Induced Kähler field is always non-vanishing when the dimension of the CP_2 projection of the space-time surface is higher than 2. One can imagine too alternative scenarios.

1. Electromagnetic flux tubes for which induced Kähler field is non-vanishing carry also classical color fields. Cooper pairs could be color singlet bound states of color octet excitations of electrons (more generally leptons) predicted by TGD and explaining quite impressive number of anomalies [K115]. These states are necessarily dark since the decay widths of gauge bosons do not allow new light fermions coupling to them. The size of these states is of order electron size scale $L(127)$ for the standard value of Planck constant. For the non-standard value of Planck constant it would be scaled up correspondingly. For $r = \hbar/\hbar_0 = 2^{14}$ the size would be around 3.3 Angströms and for $r = 2^{24}$ of order 10 nm. Color binding could be responsible for the formation of the energy gap in this case and would distinguish between ordinary two-electron states and Cooper pair. The state with minimum color magnetic energy corresponds to spin triplet state for two color octed fermions whereas for colored fermion and anti-fermion it corresponds to spin singlet (pion like state in hadron physics).

2. A more complex variant of this picture served as the original model for Cooper pairs. Electrons at given space-time sheet feed their gauge flux to large space-time sheet via wormhole contacts. If the wormhole throats carry quantum numbers of quark and antiquark one can say that in the simplest situation the electron space-time sheet is color singlet state formed by quark and antiquark associated with the upper throats of the wormhole contacts carrying quantum numbers of u quark and $\overline{d}$ quark. It can also happen that the electronic space-time sheets are not color singlet but color octet in which case the situation is analogous to that above. Color force would bind the two electronic space-time sheets to form a Cooper pair. The neighboring electrons in stripe possess parallel spins and could form a pair transforming to a large $\hbar$ Cooper pair bound by color force. The Coulombic binding energy of the charged particles with the quarks and antiquarks assignable to the two wormhole throats feeding the em gauge flux to Y^4 and color interaction would be responsible for the energy gap.

Estimate for the gap energy

If transverse oscillations are responsible for the binding of the Cooper pairs, one expects similar expression for the gap energy as in the case of BCS type super conductors. The 3-D formula for the gap energy reads as

$$
\begin{aligned}
E_g &= \hbar\omega_D exp(-1/X) \ , \\
\omega_D &= (6\pi^2)^{1/3} c_s n^{1/3} \\
X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\
n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ .
\end{aligned}
\tag{13.3.1}
$$

X depends on the details of the binding mechanism for Cooper pairs and U_0 parameterizes these details.

Since only stripes contribute to high T_c super-conductivity it is natural to replace 3-dimensional formula for Debye frequency in 1-dimensional case with

$$
\begin{aligned}
E_g &= \hbar\omega exp(-1/X) \ , \\
\omega &= kc_s n \ .
\end{aligned}
\tag{13.3.2}
$$

where n is the 1-dimensional density of Cooper pairs and k a numerical constant. X would now correspond to the binding dynamics at the surface of 1-D counterpart of Fermi sphere associated with the stripe.

There is objection against this formula. The large number of holes for stripes suggests that the counterpart of Fermi sphere need not make sense, and one can wonder whether it could be more advantageous to talk about the counterpart of Fermi sphere for holes and treat Cooper pair as a pair of vacancies for this "Fermi sphere". High T_c super conductivity would be 1-D conventional super-conductivity for bound states of vacancies. This would require the replacement of n with the linear density of holes along stripes, which is essentially that of nuclei.

From the known data one can make a rough estimate for the parameter X. If $E_w = hf = 41$ meV is assigned with transverse oscillations the standard value of Planck constant would give $f = f_0 = 9.8 \times 10^{12}$ Hz. In the general case one has $f = f_0/r$. If one takes the 10^{-12} second length scale of the transversal fluctuations at a face value one obtains $r = 10$ as a first guess. $E_g = 27$ meV gives the estimate

$$
exp(-1/X) = \frac{E_g}{E_w}
\tag{13.3.3}
$$

giving $X = 2.39$.

The interpretation in terms of transversal oscillations suggests the dispersion relation

$$
f = \frac{c_s}{L} \ .
$$

L is the length of the approximately straight portion of the flux tube. The length of the "outer" flux tube of the dipole field is expected be longer than that of stripe. For $L = x$ nm and $f_D \sim 10^{12}$ Hz one would obtain $c_s = 10^3 x$ m/s.

Estimate for the critical temperatures and for $\hbar$

One can obtain a rough estimate for the critical temperature T_{c1} by following simple argument.

1. The formula for the critical temperature proposed in the previous section generalize in 1-dimensional case to the following formula

$$
T_{c1} \leq \frac{h^2}{8m_e}(\frac{n_c}{g})^2 \ .
\tag{13.3.4}
$$

   g is the number of spin degrees of freedom for Cooper pair and n_c the 1-D density of Cooper pairs. The effective one-dimensionality allows only single $L = 2$ state localized along the stripe.The $g = 3$ holds true for $S = 1$.

2. By parameterizing n_c as $n_c = (1-p_h)/a$, $a = x$ Angstrom, and substituting the values of various parameters, one obtains

$$T_{c1} \simeq \frac{r^2(1-p_h)^2}{9x^2} \times 6.3\ meV \ . \tag{13.3.5}$$

3. An estimate for p_h follows from the doping fraction p_d and the fraction p_s of parallel atomic rows giving rise to stripes one can deduce the fraction of holes for a given stripe as

$$p_h = \frac{p_d}{p_s} \ . \tag{13.3.6}$$

   One must of course have $p_d \leq p_s$. For instance, for $p_s = 1/5$ and $p_d = 15$ per cent one obtains $p_h = 75$ per cent so that a length of four atomic units along row contains one Cooper pair on the average. For $T_{c1} = 23$ meV (230 K) this would give the rough estimate $r = 23.3$: $r = 24$ satisfies the Fermat polygon constraint. Contrary to the first guess inspired by the model of bio-superconductivity the value of $\hbar$ would not be very much higher than its standard value. Notice however that the proportionality $T_c \propto r^2$ makes it difficult to explain T_{c1} using the standard value of $\hbar$.

4. One $p_h \propto 1/L$ whereas scale invariance for reconnection probability ($p = p(x = TL/\hbar)$) predicts $T_c = x_c\hbar/L = x_c p_s \hbar/a$. This implies

$$\frac{T_c}{T_{c1}} = 32\pi^2 \frac{m_e a}{\hbar_0} x^2 g^2 \frac{p_s}{(1-(p_d/p_s)^2)^2} \frac{x_c}{r} \ . \tag{13.3.7}$$

   This prediction allows to test the proposed admittedly somewhat ad hoc formula. For $p_d << p_s$ T_c/T_{c1} does behaves as $1/L$. One can deduce the value of x_c from the empirical data.

5. Note that if the reconnection probability p is a universal function of x as quantum criticality suggests and thus also x_c is universal, a rather modest increase of $\hbar$ could allow to raise T_c to room temperature range.

The value of $\hbar$ is predicted to be inversely proportional to the density of the Cooper pairs at the flux tube. The large value of $\hbar$ needed in the modelling of living system as magnetic flux tube super-conductor could be interpreted in terms of phase transitions which scale up both the length of flux tubes and the distance between the Cooper pairs so that the ratio rn_c remains unchanged.

Coherence lengths

The coherence length for high T_c super conductors is reported to be 5-20 Angstroms. The naïve interpretation would be as the size of Cooper pair. There is however a loophole involved. The estimate for coherence length in terms of gap energy is given by $\xi = \frac{4\hbar v_F}{E_g}$. If the coherence length is estimated from the gap energy, as it seems to be the case, then the scaling up of the Planck constant would increase coherence length by a factor $r = \hbar/\hbar_0$. $r = 24$ would give coherence lengths in the range $12-48$ nm.

The interpretation of the coherence length would be in terms of the length of the connected flux tube structure associated with the row of holes with the same spin direction which can be considerably longer than the row itself. As a matter fact r would characterize the ratio of size scales of the "magnetic body" of the row and of row itself. The coherence lengths could relate to the p-adic length scales $L(k)$ in the range $k = 151, 152, .., 155$ varying in the range $(10, 40])$ nm. $k = 151$ correspond to thickness cell membrane.

Why copper and what about other elements?

The properties of copper are somehow crucial for high T_c superconductivity since cuprates are the only known high T_c superconductors. Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages the question whether the doping by holes needed to achieve superconductivity induces the phase transition transforming the electrons to dark Cooper pairs.

More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. If the atom in question is also a boson the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. Superfluid would be in question. Thus elements with odd value of A and Z possessing full shells plus single s wave valence electron are of special interest. The six stable elements satisfying these conditions are ^{5}Li, ^{39}K, ^{63}Cu, ^{85}Rb, ^{133}Cs, and ^{197}Au.

A new phase of matter in the temperature range between pseudo gap temperature and T_c?

Kram sent a link to a Science Daily popular article titled "High-Temperature Superconductor Spills Secret: A New Phase of Matter?" (see `http://tinyurl.com/49vnvsu`: see also `http://tinyurl.com/yb7rs3fs`). For more details see the article in Science [D52].

Zhi-Xun Shen of the Stanford Institute for Materials and Energy Science (SIMES), a joint institute of the Department of Energy's SLAC National Accelerator Laboratory and Stanford University, led the team of researchers, which discovered that in the temperature region between the pseudo gap temperature and genuine temperature for the transition to super-conducting phase there exists a new phase of matter. The new phase would not be super-conducting but would be characterized by an order of its own which remains to be understood. This phase would be present also in the super-conducting phase.

The announcement does not come as a complete surprise for me. A new phase of matter is what TGD inspired model of high T$_c$ superconductivity indeed predicts. This phase would consist of Cooper pairs of electrons with a large value of Planck constant but associated with magnetic flux tubes with short length so that no macroscopic supra currents would be possible.

The transition to super-conducting phase involves long range fluctuations at quantum criticality and the analog of a phenomenon known as percolation (see `http://tinyurl.com/oytvosv`) [D13]. For instance, the phenomenon occurs for the filtering of fluids through porous materials. At critical threshold the entire filter suddenly wets as fluid gets through the filter. Now this phenomenon would occur for magnetic flux tubes carrying the Cooper pairs. At criticality the short magnetic flux tubes fuse by reconnection to form long ones so that supra currents in macroscopic scales become possible.

It is not clear whether this prediction is consistent with the finding of Shen and others. The simultaneous presence of short and long flux tubes in macroscopically super-conducting phase is certainly consistent with TGD prediction. The situation depends on what one means with super-conductivity. Is super-conductivity super-conductivity in macroscopic scales only or should one call also short scale super-conductivity not giving rise to macroscopic super currents as super-conductivity. In other words: do the findings of Shen's team prove that the electrons above gap temperature do not form Cooper pairs or only that there are no macroscopic supra currents?

Whether the model works as such or not is not a life and death question for the TGD based model. One can quite well imagine that the first phase transition increasing $\hbar$ does not yet produce electron Compton lengths long enough to guarantee that the overlap criterion for the formation of Cooper pairs is satisfied. The second phase transition increasing $\hbar$ would do this and also scale up the lengths of magnetic flux tubes making possible the flow of supra currents as such even without reconnections. Also reconnections making possible the formation of very long flux tubes could be involved and would be made possible by the increase in the length of flux tubes.

13.3.3 Speculations

21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade [D22]. Emission forms a wide band (with width about 4 micrometers) in the infrared spectrum, which suggests that it comes form a large complex molecule or a solid or simple molecules found around starts. Small molecules are ruled out since they produce narrow emission lines. The feature can be only observed in very precise evolutionary state, in the transition between red giant

phase and planetary nebular state, in which star blows off dust that is rich in carbon compounds. There is no generally accepted explanation for 21-micrometer radiation.

One can consider several explanations based on p-adic length scale hypothesis and some explanations might relate to the wormhole based super-conductivity.

1. 21 micrometers corresponds to the photon energy of 59 meV which is quite near to the zero point point kinetic energy 61.5 meV of proton Cooper pair at $k = 139$ space-time sheet estimated from the formula

$$\Delta E(2m_p, 139) = \frac{1}{2}\frac{\pi^2}{(2m_p)L_e(139)^2} = \frac{1}{8}\Delta E(m_p, 137) \simeq 61.5\ meV \ \ .$$

   Here the binding energy of the Cooper pair tending to reduce this estimate is neglected, and this estimate makes sense only apart from a numerical factor of order unity. This energy is liberated when a Cooper pair of protons at $k = 139$ space-time sheet drops to the magnetic flux tube of Earth's magnetic field (or some other sufficiently large space-time sheet). This energy is rather near to the threshold value about 55 meV of the membrane potential.

2. 21 micrometer radiation could also result when electrons at $k = 151$ space-time sheet drop to a large enough space-time sheet and liberate their zero point kinetic energy. Scaling argument gives for the zero point kinetic energy of electron at $k = 151$ space-time sheet the value $\Delta(e, 151) \simeq 57.5$ meV which is also quite near to the observed value. If electron is bound to wormhole with quantum numbers of $\overline{d}$ Coulombic binding energy changes the situation.

3. A possible explanation is as a radiation associated with the transition to high T_c super conducting phase. There are two sources of photons. Radiation could perhaps result from the de-excitations of wormhole BE condensate by photon emission. $\lambda = 20.5$ micrometers is precisely what one expects if the space-time sheet corresponds to $p \simeq 2^k$, $k = 173$ and assumes that excitation energies are given as multiples of $E_w(k) = 2\pi/L_e(k)$. This predicts excitation energy $E_w(173) \simeq 61.5$ meV. Unfortunately, this radiation should correspond to a sharp emission line and cannot explain the wide spectrum.

Are living systems high T_c superconductors?

The idea about cells and axons as superconductors has been one of the main driving forces in development of the vision about many-sheeted space-time. Despite this the realization that the supra currents in high T_c superconductors flow along structure similar to axon and having same crucial length scales came as a surprise. Axonal radius which is typically of order $r = .5$ μm. $r = 151 - 127 = 24$ favored by Mersenne hypothesis would predict $r = .4$ μm. The fact that water is liquid could explain why the radius differs from that predicted in case of high T_c superconductors.

Interestingly, Cu is one of the biologically most important trace elements [D2]. For instance, copper is found in a variety of enzymes, including the copper centers of cytochrome c-oxidase, the Cu-Zn containing enzyme superoxide dismutase, and copper is the central metal in the oxygen carrying pigment hemocyanin. The blood of the horseshoe crab, Limulus polyphemus uses copper rather than iron for oxygen transport. Hence there are excellent reasons to ask whether living matter might be able to build high T_c superconductors based on copper oxide.

Neuronal axon as a geometric model for current carrying "rivers"

Neuronal axons, which are bounded by cell membranes of thickness $L_e(151)$ consisting of two lipid layers of thickness $L_e(149)$ are good candidates for high T_c superconductors in living matter.

These flux tubes with radius .4 μm would define "rivers" along which conduction electrons and various kinds of Cooper pairs flow. Scaled up electrons have size $L_e(k_{eff} = 151)$ corresponding to 10 nm, the thickness of the lipid layer of cell membrane. Also the quantum fluctuating stripes of length 1-10 nm observed in high T_c super conductors might relate to the scaled up electrons with Compton length 10 nm, perhaps actually representing zoomed up electrons!

The original assumption that exotic *resp.* BCS type Cooper pairs reside at boundaries *resp.* interior of the super-conducting rivulet. It would however seem that the most natural option is that the hollow cylindrical shells carry all supra currents and there are no Cooper pairs in the interior. If exotic Cooper pairs reside only at the boundary of the rivulet or the Cooper pairs at boundary remain critical against exotic-BCS transition also below T_c, the time dependent fluctuations of the shapes of stripes accompanying high T_c super-conductivity can be understood as being induced by the fluctuations of membrane like structures. Quantum criticality at some part of the boundary is necessary in order to transform ordinary electron currents to super currents at the ends of rivulets. In biology this quantum criticality would correspond to that of cell membrane.

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13.4 Quantitative Model Of High T_c Super-Conductivity And Bio-Super-Conductivity

I have developed already earlier [K19, K20, K85, K86] a rough model for high T_c super conductivity [D89, D91, D92, D35, D19, D103]. The members of Cooper pairs are assigned with parallel flux tubes carrying fluxes which have either same or opposite directions. The essential element of the model is hierarchy of Planck constants defining a hierarchy of dark matters.

1. In the case of ordinary high T_c super-conductivity bound states of charge carriers at parallel short flux tubes become stable as spin-spin interaction energy becomes higher than thermal energy.

The transition to super-conductivity is known to occur in two steps: as if two competing mechanisms were at work. A possible interpretation is that at higher critical temperature Cooper pairs become stable but that the flux tubes are stable only below rather short scale: perhaps because the spin-flux interaction energy for current carriers is below thermal energy. At the lower critical temperature the stability would is achieved and supra-currents can flow in long length scales.

2. The phase transition to super-conductivity is analogous to a percolation process in which flux tube pairs fuse by a reconnection to form longer super-conducting pairs at the lower critical temperature. This requires that flux tubes carry anti-parallel fluxes: this is in accordance with the anti-ferro-magnetic character of high T_c super conductivity. The stability of flux tubes very probably correlates with the stability of Cooper pairs: coherence length could dictate the typical length of the flux tube.

3. A non-standard value of h_{eff} for the current carrying magnetic flux tubes is necessary since otherwise the interaction energy of spin with the magnetic field associated with the flux tube is much below the thermal energy.

There are two energies involved.

1. The spin-spin-interaction energy should give rise to the formation of Cooper pairs with members at parallel flux tubes at higher critical temperature. Both spin triplet and spin singlet pairs are possible and also their mixture is possible.

2. The interaction energy of spins with magnetic fluxes, which can be parallel or antiparallel contributes also to the gap energy of Cooper pair and gives rise to mixing of spin singlet and spin triplet. In TGD based model of quantum biology antiparallel fluxes are of special importance since U-shaped flux tubes serve as kind of tentacles allow magnetic bodies form pairs of antiparallel flux tubes connecting them and carrying supra-currents. The possibility of parallel fluxes suggests that also ferro-magnetic systems could allow super-conductivity.

   One can wonder whether the interaction of spins with magnetic field of flux tube could give rise to a dark magnetization and generate analogs of spin currents known to be coherent in long length scales and used for this reason in spintronics (`http://tinyurl.com/5cu3qh`). One can also ask whether the spin current carrying flux tubes could become stable at the lower critical temperature and make super-conductivity possible via the formation of Cooper pairs. This option does not seem to be realistic.

In the following the earlier flux tube model for high T_c super-conductivity and bio-super-conductivity is formulated in more precise manner. The model leads to highly non-trivial and testable predictions.

1. Also in the case of ordinary high T_c super-conductivity large value of $h_{eff} = n \times h$ is required.

2. In the case of high T_c super-conductivity two kinds of Cooper pairs, which belong to spin triplet representation in good approximation, are predicted. The average spin of the states vanishes for antiparallel flux tubes. Also super-conductivity associated with parallel flux tubes is predicted and could mean that ferromagnetic systems could become super-conducting.

3. One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales.

4. The model applies also in TGD inspired model of living matter. Now however the ratio of critical temperatures for the phase transition in which long flux tubes stabilize is roughly by a factor 1/50 lower than that in which stable Cooper pairs emerge and corresponds to thermal energy at physiological temperatures which corresponds also the cell membrane potential. The higher energy corresponds to the scale of bio-photon energies (visible and UV range).

13.4.1 A More Detailed Flux Tube Model For Super-Conductivity

The following little calculations support the above vision and lead to quite predictive model.

13.4.2 Simple Quantitative Model

It is best to proceed by building a quantitative model for the situation.

1. Spin-spin interaction energy for electron pair with members de-localized at parallel magnetic flux tubes must be deduced from the standard expression for the magnetic field created by the second charge and from the expression for the magnetic interaction energy of magnetic moment with external magnetic field.

   The magnetic field created by dipole μ outside the dipole is given by

$$B = \frac{\mu_0}{4\pi a^3} \times (3nn \cdot \mu - \mu) \ . \tag{13.4.1}$$

   The factor $\frac{\mu_0}{4\pi}$ can be taken equal to $1/4\pi$ as unity in the units in which $\mu_0 = \epsilon_0 = c = 1$ holds true. n is direction vector associated with the relative position vector a.

   The magnetic interaction energy reads as $E = -\mu \cdot B$ and in the case of identical magnetic moments reads as

$$E = \frac{1}{4\pi a^3} \times (-3\mu_1 \cdot n\mu_2 \cdot n + \mu_1 \cdot \mu_2) \ . \tag{13.4.2}$$

2. The magnetic dipole moment of electron is $\mu = -(ge/2m)S$, $S = \hbar/2$, $g \simeq 2$. For proton analogous expression holds with Lande factor $g = 5.585694713(46)$.

A simple model is obtained by assuming that the distance between the members of Cooper pair is minimal so that the relative position vector is orthogonal to the flux tubes.

1. This gives for the spin-spin interaction Hamiltonian the expression

$$H_{s-s} = \frac{1}{4\pi a^3} \times (\frac{ge\hbar}{2m})^2 \times O \ , \quad O = -3(m_1)_x(m_2)_x + m_1 \cdot m_2 \ . \tag{13.4.3}$$

   m_i refers to spin in units of $\hbar$. x referes to the direction in the plane defined by flux tubes and orthogonal to them. m_x can be expressed in terms of spin raising and lowering operators as $m_x = (1/2)(m_+ + m_-)$, $m_\pm = m_x \pm im_y$. This gives

$$(m_1)_x(m_2)_x = \frac{1}{4}\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ . \tag{13.4.4}$$

   $m_1 \cdot m_2$ can be expressed as $(1/2) \times [(m_1 + m_2)^2 - m_1^2 - m_2^2]$. In the case of spin 1/2 particles one can have spin singlet and spin triplet and the value of $m_1 \cdot m_2$ is in these cases given by $m_1 \cdot m_2(singlet) = -3/4$ and $m_1 \cdot m_2(triplet) = 1/4$

   The outcome is an expression for the spin-spin interaction Hamiltonian

$$\begin{aligned} &H_{s-s} = E_{s-s} \times O \ , \quad E_{s-s} = \tfrac{1}{4\pi a^3} \times (ge\hbar/2m)^2 \times O \ , \\ &O = O_1 + O_2(S) \ , \quad O_1 = -\tfrac{3}{4}\textstyle\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ , \\ &O_2(singlet) = -\tfrac{3}{4} \ , \quad O_2(triplet) = \tfrac{1}{4} \ . \end{aligned} \tag{13.4.5}$$

2. The total interaction Hamiltonian of magnetic moment with the magnetic field of flux tube can be deduced as

$$\begin{aligned} &H_{s-flux} = -(\mu_Z)_1B_1 - (\mu_Z)_2B_2 = \tfrac{ge}{\hbar 2m}(m_1)_zB_1 + (m_2)_zB_2 \\ &= E_{s-flux} \times ((m_1)_z + \epsilon(m_2)_z) \ , \quad E_{s-flux} = \tfrac{ge\hbar B}{2m} \ . \end{aligned} \tag{13.4.6}$$

3. For the diagonalization of spin-spin interaction Hamiltonian the eigenbasis of S_z is a natural choice. In this basis the only non-diagonal terms are O_1 and E_{s-flux}. O_1 does not mix representations with different total spin and is diagonal for the singlet representation. Also the $S_z(tot) = 0$ state of triplet representation is diagonal with respect to O_1: this is clear from the explicit representation matrices of spin raising and lowering operators (the non-vanishing elements in spin 1/2 representation are equal to 1). $S_z(tot) = 0$ states are eigenstates of O_1 with eigenvalue $+3/4$ for singlet and $-3/4$ for triplet. For singlet one therefore has eigenvalue $o = 0$ and for triplet eigenvalue $o = -1/2$. Singlet does not allow bound state whereas triplet does.

   $S_z(tot) = 1$ and $S_z(tot) = -1$ states are mixed with each other. In this case the O_1 has non-diagonal matrix elements equal to $O_1(1,-1) = O_1(-1,1) = 1$ so that the matrix representing O is given by

$$O = \begin{pmatrix} \frac{1}{4} & 1 \\ 1 & \frac{1}{4} \end{pmatrix} \quad . \tag{13.4.7}$$

   The eigenvalues are $o_+ = 5/4$ and $o_- = -3/4$. Cooper pairs states are linear combinations of $S_z = \pm 1$ states with coefficients with have either same or opposite sign so that a maximal mixing occurs and the average spin of the pair vanishes.

   To sum up, there are two bound states for mere spin-spin interaction corresponding to $o = -1/2$ spin 0 triplet state and $o = -3/4$ state for which spin 1 and spin -1 states are mixed.

4. For spin singlet at parallel flux tubes the spin-flux interaction vanishes: $H(para, singlet) = 0$. Same holds true for $S_z = \pm 1$ states at biologically especially interesting antiparallel flux tubes: $H(anti, S_z = \pm 1) = 0$. For antiparallel flux tubes $S_z = 0$ states in singlet and triplet are mixed by $H(anti, S_z = 0)$. The two resulting states must have negative binding energy so that one obtains 3 bound states altogether and only one state remains unbound. The amount of mixing and thermal stability of possibly slightly perturbed singlet state is determined by the ratio x of the scale parameters of H_{s-flux} and H_{s-s}.

   The explicit form of $H(anti, S_z = 0)$ is

$$\begin{aligned} H(anti, S_z = 0) &= -\frac{E_{s-s}}{2} \begin{pmatrix} 1 & x \\ x & 0 \end{pmatrix} \\ x = -\frac{4E_{s-flux}}{E_{s-s}} &= -32\pi \frac{ma^3}{ge\hbar B} \ , \\ E_{s-s} &= \frac{1}{8\pi} (\frac{ge\hbar}{2m})^2 \frac{1}{a^3} \ . \end{aligned} \tag{13.4.8}$$

   The eigenvalues $H(anti, S_z = 0)$

$$E_{\pm} = -\frac{E_{s-s}}{4}(1 \pm \sqrt{1 + 4x^2}) \ . \tag{13.4.9}$$

   What is remarkable is that both parallel antiparallel flux tubes give rise to 2 bound states assignable to spin triplet. Singlet does not allow bound states.

5. The Planck constant appearing in the formulas can be replaced with $\hbar_{eff} = n\hbar$. Note that the value of the parameter x is inversely proportional to h_{eff} so that singlet approximation improves for large values of h_{eff}.

13.4.3 Fermionic Statistics And Bosons

What about fermionic statistics and bosons?

1. The total wave function must be antisymmetric and the manner to achieve this for spin triplet state is anti-symmetrization in longitudinal degrees of freedom. In 3-D model for Cooper pairs spatial antis-ymmetrization implies $L = 1$ spatial wave function in the relative coordinate and one obtains $J = 0$ and $J = 2$ states. Now the state could be antisymmetric under the exchange of longitudinal momenta of fermions. Longitudinal momenta cannot be identical and Fermi sphere is replaced by its 1-dimensional variant. In 3-D model for Cooper pairs spatial anti-symmetrization implies $L = 1$ spatial wave function in the relative coordinate. Antisymmetry with respect to longitudinal momenta would be the analog for the odd parity of this wave function. Ordinary super-conductivity is located at the boundary of Fermi sphere in a narrow layer with thickness defined by the binding energy. The situation is same now and the thickness should correspond now to the spin-flux interaction energy.
2. Second possibility is more exotic and could be based on antisymmetric entanglement in discrete dark degrees of freedom defined by the sheets of the singular covering assignable to the integer $n = h_{eff}/h$. For $n = 2m$ one can decompose the n discrete degrees of freedom to the discrete analogs of m spatial coordinates q_i and m canonical momenta p_i and assume that the entanglement matrix proportional to a unitary matrix (negentropic entanglement) is proportional to the standard antisymmetric matrix defining symplectic structure and expressible as a direct sum of 2×2 permutation symbols ϵ_{ij}. $J_{p_i,q_i} = -J_{q_i p_i} = 1/\sqrt{2m}$. This matrix is antisymmetric and unitary in standard sense and quaternionic sense.
3. What about bosons? I have proposed that bosonic ions (such as Ca^{++}) associated with single flux tube form cyclotron Bose Einstein condensates giving rise to spontaneous dark magnetization. Bosonic supra currents can indeed run independently along single flux tube as spin currents. Also now the thermal stability of cyclotron states require large h_{eff}. The supra-currents (spin currents) of bosonic ions could be associated with flux tubes and fermionic supra-currents with their pairs. Even dark photons could give rise to spin currents.

   At the formal level the model applies in the case of bosons too. Symmetrization/anti-symmetrization for spin singlets/triplets would be replaced with anti-symmetrization/symmetrization. The analog of Fermi sphere would be obtained for spin singlet states requiring anti-symmetrization in longitudinal degrees of freedom.

13.4.4 Interpretation In The Case Of High T_c Super-Conductivity

It is interesting to try to interpret the results in terms of high T_c super-conductivity (`http://tinyurl.com/yd8vj9g`).

1. The four eigen values of total Hamiltonian are

$$E = E_{s-s} \times \lambda \ ,$$

$$\lambda \in \{\frac{5}{4}, -\frac{3}{4}, -\frac{1}{4}(1 \pm \sqrt{1+4x^2})\} \ . \tag{13.4.10}$$

   Two bound states with different binding energies are obtained which should be an empirically testable prediction in the case of the ordinary high T_c superconductivity since it predicts two critical temperatures. Cooper pairs are apart from possible small mixing with singlet state triplet states. The average spin is however vanishing also for $S_z = \pm 1$ states-
2. Two phase transitions giving rise to Cooper pairs are predicted. The simplest interpretation would be that super-conductivity in short scales is already present below the higher critical temperature and corresponds to the currents carries forming a mixture of $S_z = \pm 1$ states. These supra currents would stabilize flux tubes below some rather short scale. At the lower critical temperature the super-conductivity assignable to $S_z = 0$ spin triplets slightly mixed with singlet would become possible and the scale in which supra-currents can run would increase due to the occurrence of the percolation phenomenon. Below the lower critical temperature the interaction with flux tubes is indeed involved in an essential manner as a mixing of singlet and triplet states. One could perhaps say that $S_z = 0$ states stabilize the flux tube pair.

3. The critical temperatures for the stability of Cooper pairs are predicted to be in ratio $3/1+\sqrt{1+4x^2}$ roughly equal the upper bound 3/2 for small x. The critical temperatures are identical for $x=\sqrt{63/4}\simeq 4$. In the ordinary high T_c super-conductivity in cuprates the two critical temperatures are around $T^*=300$K and $T_c=80K$. The ratio $T^*/T_c=3.75$ fails to be consistent with the upper bound 3/2.
4. If one takes the model deadly seriously despite its strong simplifying assumptions one is forced to consider a more complex interpretation. What comes in mind is that both kind of Cooper pairs appear first and super-conductivity becomes possible at T_c. T^* would correspond to the emergence of $S_z=\pm 1$ mixtures. The critical temperature T^{**} for the emergence $S_z=0$ pairs would not be lower than $T^{**}_{min}=(2/3)\times 300=200$ K. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales. This model conforms with the interpretation of pseudo-gap in terms o pre-formed Cooper pairs not able to form coherent supra-currents (`http://tinyurl.com/yc543vbl`).

One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min}=2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z=\pm 1$ pairs emerge. At the lower temperature $S_z=0$ states, which are mixtures of spin triplet and spin singlet state emerge.

13.4.5 Quantitative Estimates In The Case Of TGD Inspired Quantum Biology

Using the formulas obtained above one can make rough quantitative estimates and get grasp about bio-super-conductivity as predicted by the model.

1. To get grasp to the situation it is good to consider as starting point electron with nanometer scale $a=a_0=1$ nm taken as the distance between flux tubes. For $h_{eff}=n\times h$ value of Planck constant one obtains $E_{s-s}=n^2(a/a_0)^3\times E_0$. $E_0=1.7\times 10^{-7}$ eV.

   Taking $B=1$ Tesla one obtains for E_{s-flux} $E_{s-flux}=n\times E_{s-flux,0}$, $E_{s-flux,0}=6.2\times 10^{-7}$ eV. For $B=B_{end}=.2$ Gauss suggested as an important value of dark endogenous magnetic field one obtains $E_{s-flux,0}=2.5\times 10^{-11}$ eV.
2. It seems reasonable to require that the two interaction energies are of same order of magnitude. Spin-flux interaction energy is rather small. For instance, for B=1 Tesla its magnitude for electron is about $E_{s-flux,0}=6.2\times 10^{-7}$ eV so that a large value of h_{eff} seems to be necessary.
3. The hypothesis that bio-photons result in the transformations of dark photons to ordinary photons suggests that the energy scale is in the range of visible and UV photons and therefore above eV. This suggests for electron $h_{eff}/h=n\geq 10^7$. The condition that the value of E_{s-s} is also in the same range requires that a scales like $n^{1/3}$. This would give scaling, which is larger than $10^{7/3}\simeq 215$: this would mean $a\geq 2\times 10^{-7}$ m which belongs to the range of biologically most important length scales between cell membrane thickness and nucleus size.
4. The hypothesis $\hbar_{eff}=n\times\hbar=\hbar_{gr}=GMm/v_0$ [K80, **?**] implies that cyclotron energy spectrum is universal (no dependence on the mass of the charged particle. Same would hold true for the spin-flux interaction energy. Spin spin interaction energy is proportional to h^2_{eff}/m^2a^3, where a is minimum distance between members of the Cooper pair. It is invariant under the simultaneous scaling of h_{eff} and m so that all charged particles can form Cooper pairs and spin currents for flux tubes with same distance and same magnetic field strength. This would correspond to the universality of the bio-photons [K13]. This would be also consistent with the earlier explanation for the finding of Hu and Wu [J12] that proton spin-spin interaction frequency for the distance defined by cell membrane thickness is in ELF frequency scale. The proposal was that dark proton sequences are involved at both sides of the membrane.

   Universality of Cooper pair binding energies implies universality of super-conductivity all fermionic ions can form superconducting Cooper pairs as has been assumed in the models for strange effects of ELF em fields on vertebrate brain, for cell membrane as Josephson junction, and for EEG [K41], and in the model for nerve pulse [K88]. As found, Bose-Einstein condensates of bosonic ions could give rise to spontaneous dark magnetization and spin currents along single flux tube so that bosons would be associated with flux tubes and fermions with pairs of them.

The value of h_{eff} for proton would satisfy $n \geq 2 \times 10^{10}$. This would guarantee that proton cyclotron frequency for $B = B_{end}$ corresponds to thermal energy 2.5×10^{-2} eV at room temperature.

Note that I have considered also the option that the values of h_{eff} are such that the universal cyclotron energy scale in magnetic field of $B \simeq .2$ Gauss is in the range of bio-photon energies so that h_{eff} would be by a factor of order 50 higher than in the estimate coming from spin temperature.

5. This observation raises the question whether there are two widely different energy scales present in living matter. The first scale would be associated with spin-spin interaction and would correspond to the energy scale of bio-photons. Second scale would be associated with spin-flux interaction and correspond to the energy scale of resting potential just above the thermal energy at physiological temperatures.

   If this is the case, the parameter x would be of order $x \simeq 10^{-2}$ and spin-spin interaction energy would dominate. The somewhat paradoxical earlier prediction was that Cooper pairs in bio-super-conductivity would be stable at temperatures corresponding to energy of eV or even higher but organisms do not survive above physiological temperatures. The critical temperature for living matter could be however understood in terms of the temperature sensitivity of the dark magnetization at magnetic flux tubes. Although the binding energies of Cooper pairs are in bio-photon energy range this does not help since the quantum wires along, which they can propagate are unstable above room temperatures.

6. From the estimate of order 10^{-7} eV for energy scales for $a = 1$ nm and $B = 1$ Tesla and from the binding energy of Cooper pairs of order 10^{-2} eV it is clear that ordinary high T_c super-conductivity cannot correspond to the standard value of Planck constant: $h_{eff}/h \simeq 10^5$ is required. The interpretation would be that at the higher critical temperature Cooper pairs become stable but flux tubes are not stable. At the lower critical temperature also flux tubes become stable. This would correspond to the percolation model that I have proposed earlier.

   These two energy scales would be the biological counterparts of the two much lower energy scales in the ordinary high T_c super-conductivity. There ratio of these scales would be roughly 50.

13.4.6 Does Also Low Tc Superconductivity Rely On Magnetic Flux Tubes In TGD Universe?

Discussions with Hans Geesink have inspired sharpening of the TGD view about bio-superconductivity (bio-SC), high Tc superconductivity (SC) and relate the picture to standard descriptions in a more detailed manner. In fact, also standard low temperature super-conductivity modelled using BCS theory could be based on the same universal mechanism involving pairs of magnetic flux tubes possibly forming flattened square like closed flux tubes and members of Cooper pairs residing at them.

A brief summary about strengths and weakness of BCS theory

First I try to summarize basics of BCS theory.

1. BCS theory is successful in 3-D superconductors and explains a lot: supracurrent, diamagnetism, and thermodynamics of the superconducting state, and it has correlated many experimental data in terms of a few basic parameters.

2. BCS theory has also failures.

   (a) The dependence on crystal structure and chemistry is not well-understood: it is not possible to predict, which materials are super-conducting and which are not.

(b) High-Tc SC is not understood. Antiferromagnetism is known to be important. The quite recent experiment demonstrates conductivity- maybe even conductivity - in topological insulator in presence of magnetic field [L29]. This is compete paradox and suggests in TGD framework that the flux tubes of external magnetic field serve as the wires [L29].

3. BCS model based on crystalline long range order and k-space (Fermi sphere). BCS-difficult materials have short range structural order: amorphous alloys, SC metal particles 0-down to 50 Angstroms (lipid layer of cell membrane) transition metals, alloys, compounds. Real space description rather than k-space description based on crystalline order seems to be more natural. Could it be that the description of electrons of Cooper pair is not correct? If so, k-space and Fermi sphere would be only appropriate description of ordinary electrons needed to model the transition to to super-conductivity? Super-conducting electrons could require different description.

4. Local chemical bonding/real molecular description has been proposed. This is of course very natural in standard physics framework since the standard view about magnetic fields does not provide any ideas about Cooper pairing and magnetic fields are only a nuisance rather than something making SC possible. In TGD framework the situation is different.

TGD based view about SC

TGD proposal for high Tc SC and bio-SC relies on many-sheeted space-time and TGD based view about dark matter as $h_{eff} = n \times h$ phase of ordinary matter emerging at quantum criticality [K86].

Pairs of dark magnetic flux tubes would be the wires carrying dark Cooper pairs with members of the pair at the tubes of the pair. If the members of flux tube pair carry opposite B:s, Cooper pairs have spin 0. The magnetic interaction energy with the flux tube is what determines the critical temperature. High Tc superconductivity, in particular the presence of two critical temperatures can be understood. The role of anti-ferromagnetism can be understood.

TGD model is clearly x-space model: dark flux tubes are the x-space concept. Momentum space and the notion of Fermi sphere are certainly useful in understanding the transformation ordinary lattice electrons to dark electrons at flux tubes but the super conducting electron pairs at flux tubes would have different description.

Now come the heretic questions.

1. Do the crystal structure and chemistry define the only fundamental parameters in SC? Could the notion of magnetic body - which of course can correlate with crystal structure and chemistry - equally important or even more important notion?

2. Could also ordinary BCS SC be based on magnetic flux tubes? Is the value of $h_{eff} = n \times h$ only considerably smaller so that low temperatures are required since energy scale is cyclotron energy scale given by E= $h_{eff} = n \times f_c$, $f_c = eB/m_e$. High Tc SC would only have larger h_{eff} and bio-superconductivity even larger h_{eff}!

3. Could it be that also in low Tc SC there are dark flux tube pairs carrying dark magnetic fields in opposite directions and Cooper pairs flow along these pairs? The pairs could actually form closed loops: kind of flattened O:s or flattened squares.

One must be able to understand Meissner effect. Why dark SC would prevent the penetration of the ordinary magnetic field inside superconductor?

1. Could B_{ext} actually penetrate SC at its own space-time sheet. Could opposite field B_{ind} at its own space-time sheet effectively interfere it to zero? In TGD this would mean generation of space-time sheet with $B_{ind} = -B_{ext}$ so that test particle experiences vanishing B. This is obviously new. Fields do not superpose: only the effects caused by them superpose.

   Could dark or ordinary flux tube pairs carrying B_{ind} be created such that the first flux tube portion B_{ind} in the interior cancels the effect of B_{ext} on charge carriers. The return flux of the closed flux tube of B_{ind} would run outside SC and amplify the detected field B_{ext} outside SC. Just as observed.

2. What happens, when B_{ext} penetrates to SC? $h_{eff} \to h$ must take place for dark flux tubes whose cross-sectional area and perhaps also length scale down by h_{eff} and field strength increases by h_{eff}. If also the flux tubes of B_{ind} are dark they would reduce in size in the

transition $h_{eff} \rightarrow h$ by $1/h_{eff}$ factor and would remain inside SC! B_{ext} would not be screened anymore inside superconductor and amplified outside it! The critical value of B_{ext} would mean criticality for this $h_{eff} \rightarrow h$ phase transition.

3. Why and how the phase transition destroying SC takes place? Is it energetically impossible to build too strong B_{ind}? So that effective field $B_{eff} = B_{dark} + B_{ind} + B_{ext}$ experienced by electrons is reduced so that also the binding energy of Cooper pair is reduced and it becomes thermally unstable. This in turn would mean that Cooper pairs generating the dark B_{dark} disappear and also B_{dark} disappears. SC disappears.

Wee after writing the above text came the newest news concerning high Tc superconductivity. Hydrogen sulfide - the compound responsible for the smell of rotten eggs - conducts electricity with zero resistance at a record high temperature of 203 Kelvin (–70 degrees C), reports a paper published in Nature. This super-conductor however suffers from a serious existential crisis: it behaves very much like old fashioned super-conductor for which superconductivity is believed to be caused by lattice vibrations and is therefore not allowed to exist in the world of standard physics! To be or not to be!

TGD Universe allows however all flowers to bloom: the interpretation is that the mechanism is large enough value of $h_{eff} = n \times h$ implying that critical temperature scales up. Perhaps it is not a total accident that hydrogen sulfide H2S - chemically analogous to water - results from the bacterial breakdown of organic matter, which according to TGD is high temperature superconductor at room temperature and mostly water, which is absolutely essential for the properties of living matter in TGD Universe.

As a matter fact, H_2S is used by some bacteria living in deep ocean volcanic vents as a nutrient and also in our own gut: chemically this means that H_2S acts as electron donor in primitive photosynthesis like process to give ATP. That sulphur is essential for growth and physical functioning of plants might be due to the fact that it preceded oxygen based life [**?**]. For instance, Cys and met containing sulphur are very important amino-acids.

Indications for high T_c superconductivity at 373 K with $h_{eff}/h = 2$

Some time ago I learned about a claim of Ivan Kostadinov [D86] about superconductivity at temperature of 373 K (100 C) (see `http://tinyurl.com/y9hk83ak`). There is also claims by E. Joe Eck about superconductivity: the latest at 400 K [D34] (see `http://tinyurl.com/yc483hsf`). I am not enough experimentalist to be able to decide whether to take the claims seriously or not.

The article of Kostadinov provides a detailed support for the claim. Evidence for diamagnetism (induced magnetization tends to reduce the external magnetic field inside superconductor) is represented: at 242 transition reducing the magnitude of negative susceptibility but keeping it negative takes place. Evidence for gap energy of 15 mV was found at 300 K temperature: this energy is same as thermal energy $T/2 = 1.5$ eV at room temperature. Tape tests passing 125 A through superconducting tape supported very low resistance (for Copper tape started burning after about 5 seconds).

I-V curves at 300 K are shown to exhibit Shapiro steps (see `http://tinyurl.com/y7qkmubj`) with radiation frequency in the range [5 GHz, 21 THz]. Already Josephson discovered what - perhaps not so surprisingly - is known as Josephson effect (see `http://tinyurl.com/mo8549n`). As one drives super-conductor with an alternating current, the voltage remain constant at certain values. The difference of voltage values between subsequent jumps are given by Shapiro step $\Delta V = hf/Ze$. The interpretation is that voltage suffers a kind of phase locking at these frequencies and alternating current becomes Josephson current with Josephson frequency $f_J = ZeV/h$, which is integer multiple of the frequency of the current. This actually gives a very nice test for $h_{eff} = n \times h$ hypothesis: Shapiro step ΔV should be scaled up by $h_{eff}/h = n$. The obvious question is whether this occurs in the recent case or whether $n = 1$ explains the findings.

The data represented by Figs. 12, 13,14 of [D86] (see `http://tinyurl.com/y9hk83ak`) suggest $n = 2$ for $Z = 2$. The alternative explanation would be that the step is for some reason $\Delta V = 2hf/Ze$ corresponding to second harmonic or that the charge of the charge carrier is $Z = 1$. I have not been able to find any error in my calculation.

1. Fig 12 shows I-V curve at room temperature T=300 K. Shapiro step is now 45 mV. This would correspond to frequency $f = Ze\Delta V/h = 11.6$ THz. The figure text tells that the frequency

is $f_R = 21.762$ THz giving $f_R/f \simeq 1.87$. This would suggest $h_{eff}/h = n \simeq f_R/f \simeq 2$.

2. Fig. 13 shows another at 300 K. Now Shapiro step is 4.0 mV and corresponds to a frequency 1.24 THz. This would give $f_R/f \simeq 1.95$ giving $h_{eff}/h = 2$.

3. Fig. 14 shows I-V curve with single Shapiro step equal to about .12 mV. The frequency should be 2.97 GHz whereas the reported frequency is 5.803 GHz. This gives $f_R/f \simeq 1.95$ giving $n = 2$.

Irrespectively of the fate of the claims of Kostadinov and Eck, Josephson effect could allow an elegant manner to demonstrate whether the hierarchy of Planck constants is realized in Nature.

Room temperature superconductivity for alkanes

Super conductivity with critical temperature of 231 C for n-alkanes containing n=16 or more carbon atoms in presence of graphite has been reported (see `http://tinyurl.com/hnefqv9`).

Alkanes (see `http://tinyurl.com/6pm7mz6`) can be linear (C_nH_{2n+2}) with carbon backbone forming a snake like structure, branched (C_nH_{2n+2}, $n \geq 2$) in which carbon backbone splits in one, or more directions or cyclic (C_nH_{2n}) with carbon backbone forming a loop. Methane CH_4 is the simplest alkane.

What makes the finding so remarkable is that alkanes serve as basic building bricks of organic molecules. For instance, cyclic alkanes modified by replacing some carbon and hydrogen atoms by other atoms or groups form aromatic 5-cycles and 6-cycles as basic building bricks of DNA. I have proposed that aromatic cycles are superconducting and define fundamental and kind of basic units of molecular consciousness and in case of DNA combine to a larger linear structure.

Organic high T_c superconductivity is one of the basic predictions of quantum TGD. The mechanism of super-conductivity would be based on Cooper pairs of dark electrons with non-standard value of Planck constant $h_{eff} = n \times h$ implying quantum coherence is length scales scaled up by n (also bosonic ions and Cooper pairs of fermionic ions can be considered).

The members of dark Cooper pair would reside at parallel magnetic flux tubes carrying magnetic fields with same or opposite direction: for opposite directions one would have $S = 0$ and for the same direction $S = 1$. The cyclotron energy of electrons proportional to h_{eff} would be scaled up and this would scale up the binding energy of the Cooper pair and make super-conductivity possible at temperatures even higher than room temperature [K86].

This mechanism would explain the basic qualitative features of high T_c superconductivity in terms of quantum criticality. Between gap temperature and T_c one one would have superconductivity in short scales and below T_c superconductivity in long length scales. These temperatures would correspond to quantum criticality at which large h_{eff} phases would emerge.

What could be the role of graphite? The 2-D hexagonal structure of graphite is expected to be important as it is also in the ordinary super-conductivity: perhaps graphite provides long flux tubes and n-alkanes provide the Cooper pairs at them. Either graphite, n-alkane as organic compound, or both together could induce quantum criticality. In living matter quantum criticality would be induced by different mechanism. For instance, in microtubules it would be induced by AC current at critical frequencies [L34].

How the transition to superconductive state could be induced by classical radiation?

Blog and Facebook discussions have turned out to be very useful and quite often new details to the existing picture emerge from them. We had interesting exchanges with Christoffer Heck in the comment section to "Are microtubules macroscopic quantum systems?" (see `http://tinyurl.com/hwnnfcd`) and this pleasant surprise occurred also now.

Recall that Bandyopadhyay's team claims to have detected the analog of superconductivity, when microtubules are subjected to AC voltage [J5, J11] (see `http://tinyurl.com/ze366ny`). The transition to a state resembling superconductivity would occur at certain critical frequencies. For the TGD inspired model see [L23].

The TGD proposal for bio-superconductivity - in particular that appearing in microtubules - is same as that for high T_c superconductivity [K85, K86]. Quantum criticality, large $h_{eff}/h = n$ phases of Cooper pairs of electrons, and parallel magnetic flux tube pairs carrying the members of

Cooper pairs for the essential parts of the mechanism. $S = 0$ ($S = 1$) Cooper pairs appear when the magnetic fields at parallel flux tubes have opposite (same) direction.

Cooper pairs would be present already below the gap temperature but possible super-currents could flow in short loops formed by magnetic flux tubes in ferromagnetic system. AC voltage at critical frequency would somehow induce transition to superconductivity in long length scales by inducing a phase transition of microtubules without helical symmetry to those with helical symmetry and fusing the conduction pathways with length of 13 tubulins associated with micro-tubules of type B to much longer ones associated with microtubules of type A by the reconnection of magnetic flux tubes parallel to the conduction pathways.

The phonon mechanism responsible for the formation of Cooper pair in ordinary supercon-ductivity cannot be involved with high T_c superconductivity nor bio-superconductivity. There is upper bound of about 30 K for the critical temperature of BCS superconductors. Few days ago I learned about high T_c superconductivity around 500 K for n-alkanes (see `http://tinyurl.com/hwac9e9`) so that the mechanism for high T_c is certainly different [K86].

The question of Christoffer was following. Could microwave radiation for which photon energies are around 10^{-5} eV for the ordinary value of Planck constant and correspond to the gap energy of BCS superconductivity induce phase transition to BCS super-conductivity and maybe to micro-tubular superconductivity (if it exists at all)?

This inspires the question about how precisely the AC voltage at critical frequencies could induce the transition to high T_c - and bio-super-conductivity. Consider first what could happen in the transition to high T_c super-conductivity.

1. In high T_c super conductors such as copper-oxides the anti-ferromagnetism is known to be essential as also 2-D sub-lattice structures. Anti-ferromagnetism suggests that closed flux tubes form of squares with opposite directions of magnetic field at the opposite sides of square. The opposite sides of the square would carry the members of Cooper pair.
2. At quantum criticality these squares would reconnect to very long flattened squares by recon-nection. The members of Cooper pairs would reside at parallel flux tubes forming the sides of the flattened square. Gap energy would consists interaction energies with the magnetic fields and the mutual interaction energy of magnetic moments.

   This mechanism does not work in standard QM since the energies involved are quite too low as compared to thermal energy. Large $h_{eff}/h = n$ would however scale up the magnetic energies by n. Note that the notion of gap energy should be perhaps replaced with collective binding energy per Cooper pair obtained from the difference of total energies for gap phase formed at higher temperature and for superconducting phase formed at T_c by dividing with the number of Cooper pairs.

   Another important distinction to BCS is that Cooper pairs would be present already below gap temperature. At quantum criticality the conduction pathways would become much longer by reconnection. This would be represent an example about "topological" condensed matter physics. Now hover space-time topology would be in question.
3. The analogs of phonons could be present as transversal oscillations of magnetic flux tubes: at quantum criticality long wave length "magneto-phonons" would be present. The transverse oscillations of flux tube squares would give rise to reconnection and formation of

If the irradiation or its generalization to high T_c works the energy of photon should be around gap energy or more precisely around energy difference per Cooper pair for the phases with long flux tubes pairs and short square like flux tubes.

1. To induce superconductivity one should induce formation of Cooper pairs in BCS supercon-ductivity. In high T_c super-conductivity it should induce a phase transition in which small square shaped flux tube reconnect to long flux tubes forming the conducting pathways. The system should radiate away the energy difference for these phases: the counterpart of binding energy could be defined as the radiated energy per Cooper pair.
2. One could think the analog of stimulated emission (see `http://tinyurl.com/hwac9e9`). As-sume that Cooper pairs have two states: the genuine Cooper pair and the non-superconducting Cooper pair. This is the case in high T_c superconductivity but not in BCS superconductivity, where the emergence of superconductivity creates the Cooper pairs. One can of course ask whether one could speak about the analog of stimulated emission also in this case.

3. Above T_c but below gap temperature one has the analog of inverted population: all pairs are in higher energy state. The irradiation with photon beam with energy corresponding to energy difference gives rise to stimulated emission and the system goes to superconducting state with a lower energy state with a lower energy.

This mechanism could explain the finding of Bandyopadhyay's team [J5, J11] that AC perturbation at certain critical frequencies gives rise to a ballistic state resembling superconductivity (no dependence of the resistance on the length of the wire so that the resistance must be located at its ends). The team used photons with frequency scales of MHz, GHz, and THz. The corresponding photon energy scales are about 10^{-8} eV, 10^{-5}, $10-2$ eV for the ordinary value of Planck constant and are below thermal energies.

In TGD classical radiation should have also large $h_{eff}/h = n$ photonic counterparts with much larger energies $E = h_{eff} \times f$ to explain the quantal effects of ELF radiation at EEG frequency range on brain [K79]. The general proposal is that h_{eff} equals to what I have called gravitational Planck constant $\hbar_{gr} = GMm/v_0$ [?, K80]. This implies that dark cyclotron photons have universal energy range having no dependence on the mass of the charged particle. Bio-photons have energies in visible and UV range much above thermal energy and would result in the transition transforming dark photons with large $h_{eff} = h_{gr}$ to ordinary photons.

One could argue that AC field does not correspond to radiation. In TGD framework this kind of electric fields can be interpreted as analogs of standing waves generated when charged particle has contacts to parallel "massless extremals" representing classical radiation with same frequency propagating in opposite directions. The net force experienced by the particle corresponds to a standing wave.

Irradiation using classical fields would be a general mechanism for inducing bio-superconductivity. Superconductivity would be generated when it is needed. The findings of Blackman and other pioneers of bio-electromagnetism about quantal effects of ELF em fields on vertebrate brain stimulated the idea about dark matter as phases with non-standard value of Planck constant. The precise mechanism for how this happens has remained open. Also these finding could be interpreted as a generation of superconducting phase by this phase transition.

13.4.7 The implications of TGD view about magnetic fields for super-conductivity

TGD predicts two kinds of magnetic fields depending on whether flux tubes carry monopole flux or not. In Maxwellian framework flux tubes cannot carry any monopole flux. In TGD based model of high Tc superconductivity [K85, K86] monopole flux tubes current carriers are dark having nonstandard value $h_{eff} = n \times h_0$ of effective Planck constant. Also in bio-superconductivity monopole flux tubes are current carriers. An open question has been whether also ordinary super-conductivity could correspond to monopole flux tubes and I have considered the possibility that this is the case.

The recent progress in understanding the relationship between two kinds of magnetic fields allows to consider more precisely the relationship between these two kinds of super-conductivities. In particular, one can try to understand Meissner effect in ordinary super-conductivity and its absence in the predicted super-conductivity based on monopole flux tubes. The conclusion is that ordinary super-conductivity corresponds to ordinary flux tubes and that Meissner effect has no counterpart in monopole superconductivity.

It is best to start from the ordinary super-conductivity by making an unpleasant question. Meissner effect (see `http://tinyurl.com/hesedf2`) relates to the possible penetration of magnetic field to super-conductor. Supra-current creates a local magnetic field. Why doesn't this magnetic field destroy super-conductivity?

The answer would be in TGD space-time following.

1. The super-conductor consists of parallel cylindrical tubes carrying supra-currents at their boundaries. These currents create magnetic fields rotating around the cylinders but have no component in z- direction. Magnetic fields vanish at the boundaries of the cylinders.

2. Superconductors can be classified to two types. For superconductors of type I (see `http://tinyurl.com/y4wkzcql`) one has $\lambda/\xi < 1/\sqrt{2}$ whereas for superconductors of type II (see

http://tinyurl.com/y279phzb) one has $\lambda/\xi > 1/\sqrt{2}$. Here λ is the magnetic penetration length, which is roughly the radius of magnetic flux tube. ξ is the coherence length which is roughly the radius of cylinder carrying supra current at its boundary.

Supra-current generates vortices and in this manner serves as a source for magnetic field inside magnetic flux tube of field possibly penetrating into superconductor. Flux tube must contain at least one current carrying flux tube. This cannot the case for superconductor of type I. Therefore, when ordinary magnetic field penetrates to super-conductor of type I above critical value of B, it must do so in the entire super-conductor . For superconductor of type II magnetic field can penetrate superconductor of type II in a cylinder of radius of order λ containing several current carrying cylinders. In this region the super-conductivity is destroyed since supra currents have component rotating along the cylinder giving rise to a longitudinal magnetic field inside the cylinder.

What about Meissner effect in monopole superconductors?

1. Monopole flux does not require current as its source. Therefore Meissner effect does not prevent super-conductivity by requiring the super-current to be rotational to generate the magnetic field.

2. Also now the presence of supra current inside monopole flux tube serves as a source for an additional rotational contribution to the magnetic field and the rotor of this additional contribution equals to the supra current. Monopole flux tube is deformed as a consequence. This does not however make supra-current rotational.

   Monopole superconductor can be said to be intermediate between types I and II since both coherence length and magnetic length correspond to flux tube radius. A possible interpretation is that monopole superconductivity is at quantum criticality between superconductivities of type I and II.

3. The most plausible option is that the penetration of ordinary magnetic field to monopole super-conductor occur along non-monopole flux tubes at different space-time sheets so that it would therefore not spoil the super-conductivity at the monopole flux tubes.

Chapter 14

Comparing Berry phase model of super-conductivity with TGD based model

14.1 Introduction

Hiroyasu Koizumi has proposed a new theory of superconductivity (SC) based on the notion of Berry phase related with an effective magnetic field assignable to adiababically evolving systems. I learned about the theory from a popular article published in Scitechdaily (`https://cutt.ly/LmS4tOl`).

A more technical description of the model can be found in an article [D97])(`https://cutt.ly/WmBkIsp`) by Koizumi. The article has title "Superconductivity by Berry connection from many-body wave functions: revisit to Andreev-Saint-James reflection and Josephson effect".

14.1.1 Summary of Berry phase model

The Berry phase model (BPM) explains SC as an implication of a collective phase for which the Berry phase would be a prerequisite. Berry connection acting on the space of quantum states rather than in the space of gauge fields. My interpretation about the basic aspects of the Berry phase theory formed on basis of abstract of [D97] is following:

1. In standard model of super-conductity Cooper pairs form a coherent states which is not an eigenstate of electron number. In the new theory fermion number is conserved for Cooper pairs in collective phase and electrons in single electron phase.
2. If Berry connection is non-trivial, it gives rise to a collective mode that generates supercurrent. This collective mode creates number-changing operators for particles participating in this mode, and these number-changing operators stabilize the superconducting state by exploiting the Cooper instability.

   In the new theory, the role of the electron-pairing is to stabilize the nontrivial Berry connection; it is not the cause of SC: also ordinary electrons in collective phase flow without dissipation.
3. In BCS SCs the simultaneous appearance of the nontrivial Berry connection and the electron-pairing occurs. Therefore, the electron-pairing amplitude can be used as an order parameter for the super- conducting state and corresponds to Berry phase. In high-Tc SCs the temperatures for the formation of Cooper pairs and for the appearance of SC are different.
4. Andreev-Saint-James reflection [D80] and Josephson effect are explained as consequences of the presence of the Berry connection. Bogoliubov quasiparticles are created by superpositions of creation and annihilation operators and utilized also in the BCS model as a convenient tool to diagonalize the kinetic part of the Hamiltonian. In Berry phase model they are replaced by particle-number conserving Bogoliubov excitations that describe the transfer of electrons between the collective and single particle modes.

The assumption of the model for Josephson effect inducing critics is that the the current in the junctions consists of electrons rather than Cooper pairs.

1. The model treats Josephson junction as an insulator rather than piece of a super-conductor. The model predicts two distinct cases corresponding depending on whether junction is a) thin or b) thick. For a) the Bogoliubov excitations for the two SCs are assumed to be identical. For b) they are not identified. For a) the effect is a first order effect and for b) a second order effect.
2. In BPM a) explains the AC Josephson effect as first order effect when chemical potential difference is taken into account. The supercurrent would be a flow of electrons brought about by the non-trivial Berry connection, which provides an additional U(1) gauge field besides the electromagnetic one.

   This conclusion is due to the presence of chemical potential difference equal to Coulomb energy in equilibrium, otherwise the Josephson frequency spectrum would come as even integer multiples of Josephson frequency.
3. Case b) is the one considered in the standard theory. The effect is second order effect also in the BCS model. If the chemical potential difference between the two SCs is neglected, the model gives BCS prediction for Josephson frequencies.

   If the the chemical potential difference is taken into account in BCS model, the Josephson frequency spectrum would come as half integer multiples of Josephson frequency. The same prediction follows for b) also in the BPM. Some evidence for this kind of half-odd integer spectrum has been repoported.

Berry phase theory is highly interesting from TGD view point and the comparison with TGD based view about SC is well-motivated.

1. In TGD space-times can be regarded as surfaces in $M^4 \times CP_2$. The effective magnetic field related to the Berry phase has as its TGD counterpart the monopole flux part of the ordinary magnetic field made possible by the non-trivial homology of CP_2 and having no Maxwellian counterpart. Monopole flux assignable magnetic flux tubes carrying also dark matter as $h_{eff} = n_0 > h$ phases of ordinary matter.
2. The existence of Berry phase corresponds to an existence of a phase defined by an angle like coordinate varying along flow lines of an integrable flow associated with induced Kähler field. Integrability is the geometric condition for the existence of the flow and thus superfluid flow or supracurrent.

   The integrable flow is a 4-D generalization [K85, K86, K8] of the notion of 3-D Beltrami (magnetic) field [B4, B31, B16, B20]. There is no classical counterpart of dissipation as quantum-classical correspondence suggests and the surfaces in question are minimal surfaces as one expects [L155]. Generalized Beltrami flows are possible if the dimension D of CP_2 projection of the space-time surface satisfies $D \leq 4$.
3. The members of Cooper pairs in TGD picture would be associated with parallel flux tubes, which form a closed flux tube in a long enough scale. This kind of connections by flux tube pairs can be formed by reconnection of U-shaped flux tube tentacles between two systems and play crucial role in the TGD based model of quantum biology [L194].
4. The formation of Cooper pairs accurs at the level of ordinary matter and the liberation of binding energy in their formation allows their transfer to the flux tubes, where dissipation is absent or at least slower by the large value of h_{eff}. Ordinary macroscopic SC requires high enough value of h_{eff} making possible long enough U-shaped flux loops and thus flux tube pairs.

   As in BPM, the creation of Cooper pairs stabilizes the flux tubes and makes possible non-dissipative currents of both electrons and their Cooper pairs so that SC as non-dissipative current flow is possible also for electrons.
5. Cooper pairs are in a coherent state at the flux tubes and this gives very simple effective Hamiltonian describing the interactions with ordinary matter. The outcome has a lot of common with the standard theory of SC. Both Cooper pairs and electrons are possible supracurrent carriers. The assumption Cooper pairs are at magnetic flux tubes allows however to circumvent the anomalies of the standard models.

6. The Cooper pairs must be created by bosonic oscillator operators constructed from fermionic oscillator operators by bosonization. This is possible only in 1+1-dimensional situations. Thanks to the Beltrami flow the situation is effectively 1+1-dimensional. Bosonization makes it possible to identify SU(2) Kac-Moody algebra, which has an interpretation in the TGD framework.

14.1.2 BPM, TGD based model, and the anomalies

The BPM is claimed to solve several basic problems of the standard model of SC. Also TGD based model suggests a solution to these anomalies based on the assumption that electrons and Cooper pairs are dark in TGD sense and reside at magnetic flux tubes.

1. High-Tc-superconductivity remains poorly understood. My understanding of the BPM is too limited to allow how it could increase the understanding in this respect.
2. The presence of 2 transition temperatures means that Cooper pairs emerge at higher critical temperature and SC at a lower critical temperature remains poorly understood. BPM predicts that the presence of Cooper pairs stabilizes the collective phase and is a prerequisite for the Berry phase in turn making possible non-dissipative flow. To me this would suggest that these two transition temperatures are identical.

   TGD: The flux tube pairs forming closed flux tubes serve as carriers of Cooper pairs. The first transition temperature would give rise to rather short flux tubes and SC in short scales and second transition temperature to rather long flux tube and SC in long scales with a larger value of h_{eff} (the scale of quantum coherence scales like h_{eff}).
3. The experimental finding is that London magnetic moment depends on the real mass m_e of electron rather than effective mass m_e^* . If supracurrent flows at the level of ordinary matter, one would expect the appearance of m_e^*. BPM explains this if the collective phase is separate from the ordinary phase.

   TGD: The dark electrons at magnetic flux tubes would not interact directly with condensed matter so that the real mass would appear in the expression of London moment caused by rotation of dark electrons.
4. It has found that the phase transition from SC to ordinary phase in an external magnetic field does not cause dissipation although one would expect this if Cooper pairs split to ordinary electrons. This can be understood in BPM if electrons in collective phase do not dissipate and thus do not interact with ordinary matter.

   TGD: The dissipation would be absent if the dark electrons from the split Cooper pairs do not dissipate. This is indeed true. One could thus talk about analogs of supra currents for electrons.

The proposed view encourages several questions. The formation of the Cooper pairs appears as a condition stabilizing the space-time sheets carrying dark matter and all preferred extremals could satisfy the conditions guaranteeing integrable flow and existence of a phase factor varying along flow lines. Could supra phases as non-dissipative phases of also fermionic states exist in all scales? Could the breaking of supra phase property be only due to the finite size of the space-time sheets? Could even hydrodynamic flow involve super-fluidity of some kind - perhaps based on neutrinos or neutrino Cooper pairs as speculated earlier?

14.2 TGD based model of superconductivity

TGD inspired model of super-conducitivity has developed slowly during years [K85, K86] [L32] [L86].

14.2.1 Brief summary of TGD based model

The breakthrough came around 2005 with the emergence of the idea about a hierarchy of phases of ordinary matter having non-standard value $h_{eff} = nh_0$ of Planck constant having arbitrarly large values and behaving in many respects like dark matter. Super-conducting phases would reside at the magnetic flux tubes carrying monopole flux and large value of h_{eff} would be crucial for their stability even at high temperatures.

General mechanism of superconductivity in TGD framework

The ideas about high temperature SC have evolved gradually as a reaction to experimental input and evelution in the understanding of TGD.

1. The many-sheeted space-time concept suggests a very general mechanism of SC based on a transfer of charged particles from atomic space-time sheets to larger space-time sheets. Later these space-time sheets were identified as magnetic flux tubes carrying as $h_{eff} = nh_0$ phases behaving like dark matter.

   The first guess was that larger space-time sheets are very dry, cool and silent so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met. The criticism against this model was that particles touch all space-time sheets having non-empty Minkowski space projection to the region where the particle is so that thermal equilibrium is generated. Darkness as $h_{eff} > h$ property would allow even same temperature since various energy scales would typically scale like h_{eff} implying thermal stability.

   One must however take the assumption about thermal equilibrium with a grain of salt. The TGD based model for the aging of a living system [L195] assumes that the space-time sheets carrying dark matter slowly approach thermal equilibrium with the space-time sheets carrying ordinary matter [L191]. The slow approach to thermal equilibrium would be due to a small amount of dissipation at flux tubes.

2. The possibility of large h_{eff} quantum coherent phases makes the assumption about thermal isolation between space-time sheets un-necessary. In the model to be discussed in this article Cooper pairs are created at the level of ordinary matter by standard mechanisms and transferred to flux tubes.

3. It became clear quantum criticality predicting a new kind of SC explaining the strange features of high T_c SC is essential. Two kinds of Cooper pairs, or rather flux tubes are assumed. They correspond to a different values of $h_{eff} > h$. Either the Cooper pairs or flux tubes with smaller value of h_{eff} have shorter life time (proportional to h_{eff}). Both Cooper pairs and flux tubes correspond to super-conductivity but in different time and length scales. In the transition to SC in long scales the closed but short flux tubes looking like flux tube pairs reconnect to long flux tubes.

   Below temperature $T_{c_1} > T_c$ only the Cooper pairs with smaller value of h_{eff} are present and their short lifetime implies that SC is broken to ordinary conductivity in longer scales satisfying scaling laws characteristic for criticality. At T_c Cooper pairs and flux tubes with longer lifetime become possible and have considerably longer life time.

   These two superconducting phases compete in a certain narrow interval around critical temperature T_c for which body temperature of endotherms is a good candidate in the case of living matter.

4. Magnetic flux tubes would be carriers of dark particles and according to the findings about high temperature SC magnetic fields would be crucial for SC. Two parallel flux tubes carrying magnetic fluxes in opposite directions is the simplest candidate for a super-conducting system. This conforms with the observation that antiferromagnetism is somehow crucial for high temperature SC. The spin interaction energy is proportional to h_{eff} and can be above thermal energy: if the hypothesis that dark cyclotron energy spectrum is universal is accepted, then the energies would be in bio-photon range and high temperature SC is obtained. If fluxes are parallel spin $S = 1$ Cooper pairs are stable. $L = 2$ states are in question since the members of the pair are at different flux tubes. These two kinds of Cooper pairs could correspond to BCS type and exotic Cooper pairs.

   The fact that the critical magnetic fields can be very weak or large values of $\hbar$ is in accordance with the idea that various almost topological quantum numbers characterizing induced magnetic fields provide a storage mechanism of bio-information.

5. This mechanism of high temperature SC is extremely general and in principle works for electrons, protons, bosonic ions and Cooper pairs of fermionic ions, charged molecules and even

neutrinos and an entire zoo of high T_c bio-SCs, super-fluids and Bose-Einstein condensates is predicted. The variant of the model to be discussed in this article predicts that also charged fermionic states give rise to non-dissipative currents and that the formation of Cooper pairs a prerequisite for the $h_{eff} > h$ phase.

6. For gravitational flux tubes the generalization of Nottale hypothesis [E9] states that $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ is very large and to the particle mass. Therefore the binding energy of Cooper pairs identifiable as spin-spin interaction energy and does not depend on the mass of the Cooper pair. Supraphases would be universal in this case. This form of superconductivity is proposed to be crucial for living matter.

Quantitative model of high-T_c SC and bio-SC

I have developed already earlier [K19, K20, K85, K86] a rough model for high T_c super conductivity [D89, D91, D92, D35, D19, D103]. The members of Cooper pairs are assigned with parallel flux tubes carrying fluxes which have either same or opposite directions. The essential element of the model is hierarchy of Planck constants defining a hierarchy of dark matters.

1. In the case of ordinary high T_c SC bound states of charge carriers at parallel short flux tubes become stable as spin-spin interaction energy becomes higher than thermal energy.

   The transition to SC is known to occur in two steps: as if two competing mechanisms were at work. A possible interpretation is that at higher critical temperature Cooper pairs become stable but that the flux tubes are stable only below rather short scale: perhaps because the spin-flux interaction energy for current carriers is below thermal energy. At the lower critical temperature the stability would is achieved and supra-currents can flow in long length scales.

2. The phase transition to SC is analogous to a percolation process in which flux tube pairs fuse by a reconnection to form longer super-conducting pairs at the lower critical temperature. This requires that flux tubes carry anti-parallel fluxes: this is in accordance with the anti-ferro-magnetic character of high T_c super conductivity. The stability of flux tubes very probably correlates with the stability of Cooper pairs: coherence length could dictate the typical length of the flux tube.

3. A non-standard value of h_{eff} for the current carrying magnetic flux tubes is necessary since otherwise the interaction energy of spin with the magnetic field associated with the flux tube is much below the thermal energy.

There are two energies involved.

1. The spin-spin-interaction energy should give rise to the formation of Cooper pairs with members at parallel flux tubes at higher critical temperature. Both spin triplet and spin singlet pairs are possible and also their mixture is possible.

2. The interaction energy of spins with magnetic fluxes, which can be parallel or antiparallel contributes also to the gap energy of Cooper pair and gives rise to mixing of spin singlet and spin triplet. In TGD based model of quantum biology antiparallel fluxes are of special importance since U-shaped flux tubes serve as kind of tentacles allow magnetic bodies form pairs of antiparallel flux tubes connecting them and carrying supra-currents. The possibility of parallel fluxes suggests that also ferro-magnetic systems could allow SC.

   One can wonder whether the interaction of spins with magnetic field of flux tube could give rise to a dark magnetization and generate analogs of spin currents known to be coherent in long length scales and used for this reason in spintronics (`http://tinyurl.com/5cu3qh`). One can also ask whether the spin current carrying flux tubes could become stable at the lower critical temperature and make SC possible via the formation of Cooper pairs. This option does not seem to be realistic.

14.2.2 TGD counterparts of the collective phase, novel magnetic field, and Berry's phase

In the standard model of superconductivity SC is characterized by a complex order parameter for which the Berry phase would serves as an analog in BPM. Berry phase is a consequence of adiabaticity and characterizes collective phase. One can assign to the Berry phase effective $U(1)$ gauge field which reduces to magnetic field in a static situation. What are the TGD counterparts of these notions?

Beltrami flow as space-time correlate for non-dissipative flow

TGD provides the geometrization of classical physics in terms of space-time surfaces carrying gravitational and standard model field as induced fields so that both the supra current and the phase should have geometric intepretation. This serves as a powerful constraint on the model.

1. Supra current must correspond to a flow. The flow must be integrable in the sense that the coordinate defined along flow lines defines a global coordinate at flux tubes. One can indeed argue that an operational defition of a coordinate system requires that coordinates correspond to coordinates varying along flow lines of some physical flow. The exponential of the coordinate would define the phase factor of the complex order parameter such that its gradient defines the direction of the supracurrent.

   If the motion of particles is random one cannot talk of a hydrodynamic flow but something analogous to the motion of gas particles or Brownian motion. In the TGD framework this situation corresponds to disjoint space-time sheets as a representation of particle orbits. The flow property could however hold true inside the "pieces" of space-time. The coherence scales of flow would become short.

2. One must make it clear that here an approximation is made. Elementary particles have as building bricks wormhole contacts defining light-like partonic orbits to which one can assign light-like curves as M^4 projections. For a vanishing value $\Lambda = 0$ of cosmological constant (real analytic functions at M^8 level), these curves are light-like (light-likeness condition reduces to Virasoro conditions) whereas for $\Lambda > 0$ (real polynomials) at M^8 level the projections consist of pieces which are light-like geodesics somewhat like in the twistor diagrams [L155]. Smooth curve is replaced with its approximation.

   For massive particles, this orbit would be analogous to zitterbewegung orbit and the motion in the long scales would occur with velocity $v < c$: this provides a geometric description of particle massiation. The supracurrent would not actually correspond to the flow as such but to CP_2 type extremals along the flow lines.

3. In the Appendix appearing also in [K8], I have briefly discussed a decades old proposal that the 4-D generalization of so called Beltrami flow [B4, B31, B16, B20], which defines an integrable flow in terms of flow lines of magnetic field, could be central in TGD. Superfluid flows and supra currents could be along flux lines of Beltrami flows defined by the Kähler magnetic field [K14, K7].

   If the Beltrami property is universal, one must ask whether even the ordinary hydrodynamics flow could represent Beltrami flow with flow lines interpreted in terms of flow lines Kähler magnetic field appearing as a a part of classical Z^0 field. Could hydrodynamical flow be stabilized by a superfluid made of neutrino Cooper pairs. h_{eff} hierarchy of dark matters in turn inspires the question whether weak length scale could be scaled up to say cellular length scales (neutrino mass corresponds to a length scale of large neuron).

4. The integrability condition

   $$j \wedge dj = 0 \tag{14.2.1}$$

   of the Beltrami flow states that the flow is of form

   $$j = \Psi d\Phi \ , \tag{14.2.2}$$

   where Φ and Ψ are scalar functions, which means that Ψ defines a global coordinate varying along the flow lines.

5. Beltrami property means that the classical dissipation characterized by the contraction of the Kähler current

$$j^{\alpha} = D_{\beta} J^{\alpha\beta} \tag{14.2.3}$$

with Kähler form $J_{\alpha\beta}$ is absent:

$$j^{\beta} J_{\alpha\beta} = 0 \ . \tag{14.2.4}$$

In absence of Kähler electric field (stationary situation), this condition states the 3-D current is parallel with the magnetic field that it creates.

In 4-D case, the orthogonality condition guarantees the vanishing of the covariant divergence of the energy momentum tensor associated with the Kähler form. This condition is automatically true for the volume part of the energy momentum tensor but not for the Kähler part, which is essentially energy momentum tensor for Maxwell's field in the induced metric. As far as energetics is considered, the system would be similar to Maxwell's equations.

The vanishing of the divergence of the energy momentum tensor would support Einstein's equations expected at QFT limit of TGD when many-sheeted space-time is approximated with a slightly curved region of M^4 and gauge and gravitational fields are defined as the sums of correspond induced fields (experienced by test particles touching all space-time sheets).

6. An interesting question is whether Beltrami condition holds true for all preferred extremals [K7] [L155], which have been conjectured to be minimal surfaces analogous to soap films outside the dynamically generated analogs of frames at which the minimal surface property fails but the divergences of isometry currents for volume term and Kähler action have delta function divergences cancelling each other. The Beltrami conditions would be satisfied for the minimal surfaces.

If the preferred extremals are minimal surfaces and simultaneous extremals of both the volume term and the Kähler action, one expects that they possess a 4-D analog of complex structure [L155]: the identification of this structure would be as Hamilton-Jacobi structure [K7] to be discussed below.

7. Earlier I have also proposed that preferred extremals involving light-like local direction as direction of the Kähler current and orthogonal local polarization direction. This conforms with the fact that Kähler action is a non-linear generalization of Maxwell action and minimal surface equations generalize massless field equations. Locally the solutions would look like photon like entities.

This inspires the question whether all preferred extremals except CP_2 type extremals defining basic building bricks of space-time surfaces in H have a 2-D or 3-D CP_2 projection and allow interpretation as thickening of flux tubes? CP_2 type extremals have 4-D CP_2 projection and light-like M^4 projection and an induced metric with an Euclidean signature.

Could all conserved currents define integrable flows?

In the TGD framework, the classical field equations for the space-time surface can be regarded as hydrodynamical in the sense that they express the conservation of the currents associated with the isometries of $H = M^4 \times CP_2$ [K91]. The classical field equations for the preferred extremals follow as consistency conditions for the modified Dirac equation obeyed by a second quantized induced spinor field [K122], whose second quantization is induced by the quantization of free spinor fields of H [L118].

An attractive conjecture is that all isometry currents or at least part of them (depending on the situation) are also Beltrami currents. For $j^A = \Psi^A d\Phi^A$ this implies $d\Psi^Q \wedge d\Phi^A = 0$ so that Ψ is function of Φ and j^A is expressible as a gradient of a scalar function: $j^A = d\chi^A$ and defines an integrable flow with a global coordinate varying along the flow lines of the current.

This prediction is obviously very powerful. This condition is linear and could make sense also for the fermionic currents involving bilinears of the oscillator operators. One would have genuine quantum hydrodynamics. In the TGD framework, the classical field equations for the space-time surface can be regarded as hydrodynamical in the sense that they express the conservation of the currents associated with the isometries of $H = M^4 \times CP_2$. The field equations follow as consistency conditions for the modified Dirac equation for a second quantized induced spinor field whose second quantization is induced by the quantization of free spinor fields of H.

The obvious objection against the strong form of the conjecture is that gradient currents are irrotational. This is true in Euclidean space but if the first homology group of the 3-surface is non-trivial. Gradient current can be rotational in the same sense as the vortices of supraflow, which have a quantized circulation concentrated at the axis of rotation.

Some examples

Some special cases help to get some perspective.

1. For $j^\alpha = 0$ condition he condition is trivially true: this is true for CP_2 type extremals. For massless extremals (MEs) the condition is true because of light-likeness of j^α. MEs are proposed to have a generalization with 3-D CP_2 projection.
2. In [K14, K8] it is found that for non-trivial solutions the dimension of the CP_2 projection of the space-time surface is $D = 2$ or $D = 3$. $D = 2$ would include string-like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ having a 2-D string world sheet X^2 as an M^4 projection: in this case $j^\alpha = 0$ would hold true so these extremals cannot describe SC. This phase would be highly ordered.
3. $D = 3$ phase would be between order and chaos and extremely complex: in this case j^α could be non-vanishing. The topologies of the flux lines for magnetic fields satisfying the Beltrami condition gives an idea about the complexity. SC would correspond to this situation.

Does the M^4 part of Kähler form produce problems?

The auml; of TGD [L65, L85] suggests that the Kähler form of H has also M^4 part. M^4 part could give rise to observed small CP breaking and be relevant also for matter antimatter asymmetry [L106, L130].

The M^4 Kähler form corresponds to an analog of a self-dual instanton field for which E and B are constant, orthogonal and have the same strength so that the action vanishes for the canonically imbedded M^4. Physically M^2 is characterized by light-like direction and E^2 complex coordinate. This field selects a preferred decomposition $M^2 \times E^2$ of M^4 and breaks Lorentz invariance. How can one save Lorentz invariance?

One can also consider local selections of polarization and light-like momentum directions. I call Hamilton-Jacobi structures [K7] and they provide a concrete realization of the analog of complex structure in the case of M^4.

Hamilton-Jacobi structure is an integrable distributions of M^2 and E^2 defining slicings of M^4 by string world sheets having an orthogonal Euclidian 2-surface at each point. The moduli space for the Hamilton-Jacobi structures serves as the analog of the moduli space of complex structures for 2-D surface. Hamilton-Jacobi structure should not be God-given but be dynamically determined and part of WCW.

The existence of $M^8 - H$ duality implies this. The construction of $X^4 \subset M^8$ assigns to it $M^4 \subset M^8$. Space-time surface $X^4 \subset M^8$ as a "root" of an octonionic polynomial associates to M^4 a Hamilton-Jacobi structure. This makes it possible to parametrize the tangent spaces of $X^4 \subset M^8$ by CP_2 coordinates and therefore $M^8 - H$ duality as a map $X^4 \subset M^8 \rightarrow X^4 \subset H$.

Could the contribution of M^4 Kähler action to the total Kähler current spoil the minimal surface property by spoiling the analytic structure? Could the existence of a 4-D analog of the complex structure and implying minimal surface property prevent this? Note that Beltrami flow property is not lost if the contribution $j^\alpha(M^4)$ to Kähler current vanishes.

14.2.3 Coherent states and the problem with fermion number conservation

The number of electrons and Cooper pairs are ill-defined for SC. This is required by the existence of an order parameter ψ having a well-defined phase. In the phase space picture of the harmonic oscillator phase angle is a conjugate of the radial phase space coordinate, whose quantized value in the Bohr model characterized by an integer n characterizing the energy eigenvalues of the harmonic oscillator. In quantum field theory n has interpretation as the number of particles in a given mode. Phase is well-defined for coherent states for Cooper pairs, which are eigenstates of annihilation operators of Cooper pairs. In QFTs the eigenvalues of annihilation operators define analogs of Fourier components of classical fields.

One can argue that the assumption of ill-defined fermion number and energy is unphysical. In the TGD framework one can consider two solutions to the problem.

1. Zero energy ontology (ZEO) provides the first candidate for a solution. In ZEO quantum state is a superposition of deterministic time evolutions and by holography equivalent to a superposition of pairs of ordinary 3-D quantum states located at the boundaries of causal diamond (CD) identified as intersection of future and past directed light-cones. These 3-D states have the same total quantum numbers and for keeping purposes their quantum numbers can be taken to be opposite so that the entire state has zero quantum numbers. Zero energy state can be a superposition of states for which the 3-D states at either boundary with varying quantum numbers such as energy and fermion number. There are no problems with the conservation of fermion number and energy. The density matrix describing the entanglement between the 3-D states at the opposite boundaries of CD is non-trivial for these states and the interpretation in terms of a thermal state is attractive.
2. Second solution is that the system is not closed. The total number of electrons and total energy are well-defined only for the system consisting of ordinary matter and dark matter at magnetic flux tubes. Superconductivity would be direct proof of the reality of dark matter. The transition to super-conductivity would transfer Cooper pairs formed at the level of ordinary matter to the magnetic flux tubes as dark phase.

   The collective phase proposed in BPM is analogous to the dark matter at flux tubes. The novel magnetic field as an effective magnetic field assigned with the Berry phase would correspond in TGD framework to Kähler magnetic field at flux tubes carrying monopole flux not possible in Maxwelian world.

   This option seems to be the realistic one.

Bosonization requires effective 1+1-dimensionality

It is convenient to denote the oscillator operators for electrons at the level of ordinary matter by $b_k^\dagger$ and b_k and oscillator operators for Cooper pairs at flux tubes by $c_m^\dagger$ and c_m. They are assumed to satisfy standard anticommutation/commutation relations.

1. The bosonic oscillator operators c_N creating Cooper pairs must be representable as superpositions of electron pairs. An even stronger condition is that a subset of fermionic oscillator operator pairs are representable as bosonic oscillator operators. This requires what is known as bosonization. Bosonization was discovered independently by particle physicists Sidney Coleman and Stanley Mandelstam and condensed matter physicists Daniel C. Mattis and Alan Luther. Unfortunately the Wikipedia article about bosonization (`https://cutt.ly/HmGYPnM`) is very confusing and it is better to read the article [B12] (`https://cutt.ly/BmGNzeA`) about bosonization. Remarkably, bosonization is possible only when the system is effectively 1+1-dimensional.
2. One considers chiral fermions for which the spinor fields with different helicities are decomposed to parts ψ with wave vectors $k>0$ and $\overline{\psi}$ with wave vectors $k<0$.

$$\begin{aligned} \psi &= \int_{k>0}\frac{dk}{2\pi}[exp(ikx)\alpha(k)+exp(-ikx)\beta^\dagger(k)] \ , \\ \overline{\psi} &= \int_{k<0}\frac{dk}{2\pi}[exp(ikx)\alpha(k)+exp(-ikx)\beta^\dagger(k)] \ . \end{aligned} \tag{14.2.5}$$

   It should be noticed that the definition of $\overline{\psi}_+$ does not involve hermitian conjugation as usually.
3. ψ is expressed in terms of bosonic field ϕ as

$$\psi =: exp(i\int_\infty \partial_{++}\phi): \ , \quad \overline{\psi} =: exp(-i\int_\infty \partial_{++}\phi): \ . \tag{14.2.6}$$

The subscript $\pm$ refers to either light-like coordinate.

The bosonic and fermionic currents are related by

$$\partial_{++}\phi =: \overline{\psi}\psi : \quad . \tag{14.2.7}$$

Note that the right hand side has fermion number 2. The condition $\partial_{+-}\phi = 0$ is satisfied and corresponds to massless d'Alembert equation in 1+1 dimensions. Coherent state is an eigenstate of ϕ and therefore of $\partial_{++}\phi$) and thus an eigenstate of the supracurrent.

4. The explicit formulas for the bosonization are given in the book "Field Theories of Condensed Matter Physics" by Eduardo Fradkin [B12] in the chapter about Luttinger liquid (page 164). Although this model does not apply as such in the TGD framework, it gives an idea about the construction.

   The bosonized expression fermionic oscillator operators with opposite spins and chiralities are mapped to the bosonized variants by the rule

$$\begin{array}{ll} \psi^{\dagger}_{R,\uparrow} \rightarrow exp(i\sqrt{2\pi}\theta_c) \ , & \psi^{\dagger}_{R,\downarrow} \rightarrow exp(-i\sqrt{2\pi}\theta_c) \ , \\ \psi^{\dagger}_{L,\uparrow} \rightarrow exp(i\sqrt{2\pi}\Phi_s) \ , & \psi^{\dagger}_{L,\downarrow} \rightarrow exp(-i\sqrt{2\pi}\Phi_s) \ . \end{array} \tag{14.2.8}$$

   In the singlet case, these rules give the correspondences

$$O_{SS} = \psi^{\dagger}_{R\uparrow}\psi^{\dagger}_{L\downarrow} \quad \rightarrow \quad exp(i\sqrt{2\pi}\theta_c)exp(-i\sqrt{2\pi}\Phi_s) \ . \tag{14.2.9}$$

   In the triplet case, one obtains

$$\begin{array}{lll} O^{1}_{TS} = \psi^{\dagger}_{R\uparrow}\psi^{\dagger}_{R\uparrow} & \rightarrow & exp(i\sqrt{2\pi}\theta_c)exp(i\sqrt{2\pi}\phi_s) \ , \\ O^{-1}_{TS} = \psi^{\dagger}_{R\downarrow}\psi^{\dagger}_{R\downarrow} & \rightarrow & exp(-i\sqrt{2\pi}\theta_c)exp(-i\sqrt{2\pi}\phi_s) \ 0. \end{array} \tag{14.2.10}$$

One must generalize these formulas to the TGD framework for a given flux tube. It is important to notice that there is quantum superposition over different flux tube configurations in the "world of classical worlds" (WCW) so that the inclusion of WCW degrees of freedom not present in QFT description is unavoidable.

1. The fermionic modes of opposite spin are defined at the same closed flux tube. Whether one should restrict the fields with opposite chirality to different flux tube portions is an open question.

2. The fermionic oscillator operators at space-time surface are labelled by a longitudinal momentum like quantum number, which in suitable units for closed flux tube allowing in a good approximation as a straight flux tube locally becomes integer valued momentum locally parallel to the flow line - the momentum scale is determined by Fermi momentum.

   The members of pairs have momenta $P_{\pm} = p_{cm}/2 \pm k$, where k has magnitude of order Fermi momentum, and p_{cm} is the total longitudinal momentum, which has an upper bound below Fermi momentum. The transversal quantum numbers are integer valued using as a basic unit $p_{min} = \hbar_{eff}/L$, where L of the order of the length of the flux tube.

   Since one has $p_{cm} = \hbar_{eff}/\lambda$ for Cooper pairs, their wavelengths are scaled up by the ratio $\hbar_{eff}/\hbar$ from their normal values. Also the length L of the flux tube is scaled up in this way from that for $h_{eff} = h$.

3. Additional quantum numbers are angular momentum eigenvalue m in the local flux tube direction and harmonic oscillator quantum number n labelling cyclotron states. The most plausible option is that one has phases characterized by the values of n and n.

   The breaking of rotational symmetry caused by the magnetic field takes place for a given space-time surface in the superposition. For $m > 0$ the angular momentum eigenvalues of cyclotron states contribute and one obtains Cooper pairs with relative angular momentum. Fermi statistics allows only even integer valued total angular momentum.

Kac-Moody symmetry associated with the bosonization

In [B12] it is mentioned that the bosonization gives rise to SU(2) Kac-Moody algebra such that I_3 generators is generated by the ϕ and generators $I_\pm$ by normal order exponentials of ϕ. This construction is applied in string models by extending the Cartan algebra represented by scalar fields to the entire algebra.

TGD predicts that the isometries of H give rise to an extended Kac-Moody algebra assignable to the 3-D light-like orbits of the partonic 2-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian.

This algebra is localized not only with respect to the complex coordinate z of the partonic 2-surface but also with respect to the light-like coordinate r varying along the partonic orbit. The extension is possible because light-likeness implies metric 2-dimensionality.

General coordinate invariance motivates the question whether this Kac-Moody algebra extends to a slicing by light-like 3-surfaces parallel to the partonic orbits.

Bosonization requires Beltrami property

Bosonization requires effective 1+1-dimensionality. This is guaranteed by the Beltrami flow property of supra currents. In TGD all fermionic oscillator operators at space-time surface are representable in terms of oscillator operators associated with the spinor harmonics of $H = M^4 \times CP_2$. The existence of Beltrami flow implies the existence of single preferred coordinate assignable to the flux tubes and if the transversal degrees of freedom are frozen for the Cooper pairs in given phase of SC, the system is effectively 1-D.

One can consider a variety of phases in which the cyclotron excitations assignable to the transversal degrees of freedom assignable are present. These cyclotron states and transitions between them play a key role in TGD inspired view about quantum biology.

Why the formation of Cooper pairs is necessary for the formation of $h_{eff} > h$ dark phase?

Why would the formation of Cooper pairs be necessary for the formation of the dark phase? Here the understanding of the energetics $h_{eff} > h$ phases helps.

1. Quite generally, the energy of the quantum state increases with h_{eff} so that the creation of the dark electrons requires energy.

   This energy would be provided in the formation of the Cooper pair as the liberated binding energy. Cooper pairs would be formed already at the level of the ordinary matter. The bosonic field modelling Cooper pairs would couple to 2-electron bilinear characterizing the quantum state of the Cooper pair.

   Since Cooper pairs are formed at the level of ordinary matter, the view of the formation of Cooper pairs is consistent with the conventional picture involving photons and effective attractive interaction generated by the attractive interaction between electrons and atoms.

2. In this process fermion number decreases by 2 units (in the recombination of electron and hole it would decrease by 1 unit). This process is analogous to Andreev-Saint-James reflection [D80] (`https://cutt.ly/AmDYDTG`), which could therefore be seen as direct evidence for the transfer of electron pairs to magnetic flux tubes. Andreev-Saint-James reflection occurs at the normal metal-SC interface and gives rise to lower energy states at the surface of unconventional SC.

14.2.4 The general form of the effective Hamiltonian

Consider now the general form of the effective Hamiltonian H_{eff} obtained from a quartic Hamiltonian in oscillator operators of H spinor field at space-time surface.

1. The effective Hamiltonian operator H_{eff} modelling the system would be formed as a linear in the oscillator operators $c_k^\dagger$ (c_k) creating (annihilating) Cooper pairs at flux tubes and products $b_k b_l$ ($b_k^\dagger b_l^\dagger$) of annihilation (creation) operators for ordinary electrons.

If also free electrons are possible at flux tubes, H_{eff} contains also a part, which is bilinear both in the electronic oscillator operators at flux tubes and at the level of ordinary matter.

2. H_{eff} contains a term of form $H_1 = H_2 + H_2^\dagger$

$$H_2 = C^{Nkl} c_N b_k^\dagger b_l^\dagger \quad . \tag{14.2.11}$$

3. For coherent states of Cooper pairs the action of the annihilation operators c_N reduces to a multiplication with a complex number C_N so that H_2 reduces to a kinetic term

$$H_2 = B_{kl} b_k^\dagger b_l^\dagger \quad , \quad B_{kl} = C^{Nkl} C_N \quad . \tag{14.2.12}$$

The kinetic part has the same form as the kinetic term of H_{eff} in the standard model for SC. One can diagonalize this part of Hamiltonian by a Bogoliubov transformation `https://cutt.ly/DmDcbC7` mixing the creation and annihilation operators for electrons with different quantum numbers. Bogololiubov transformation can be regarded as a symplectic transformations at the level of phase space.

4. The remaining terms can be treated as a perturbation. $H_2^\dagger$ is of form

$$H_2^\dagger = \overline{C}^{Nkl} c_N^\dagger b_k b_l \quad . \tag{14.2.13}$$

$H_2^\dagger$ makes possible the transfer of electron pairs to the flux tubes as Cooper pairs. It also makes possible the Andreev-Saint-James reflection regarded as the reflection of the electron as a hole from the boundary of SC.

5. H_{eff} contains also a quartic term quadratic in electronic oscillator operators both at the flux tubes and at the level of ordinary matter. This term makes possible the transfer of electrons to electron pairs not forming Cooper pairs at flux tubes.

The oscillator operators $b_k(tube)$ at flux tube creating single fermion states should correspond to oscillator operators not appearing in $\partial\phi_{++} =: \overline{\psi}\psi :$.

6. The assumption that a closed flux tube forming effectively a flux tube pair is involved suggests that the members of the Cooper pair are at different flux tubes. If this is the case the fermionic oscillator operators at different flux tubes anticommute and the commutator of the bosonic oscillator operators does not involve bi-local terms.

14.2.5 A more precise formulation of TGD based theory by starting from BCS theory

It is instructive to see whether BCS theory could allow a more detailed formulation of the TGD inspired theory. The Wikipedia article (`https://cutt.ly/4mBkA5i`) gives a good summary of BCS theory.

1. Electrons of the lattice are treated as free Fermi gas and at zero temperature electrons are below the Fermi surface. In the simplest situation, Fermi surface is a sphere defined by Fermi energy (`https://cutt.ly/UmBkFhb`)

$$E_F = \frac{p_F^2}{2m_e} = \frac{\hbar^2}{2m_e}(3\pi^2 n_e)^{2/3} \quad . \tag{14.2.14}$$

Here n_e is the density of conduction electrons. Fermi temperature is equal to Fermi energy in the natural units. Examples of the values of the Fermi energy, Fermi temperature, Fermi velocity, and electron number density can be found in `https://cutt.ly/zmBkHt7`.

2. Fermi statistics implies that the transition to super-conductivity involving formation of Cooper pairs occurs for electrons near the Fermi surface. Any attractive interaction between electrons can cause the creation of Cooper pairs and the mechanism based on the interaction with phonons is the mechanism in BCS theory.

Critical temperature as Hagedorn temperature for magnetic flux tubes

The transition to super-conductivity involves an exponential increase in the heat capacity. This could be seen as a support for the flux tube picture. Flux tubes are string like objects and have an infinite number of degrees of freedom and the feed of energy excites these degrees of freedom so that temperature increases very slowly.

This implies a maximal temperature known as Hagedorn temperature T_H in string model context. The identification $T_c = T_H$ is suggestive. Living matter can remain functional in a rather narrow range of temperatures. I have proposed that the critical temperature corresponds to Hagedorn temperature [L191] for the magnetic body of the system receiving information from and controlling the biological body.

If the identification of T_c as Hagedorn temperature for the magnetic flux tubes is correct, the spectrum of the critical temperatures could be universal. On the other hand, in the general BCS model of SC, critical temperature depends on the mechanism for the formation of Cooper pairs.

1. For attractive interaction caused by phonon vibrations one has

$$T_c = 1.134 \times E_D \times exp(-\frac{1}{N(0)}) \ , \quad N(0) = n(0)V \ . \tag{14.2.15}$$

   Here $N(0)$ is the total number of conduction electrons at $T = 0$ and $E_D = \hbar\omega_D$ is Debye energy defined as the maximal value of frequency $f_D = c_s/\lambda_D$ for sound wave defined by the minimal wavelength λ_D by the minimal size of objects involved in the oscillations. The size of the lattice cell gives an order of magnitude estimate for λ_D (`https://cutt.ly/RmBkKKI`.

2. The Debye frequencies of 1-D chain, 2-D square lattice, and 3-D cubic lattices are given by $\omega_D = k_n c_s/a$. $k_1 = \pi$, $k_2 = 2\sqrt{\pi}$, $k_3 = (6\pi^2)^{1/3}$. One obtains an idea about the range of the sound velocities at `https://cutt.ly/hmBkZGX`, which are typically by two orders of magnitude large than the sound velocity in air.

$T_c = T_H$ requires an interaction between condensed matter and magnetic flux tubes carrying dark matter.

1. In the TGD inspired model of living matter [L194, L121], the magnetic body (MB) receives information from the biological body (BB) and controls it. For instance, biophotons would be dark photons transformed to ordinary photons.
2. Communication and control would use energy conserving resonant interaction between dark matter associated with the flux tubes and ordinary matter. In particular, sound waves with $h_{eff} = h$ can be transformed to dark photons with $h_{eff} = h_{gr}$ satisfying $E = hf_{high} = \hbar_{eff} f_{low}$, could be example of energy resonance. Living matter is ferroelectric and the transformation of acoustic waves to dark em waves is possible.
3. The resonant transformation of photons to dark photons and back to phonons could give rise to the interaction usually interpreted as a phonon exchange. In the model of cell membrane and EEG, cell membrane sends dark Josephson photons to MB and MB responds by sending dark cyclotron photons absorbed by dark variant of DNA central in TGD inspired model of genetic code [L121]. Also acoustic oscillations of cell membrane and DNA are important and also these could participate in the resonance.

TGD based interpretation of the gap energy

The decrease of some kind of binding energy as one approaches T_c from below is highly suggestive. Some kind of binding energy - gap energy ΔE - seems to be involved. At $T = 0$, BCS theory predicts the universal relationship between ΔE and critical temperature T_c

$$\Delta E(T = 0) = 1.1764 T_c \ . \tag{14.2.16}$$

As one approaches T_c, the gap energy obeys the formula

$$\Delta E(T) = 3.06\sqrt{1-\frac{T}{T_c}} \ . \tag{14.2.17}$$

Consider now the TGD inspired interpretation of the gap energy.

1. In the TGD framework ΔE represents the difference $\Delta E = E_B - E_{dark}$ of the binding energy E_B liberated in the formation of the Cooper pair the additional energy of the dark Cooper pair due to $h_{eff} > h$ property (the energy of state as function of h_{eff} increases with h_{eff}). The decrease of E_B with increasing T, which could be caused by weakening of phonon-electron interactions, implies critical temperature.

   For temperatures below T_c, $\Delta E = E_B - E_{dark} < 0$ implies that $h \to h_{eff}$ transition is possible. The surplus energy can be realized as kinetic energy of supra currents. At T_c ΔE vanishes and above T_c $h \to h_{eff}$ transition is impossible.

2. One can however consider a situation in which external energy feed could provide the needed energy. There are situations in which this kind of transitions might be induced thermally or by external energy feed. Indeed, in biology metabolic energy feed would make possible high-Tc superconductivity above Tc.

3. From the gap energy, BCS model predicts the maximal momentum of the Cooper pair as $p^{1)}_{max} = 2m_e\Delta E/p_F$ (in units $c = 1$) allowing to estimate the velocity range for the Cooper pairs of supracurrent.

   In TGD ΔE would go to the longitudinal energy of cyclotron state and transversal cyclotron energy due to the magnetic field of the flux tube. If all energy goes to the momentum, one has $p^{2)}_{max} = \sqrt{4m_e\Delta E}$. This gives for the ratio $p^{2)}_{max}/p^{1)}_{max}$

   $$\frac{p^{2)}_{max}}{p^{1)}_{max}} = \sqrt{E_F}\Delta = \sqrt{\frac{E_F}{1.764T_c}} \ .$$

   For conventional SCs, this ratio is of order $10^3 - 10^4$ since the value of E_F varies in the range 2-10 eV and the value of T_c is in the range $.1 - 1$ meV. This would suggest that cyclotron energy of the Cooper pair with the scale $\hbar_{eff}qB/m_e$ takes most of the energy.

What could be the values of the monopole flux magnetic field and h_{eff}?

In order to say something about the value of B and h_{eff}, some assumptions are needed.

1. The generalization of the Nottale hypothesis [E9] to TGD context [K96, K78] makes sense. Nottale hypothesis introduces gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where M in the recent situation is the Earth's mass M_E and v_0 is velocity parameter.

2. The monopole part of the Earth's magnetic field corresponds to the endogenous magnetic field $B_{end} \simeq 2B_E/5 = .2\times 10^{-4}$ Tesla [K85, K86] [L194] deduced from the effects of ELF em fields on mammal brain by Blackman and others [J7]. The spectrum of B_{end} is assumed to contain also other values, in particular a representation of 12-note scale [L22, L121, L137] but this particular value seems to be of special importance.

3. The monopole flux tubes, which carry the field B_{end} are identifiable as gravitational flux tubes mediating gravitational interaction. Whether this is the case or not has remained an open question.

4. Assume that gravitational flux tubes are essential for SC so that quantum gravitation in the TGD sense would be a central element of SC. Therefore SC would not be a mere local condensed matter phenomenon but depend also on M_E and the Earth's gravitational field. Life is also a phenomenon of this kind and the TGD based quantum model for living systems indeed involves high-Tc superconductivity.

Consider now the consequences of these assumptions.

1. For $\hbar_{gr}$, cyclotron energies

$$E_c(\hbar_{gr}) = \hbar_{gr}\frac{qB_{end}}{m} = \frac{GM}{v_0}qB_{end} = \frac{\hbar_{gr}}{\hbar}E_c(\hbar) \quad (14.2.18)$$

2. are independent of the mass m of the charged particle. This universality reflects Equivalence Principle.

   Second consequence is that the gravitational Compton length

$$\lambda_{gr} = \frac{\hbar_{gr}}{m} = \frac{GM}{v_0} \quad (14.2.19)$$

   is also universal.

3. The model of fountain effect of super-fluidity suggests $v_0 = c/2$ near the surface of Earth. This predicts that λ_{gr} equals to Scwartschild radius r_S which is 9 mm for Earth. All particles would have this gravitational Compton length.

   Also smaller values of v_0 are possible: for instance, $v_0/c \simeq 2^{-11}$ would be true for the 4 inner planets of the Sun [L153, L152, L141].

4. $v_0 = c/2$ predicts that in the case of electron

$$\frac{\hbar_{gr}(m)}{\hbar} = \frac{2GMm}{v_0\hbar} = \frac{r_S}{L_c(m)} \quad . \quad (14.2.20)$$

   From the value $r_S = 9$ mm for the Earth's Schwartschild radius and the value of electron Compton length $L_c(e) = 2.4 \times 10^{-12}$ m, one obtains

$$\frac{\hbar_{gr}(e)}{\hbar} \simeq .4 \times 10^{10} \quad .$$

   The cyclotron frequency f_c of electron in the endogenous magnetic field B_{end} is $f_c \simeq 6 \times 10^5$ Hz giving for cyclotron energy $E_c(\hbar) = 2.48 \times 10^{-9}$ eV. This gives for

$$E_c(\hbar_{gr}) \simeq 9.3 \ \text{eV} \quad ,$$

   which is near to the upper bound of the Fermi energies $E_F(T = 0)$ for electrons in condensed matter.

5. For the Cooper pairs of ions suggested to be crucial for living matter, the same prediction holds true. The same prediction for E_c holds true for bosonic ions. What is interesting is that the prediction would have the same scale as for electrons for neutrinos and their possibly existing Cooper pairs. For neutrinos and neutrons E_c would be replaced by the cyclotron energy in classical Z^0 magnetic fields necessarily accompanying induced Kähler fields at monopole flux tubes.

   The large parity breaking effects in living matter have no convincing explanation in the standard physics framework in living matter. This supports the view about large h_{eff} scaling up also the weak Compton scale. $\hbar_{eff} = \hbar_{gr} = GM_Em/v_0$ with $v_0 = c/2$, the gravitational Compton length would be $\lambda_{gr} = r_S = .9$ cm for all particles including neutrinos and weak bosons. Since dark weak bosons would be effectively massless below this scale, large weak interaction induced parity breaking effects would take place below Λ_{gr}. It is of course not clear whether there exists a mechanism for the formation of neutrino Cooper pairs.

   For Sun and inner planets one has $v_0 \simeq 2^{-11}$ and $r_S = 3$ km. This gives $\lambda_{gr} \simeq 2^{10}r_S = 6$ Mm to be compared with the radius $r_S = 6.37$ Mm of Earth. Does this mean that there is a quantum coherent phase in this scale associated with the Earth?

TGD based model of Josephson effect

The basic assumption is that the flux tube connection carries a quantum coherent superconducting phase at Josephson junction. In the simplest description, one can apply the Schrödinger equation for the Scrödinger amplitude of Cooper pairs. Therefore the situation reduces to that already considered by Josephson. Is the Hamiltonian just a single particle Hamiltonian for Cooper pairs.

The kinetic part of the Cooper pair Hamiltonian is quadratic in Cooper pair oscillator operators at both sides. The kinetic part becomes linear by coherent state property. Coupling to the vector potential is with charge 2e as in the standard model. Cooper pairs and free electrons move in an external voltage plus helical magnetic field carrying monopole flux giving rise to the "novel" magnetic field.

The covariant constancy condition

$$(\partial_\mu - 2eA_\mu)\psi = 0 \tag{14.2.21}$$

is satisfied for two coordinates: for the time coordinate (or possibly light-like coordinate) and for the longitudinal coordinate varying along the flow lines of the Beltrami flow. A_μ reduces inb 1-D situation to gradient. Covariant constancy is satisfied at the flux tubes along the helical flux lines and gives Josephson effect in standard manner. The phase is essentially the integral of voltage.

By coherent state property H becomes linear perturbation just like a perturbation of a harmonic oscillator by a periodic force. The effect is non-trivial only in second order perturbation theory. Chemical potential term is not needed at the level of MB.

The 4 anomalies in TGD framework

The article of Koizumi [D97] mentions 4 anomalies of the BCS model (no generally accepted model of high-Tc SC exists). Besides the absence of the difference of chemical potentials in the condition defining Josephson frequencies, 3 other anomalies are mentioned. These anomalies do not plague the TGD based model. The basic reason is that Cooper pairs reside at the magnetic flux tubes.

1. There is only one transition temperature in the BCS model of SC whereas high-T_c superconductivity involves 2 transition temperatures. In the TGD framework the first transition temperature leads to a superconductivity but in spatial and time scales (proportional to h_{eff}), which are so short that macroscopic super-conductivity is not possible. In the lower transition temperature h_{eff} increases and the flux tubes reconnect in a stable manner to longer flux tubes. The instability of this phase at critical temperature would be due to the geometric instability of the flux tubes.
2. London moment depends on the real electron mass m_e rather than the effective mass m_e^* of the electron. This effect relates to a rotating magnet. There is a supra current in the boundary region creating the magnetic moment. The explanation is that the electrons resulting from the splitting of Cooper pairs at the flux tubes of magnetic field do not interact with the ordinary condensed matter so that the mass is m_e-
3. For SCs of type I, the reversible phase transition from SC to ordinary phase in an external magnetic field does not cause dissipation. One would expect that the splitting of Cooper pairs produces electrons, which continue to flow and dissipate in collisions with the ordinary condensed matter. The reversibility of the phase transition can be understood if the electrons continue to flow at the flux tubes as supracurrents.
4. Magnetic flux tubes also solve the anomaly related to chemical potential: chemical potentials are present but not at the level of magnetic flux tubes so that the erratic calculation gives a correct result in the standard approach.

The basic objection against the TGD based proposal

The basic objection against the TGD based model of superconductivity is that supercurrents flow along monopole flux tubes but an experimental fact is that magnetic field destroys superconductivity. The problem disappears by analyzing the anatomy of magnetic fields in the TGD framework.

1. TGD predicts two kinds of flux tubes carrying Earth's magnetic field B_E with a nominal value of .5 Gauss. This prediciton is quite general. The flux tubes have a closed cross section - this is possible only in TGD Universe, where the space-time is 4-surface in $M^4 \times CP_2$. The flux tubes can have a vanishing Kähler magnetic flux or non-vanishing quantized monopole flux: this has no counterpart in Maxwellian electrodynamics.

   For Earth, the monopole part would correspond to about .2 Gauss - 2/5 of the full strength of B_E.

2. Monopole part needs no currents to maintain it and this makes it possible to understand how the Earth's magnetic field has not disappeared a long time ago. This also explains the existence of magnetic fields in cosmological scales.

   The orientation of the Earth's magnetic field is varying. In the TGD based model, the monopole part plays the role of master. When the non-monopole part becomes too weak, the magnetic body defined by the monopole part changes its orientation. This induced currents refresh the non-monopole part [L30]. The standard dynamo model is part of this model.

3. There is an interesting (perhaps more than) analogy with the standard phenomenological description of magnetism in condensed matter. One has $B = H + M$. H field is analogous to the monopole part and the non-monopole part is analogous to the magnetization M induced by H. $B = H + M$ would represent the total field. If this description corresponds to the presence of two kinds of flux tubes, the TGD view about magnetic fields would have been part of electromagnetism from the beginning!

   Flux tubes can also carry electric fields and also for them this kind of decomposition makes sense. Could also the fields D, P, and E have a similar interpretation?

   In the linear model of magnetism, one has $M = \chi H$ and $B = \mu H = (1+\chi)H$. For diamagnets one has $\chi \leq 0$ and for paramagnets $\chi \geq 0$. Earth would be paramagnetic with $\chi \simeq 3/2$ if the linear model works. χ is a tensor in the general case so that B and H can have different directions.

4. Superconducting phase is a perfect diamagnet so that $B = H + M = 0$. Supra currents generate M, which effectively cancels H. This happens for the interaction of the test particle with the fields H and M, which are at different space-time sheets. In the interaction the test particle touches these space-time sheets and the effects superpose linearly. At the QFT limit this corresponds to the vanishing of B. B does not destroy superconductivity but superconductivity destroys B. In the Meissner effect superconductivity is lost and B is weakened and monopole field H and possible flux tubes of the external field become visible.

14.3 Summary and conclusions

TGD suggests that superconducting charge carriers Cooper pairs of them. In this article I have compared this view with the view represented in [D97]. In the following I will will summarize this article and conclude with the recent TGD based view of high Tc superconductivity as it is now (year 2024).

14.3.1 Comparison of BPM and TGD inspired model of SC

Consider now the relation of BPM to TGD inspired model of SC.

1. In TGD, the phase factor of complex order parameter would be an exponential of a longitudinal coordinate Φ related to a helical flux along a flux tube serving as a longitudinal coordinate. For closed flux tubes with the shape of a long flattened square, the phase factors at the two flux tubes would be exponentials of the same longitudinal cyclic coordinate. There is no obvious reason for the interpretation as Berry's phase although this interpretation cannot be excluded.

2. In TGD, the "novel magnetism" associated with the Berry phase would correspond to the monopole part of the magnetic field not present in Maxwellian theory. The monopole part plays a central role in TGD inspired quantum biology and also in the model of galaxies

and stars [L91, L103]. They appear also in the models of hadrons and nuclei and their dark variants leading to a new physics about hadrons and nuclei.

The flux tubes have closed transversal cross sections and are therefore not possible in Minkowski space. These flux tubes appear in all scales and form a fractal hierarchy.

Also flux tubes with closed cross section with 2-D homologically trivial projection are possible and carry vanishing magnetic flux as also half flux tubes glued to background 3-surfaces as representation of ordinary flux tubes for which cross section as the topology of disk.

3. The decay of the Beltrami phases could correspond to the decay of a flux tube carrying a Beltrami flow to thinner flux tubes parallel to the original flow. SC would reduce to SC in a shorter scale. The two transitions for high Tc cuprate SCs could correspond to reverse transitions in which flux tubes fused to thicker and longer flux tubes. Low temperature would stabilize longer and thicker flux tubes against splitting to shorter and thinner ones.

It is useful to list the basic differences between BPM and the TGD based model.

1. The authors identify Josephson junction as an insulator. In the TGD framework the junction would consist of superconducting flux tubes accompanied by a parallel structure at the level of ordinary matter, which can be an insulator.
2. In TGD there is a supracurrent of Cooper pairs but it occurs at magnetic flux tubes. Also a supracurrent of electrons is possible.
3. A pair of flux tubes is present in the junction. A reconnection of U-shaped tentacles gives rise to the junctions. Flux tube junctions stabilized have $h_{eff} > h$ and the states have higher energy. The energy liberated in the formation of Cooper pairs provides the energy needed to increase h_{eff}.
4. BPM produces Josephson effect using first order Hamiltonian for thin junctions. For thick junctions a second kind of Josephson effect would result for long junctions.

   In TGD JE does not depend on the length of JE assuming that the junction is accompanied by a magnetic flux tube pair. JE results as a second order effect from the effective Hamiltonian for Cooper pairs which is by coherent state property linear in oscillator operators of Cooper pairs. Situation is essentially the same as in the standard model. Also the mechanism for the formation of Cooper pairs remains the same.
5. BPM predicts chemical potential term. In the TGD framework this is neither predicted nor needed since chemical potential is not needed at the flux tube level. Standard calculation gives a correct result although it is not logically consistent.

14.3.2 Speculations, questions, and conclusion

The only way to make progress is to speculate and then challenge the speculations by making critical questions. The following represents a list of such speculations and critical questions.

Speculations

Consider first some speculations.

1. The TGD inspired model suggests that SC could be possible also above T_c by using energy feed providing the energy needed to increase the value of h_{eff}. This would be the basic role of metabolism. This could have far reaching technological consequences and also profound implications concerning the creation of artificial life.

   Furthermore, the TGD based model for "cold fusion" [L27, L54, L117] led to a reformulation of nuclear physics [L103] in which phase transition to dark phase of nuclei has a key role also in the ordinary nuclear reactions as a description of tunnelling phenomenon.
2. In the TGD inspired quantum biology, the cell membrane is identified as a generalized Josephson junction between superconductors assignable to lipid layers of the cell membrane (actually decomposing in a better resolution to membrane proteins acting as Josephson junctions). One can ask what a straightforward application of the basic formulas gives in the case of neuronal membrane.

One can estimate the gap energy Δ from the formula $\Delta = \hbar\omega_D$ using the already discussed formula $\omega_D = k_n c_s/a$, where k_n depends on the effective dimension of the lattice like system and has values $k_n \in \{3.14, 3.54, 2.66\}$ for $n = 1, 2, 3$. Sound velocity c_s can be replaced with the conduction velocity v of nerve pulses varying in the range $v/c \in [.1, 1] \times 10^6$. The formula would give for $n = 2$ and maximal value $v/c = 10^{-6}$ $E_D = .044$ eV which is in the range of neuronal membrane potentials.

3. The role of $\hbar_{gr}$ and B_{end} in the model would suggest that the SC observed in laboratories is not a mere local condensed matter phenomenon. What happens to SC on Mars? Is the Earth mass replaced with that of Mars and the monopole part B_{end} with its value in Mars? There is evidence that B_{end} is non-vanishing: for instance, Mars has auroras.

4. If the monopole flux tube indeed mediates graviton exchanges, one can wonder whether SC itself is an essentially quantum gravitational phenomenon. Could the attractive interaction between electrons of the Cooper pair be somehow due to gravitation?

   The extremely weak direct gravitational interaction between electrons and nucleons cannot be responsible for the formation of Cooper pairs. One can however argue that Earth takes the role of atomic nuclei in the proposed description. Earth attracts the electrons and causes an effective attraction between them. Could this interaction force the wave functions of the electrons of the Cooper pair with wavelength $\Lambda_{gr} = r_S = 2GM \simeq 9$ mm to overlap and form a quantum coherent state.

   The proposed duality between gauge theories and gravitation, in particular AdS/CFT duality, has a TGD counterpart. The dynamics for the orbits of partonic 2-surfaces and lower-dimensional surface defining a frame for the space-time surface as an analog of soap film [L155] would be dual to the dynamics in the interior of the space-time surfaces.

   Could the descriptions in terms of cyclotron photon exchanges and graviton exchanges be dual to each other? Note also that at the fundamental level classical TGD are expressible using only 4 classical field-like variables as a selected subset of embedding space coordinates. This implies extremely strong constraints between fundamental interactions.

Critical questions

Consider now some critical questions.

1. Suppose that Cooper pairs are formed at the level of ordinary matter by interaction with phonons (say) and transferred to MB.

   Q: How can the Cooper pairs survive at MB, where acoustic oscillations mediating interaction with atoms are not present?

   A: The presence of the resonant interaction between photons and dark photons would make possible the survival of the Cooper pairs at MB.

   Second option is that the Cooper pairs remain in the ordinary matter and only the electrons are transferred to the flux tubes and the energy liberated in the formation of Cooper pairs makes the transfer energetically possible. Supracurrents would indeed consist of electrons as proposed in [D97].

2. I have routinely used the statement "particle resides at magnetic body".

   Q: What does this really mean?

   A: In many-sheeted space-time, the space-time sheets with common 4-D M^4 projection are extremely near to each other and the test particle touches all the sheets. The conclusion in the case of gravitational flux tubes has been that the particle touches all sheets of the many-sheeted magnetic body rather than resides at it.

   Here one must remember that also many-sheetedness with respect to CP_2 is predicted and leads to the proposal that coherent flux tube bundles in M^4 as many-sheeted space-time with respect to CP_2 explain the value of G in terms of CP_2 length squared following from TGD as a prediction [K10]. In this case, the test particle does not touch all the sheets unless it has a large value of h_{eff}: $h_{eff} = h_{gr}$ could imply this.

   Q: But doesn't this mean that the particle touches all space-time sheets for all flux tubes?

A: The generalization of Beltrami hypothesis might actually prevent this. If the M^4 part of the Kähler current is proportional to instanton current and conserved, the M^4 projection of flux tube is 3-D so instanton density vanishes. In this case space-time surfaces have 3-D M^4 projection and are like orbits of membranes and the above argument fails.

It can of course, also happen that only the sum of M^4 and CP_2 currents has vanishing divergence: in this case the M^4 and CP_2 projections would be 4-D.

Clearly, the situation is unclear but it is now possible to formulate questions and possible answers precisely.

3. The isotope effect of superconductivity means the proportionality $T_c \propto M^p$, where M is the mass of the isotope. The values of p are near $p = -1/2$. This implies the proportionality $\Delta \propto M^p$.

   Q: Can the $T_c = T_H$ hypothesis be consistent with the isotope effect?

   A: Assume that the scale of dark cyclotron energies determines to a high extent the value of Δ. Cyclotron energies are of the form $E_c = \hbar_{gr} qB/m = (GM/v_0)qB_{end}$. Nottale hypothesis implies that v_0 takes the role of a dimensionless coupling constant strength for gravitation and very probably does not vary [L141].

   The local value of B_{end} can however vary and depend on M. This would mean a local variation of the thickness of the flux tube as a response to the contact of the isotope with the isotope. This in turn would cause the local change of the string tension as a sum of densities of the volume and Kähler magnetic energies per unit length.

Which of the TGD based views of superconductivity is correct?

I have considered several TGD inspired views of superconductivity.

1. The key assumption is the presence of phases of ordinary matter with effective Planck constant which can be rather large. The original assumption was that Cooper pairs consist of pairs of dark particles at magnetic monopole flux tubes [K85, **?**, **?**, **?**].

2. One can however ask whether the Cooper pairs are at the level of ordinary matter and whether their formation liberates the binding energy allowing to transform electrons to their dark cariants with large h_{eff}. The TGD view of the Pollack effect as a way to create dark protons at gravitational monopole flux tubes using the energy of solar photons has been considerably generalized [L175] and in principle also the creation of dark electrons is possible [L188]. The energy needed could come from formation of bound states of atoms.

   This view of the Pollack effect suggests that also the formation of Cooper pairs of ordinary electrons could provide the energy needed to generate dark electrons. For this option one could consider dark electrons as charge carriers but also dark Cooper pairs are possible. The splitting of this kind Cooper pairs however creates electrons, which dissipate in conflict with the experimental findings discussed in the introduction. Therefore this option must be given up.

3. Also the possibility that charge carriers are dark electrons rather than Cooper pairs is excluded. Dark electrons could however correlate with the holes that they have left behind: one would have a "half-Cooper pair". Could these "half-Cooper pairs" be present in the temperature range $[T_c, T_{c1}]$, where there is no super-conductivity. The earlier proposal was that the flux tube pairs are so short that the nanoscopic or macroscopic supra currents are not possible.

The recent view about TGD (2024) allows us to conclude that the original view is nearer to the truth. The following represents the recent perspective to high Tc- and bio-superconductivity.

Number theoretic view of TGD predicts a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant $h_{eff} = nh_0$. The simplest assumption is that n is the dimension of algebraic extension of rationals. For a more complex option it is a product of dimensions of two algebraic extensions.

These phases behave like dark matter and would be located at monopole magnetic flux tubes and also electric flux tubes. They would not be galactic dark matter but correspond to the missing baryonic matter whose fraction has been increasing during the cosmological evolution. Galactic dark matter would correspond to the energy of cosmic strings (space-time surfaces with 2-D M^4 and CP_2 projections). The unavoidable number theoretical evolution implies the increase of the number theoretical complexity and therefore increase of n. The larger the value of n the longer the quantum coherence scale of the system.

1. The predicted huge values of h_{eff} assignable to classical gravitational and electric fields of astrophysical objects [L175] mean that weak interactions become as strong as em interactions below the scale up Compton length of weak bosons, which, being proportional to h_{eff}, can be as large as cell size. This amplifies parity violation effects visible for instance in hydrodynamics [K2].

2. Large h_{eff} phases behave like dark matter: they do not however explain the galactic dark matter, which in the TGD framework is dark energy assignable to cosmic strings (no halo and an automatic prediction of the flat velocity spectrum). Instead, large h_{eff} phases solve the missing baryon problem. The density of baryons has decreased in cosmic evolution (having biological evolution as a particular aspect) and the explanation is that evolution as unavoidable increase of algebraic complexity measured by h_{eff} has transformed them to $h_{eff} \geq h$ phases at the magnetic bodies (thickened cosmic string world sheets, 4-D objects), in particular those involved with living matter.

3. The large value of h_{eff} has besides number theoretical interpretation [L114, L115, L182, L187] also a geometric interpretation. Space-time surface can be regarded as many-sheeted over both M^4 and CP_2. In the first case the CP_2 coordinates are many-valued functions of M^4 coordinates. In the latter case M^4 coordinates are many-valued functions of CP_2 coordinates so that QFT type description fails. This case is highly interesting in the case of quantum biology. Since a connected space-time surface defines the quantum coherence region, an ensemble of, say, monopole flux tubes can define a quantum coherent region in the latter case: one simply has an analog of Bose-Einstein condensate of monopole flux tubes.

The flux tube condensate as a covering of CP_2 means a dramatic deviation from the QFT picture and is a central notion in the applications of quantum TGD to biology. Therefore some examples are in order.

1. Fermi liquid description of electrons relies on the notion of a quasiparticle as an electron plus excitations of various kinds created by its propagation in the lattice. In some systems this description fails and these systems would. have a natural description in terms of space-time surfaces which are multiple coverings of CP_2, say flux tube condensates.

2. In high Tc superconductors and bio-superconductors [K85, K86] the space-time surface could correspond to this kind of flux tube condensates and Cooper pairs would be fermion pairs with members at separate flux tubes. The connectedness of the space-time surface having about $h_{eff}/h = n$ flux tubes would correlate the fermions.

3. Bogoliubov quasiparticles related to superconductors are regarded as superpositions of electron excitation and hole. The problem is that they have an ill-defined fermion number. In TGD, they would correspond to superpositions of a dark electron accompanied by a hole which it has left behind and therefore having a well-defined fermion number. Bogoliubov quasiparticle is indeed what can be seen using the existing experimental tools and physical understanding.

4. Strange metals would be an example of a system having no description using quasiparticles, as the linear dependence of the resistance at low temperatures demonstrates. I have considered a description of them in terms of Cooper pairs at short closed flux tubes [K85, L145]: this would however suggest a vanishing resistance in an ideal situation. Something seems to go wrong.

   An alternative description could be in terms of superpositions of dark electrons and holes assignable to the flux tube condensate. Strange metal is between Fermi liquid and superconductor: this conforms with the fact that strange metals are quantum critical systems. The transition to high Tc superconductivity is preceded by a transition to a phase in which something resembling Cooper pairs is present.

A natural looking interpretation would be in terms of a flux tube condensate and pairs of dark and ordinary electrons. Also now the flux tubes could be short. In this chapter I have considered the possibility that high Tc superconductors could be this kind of "half-superconductors" but this option seems to be wrong: for high Tc superconductors this phase could however appear in the temperature range $[T_c, T_{c1}]$ where superconductivity is not present. Note that the phase transitions between "half-superconductivity" and superconductivity could play a central role also in living matter.

14.4 Appendix: General considerations related to Beltrami flows

The following text is based on the updated view about the material from the appendix of [K8]. More details can be found in [K7, K14, K8].

14.4.1 Beltrami ansatz and minimal surface ansatz for the preferred extremals of Kähler action

The vanishing of Lorentz 4-force for the induced Kähler field means that the vacuum 4-currents are in a mechanical equilibrium.

1. Lorentz 4-force vanishes for all known solutions of field equations which inspires the hypothesis that all extremals or at least the absolute minima of Kähler action satisfy the condition. The vanishing of the Lorentz 4-force in turn implies local conservation of the ordinary energy momentum tensor. Its vanishing encourages the proposal that Einstein's equations hold true at the Yang-Mills-Einstein limit of TGD.

   The absence of the classical dissipation is highly attractive in the case of supra phases. This condition could be universal and be satisfied below the scales defined by the space-time surface.

   The corresponding condition is implied by Maxwell-Einstein's equations in General Relativity.

2. The hypothesis would mean that the solutions of field equations are what might be called generalized Beltrami fields defining integrable flows serving as candidates for flow lines of the superfluid flow and supracurrents.

3. The hypothesis that Kähler current is proportional to a product of an arbitrary function ψ of CP_2 coordinates and of the instanton current

   $$j_I^\alpha = \epsilon^{\alpha\beta\gamma\delta} A_\beta J_{\gamma\delta} \tag{14.4.1}$$

   solves the 4-D Beltrami condition and reduces to it when electric field vanishes.

   Instanton current has a vanishing divergence for $D_{CP_2} < 4$, and Lorentz 4-force indeed vanishes since the contractions of the gradients of $D < 4$ CP_2 coordinates with a 4-D permutations symbol are involved. Instanton current vanishes for $D = 2$. Note that massless extremals having 2-D CP_2 projection carry non-vanishing light-like current and vanishing instanton current.

   The condition implies that Kähler current can be non-vanishing only if the dimension D_{CP_2} of the CP_2 projection of the space-time surface is less than four so that in the regions with $D_{CP_2} = 4$ (say CP_2 type extremals) Maxwell's vacuum equations are satisfied by the Kähler form.

4. Beltrami fields are known to be extremely complex but highly organized structures and the same is expected to be true for their generalizations (it is not clear whether Kähler current j is always vanishing or light-like).

   An interesting conjecture is that topologically quantized many-sheeted magnetic and Z^0 magnetic Beltrami fields and their 4-D generalizations serve as templates for the helical molecules populating living matter, and explain both chirality selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

5. Field equations can be reduced to algebraic conditions stating that energy momentum tensor and second fundamental form have no common components (this occurs also for minimal surfaces in string models) and only the conditions stating that Kähler current vanishes, is light-like, or proportional to instanton current, remain and define the remaining field equations. The conditions guaranteeing topologization to instanton current can be solved explicitly. Solutions can be found also in the more general case when Kähler current is not proportional to instanton current (massless extremals). On the basis of these findings there are strong reasons to believe that classical TGD is exactly solvable.

Minimal surface ansatz [L155] for the preferred extremals based on 4-D generalization of complex structure to Hamilton-Jacobi structure. It emerges naturally at M^8 level as a prerequisite of M^8-H duality, and is induce at the level of H by M^8-H duality [L57, L58, L59, L114, L115, L138].

The twistor twistor lift of TGD [L65, L85] leads to a concrete action principle at the level of H involving volume term and Kähler action obtained by a dimensional reduction of the Kähler action at the level of twistor space of H. The Kähler action for twistor space exists only in case of H. Therefore there are 3 different views about preferred extremals and they are proposed to be equivalent.

14.4.2 The dimension of CP_2 projection as classifier for the fundamental phases of matter

The dimension D_{CP_2} of CP_2 projection of the space-time sheet encountered already in p-adic mass calculations classifies the fundamental phases of matter. For $D_{CP_2}=4$ empty space Maxwell equations hold true. This phase is chaotic and analogous to a demagnetized phase. It might be that only CP_2 type extremals with Euclidean signature of the induced metric and 1-D light-like M^4 projection correspond to this phase.

$D_{CP_2}=2$ phase is analogous to the ferromagnetic phase: highly ordered and relatively simple. $D_{CP_2}=3$ is the analog of spin glass and liquid crystal phases, extremely complex but highly organized by the properties of the generalized Beltrami fields. This phase is the boundary between chaos and order and corresponds to life emerging in the interaction of magnetic bodies with bio-matter. It is possible only in a finite temperature interval (note however the p-adic hierarchy of critical temperatures) and characterized by chirality just like life. Both these phases could correspond to SC.

14.4.3 Connection of Beltrami flows with PCAC hypothesis, massivation, and CP violation

Conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC) are essential elements of old-fashioned hadron physics and hold true also in the standard model.

1. The simplest ansatz, which realizes the Beltrami hypothesis, states that the vectorial Kähler current J equals apart from sign $c=\pm 1$ to instanton current I, which is axial current:

$$J = \pm I \ \ c \ . \tag{14.4.2}$$

The condition states that only the left or right handed current chiral defined as

$$J_{L/R} = J \pm I \tag{14.4.3}$$

is non-vanishing. For $c \neq 1$, both J_L and J_R are non-vanishing. Since both right- and left-handed weak currents exist, $c \neq 1$ seems to be a plausible option.

By quantum classical correspondence, these currents serve as space-time correlates for the left- and right-handed fermion currents of the standard model. Note however that induced gamma matrices differ from those of M^4: for instance, they are not covariantly constant but define by field equations a current with a vanishing covariant divergence. Field equations serve as a consistency condition for the modified Dirac action.

2. A more general condition allows c to depend on space-time coordinates. The conservation of J forces conservation of I if the condition $\partial_\alpha c I^\alpha = 0$ is true. This gives a non-trivial condition only in regions with 4-D CP_2 and M^4 projections.

3. The twistor lift of TGD [L65, L85] requires that also M^4 has Kähler structure. Therefore J and I and corresponding Kähler gauge potential A have both M^4 part and CP_2 parts and Kähler action K, A_K, J_K, J and I are sums of M^4 and CP_2 parts:

$$\begin{array}{ll} A_K = A_K(M^4) + A_K(CP_2) \ , & J_K = J(M^4) + J_K(CP_2) \ , \\ K = K(M^4) + K(CP_2) \ , & J = J(M^4) + J(CP_2) \ . \\ I = I(M^4) + I(CP_2) \ . & \end{array} \tag{14.4.4}$$

   Only the divergence of I must vanish:

$$\partial_\alpha I^\alpha = 0 \ . \tag{14.4.5}$$

   A possible interpretation is in terms of the 8-D variant of twistorialization by twistor lift [L65, L85] requiring masslessness in 8-D sense.

   PCAC states that the divergence of the axial current is non-vanishing. This is not in conflict with the conservation of the total instanton current I. PCAC corresponds to the non-conservation $I(CP_2)$, whose non-conservation is compensated by that of $I(M^4)$.

4. For regions with at most 3-D M^4- and CP_2 projections, the M^4- and CP_2 instanton currents have identically vanishing divergence. In these regions the conservation of I is not lost if c has both signs. c could be also position dependent and even differ for $I(M^4)$ and $I(CP_2)$ in these regions.

   $D_\alpha I^\alpha$ vanishes for the known extremals. For the simplest CP_2 type extremals and for extremals with 2-D CP_2 projection, I itself vanishes. Therefore parity violation is not possible in these regions. This would suggest that these regions correspond to a massless phase.

5. $D_\alpha I^\alpha \neq 0$ is possible only if both M^4 and CP_2 projections are 4-D. This phase is interpreted as a chaotic phase and by the non-conservation of electroweak axial currents could correspond to a massive phase.

   CP_2 type extremals have 4-D projection and for them Kähler current and instanton current vanish identically so that also they correspond to massless phase (M^4 projection is light-like). Could CP_2 type extremals allow deformations with 4-D M^4 projection (DEs)?

   The wormhole throat between space-time region with Minkowskian signature of the induced metric and CP_2 type extremal (wormhole contact) with Euclidian signature is light-like and the 4-metric is effectively 3-D. It is not clear whether this allows 4-D M^4 projection in the interior of DE.

The geometric model for massivation based on zitterbewegung of DE provides additional insight [L155].

1. $M^8 - H$ duality allows to assign a light-like curve also to DE. For space-time surfaces determined by polynomials (cosmological constant $\Lambda > 0$), this curve consists of pieces which are light-like geodesics.

   Also real analytic functions ($\Lambda = 0$) can be considered and they would allow a continuous light-like curve, whose definition boils down to Virasoro conditions. In both cases, the zigzag motion with light-velocity would give rise to velocity $v < c$ in long length scales having interpretation in terms of massivation.

2. The interaction with $J(M^4)$ would be essential for the generation of momentum due to the M^4 Chern-Simons term assigned with the 3-D light-like partonic orbit. M^4 Chern-Simons term can be interpreted as a boundary term due to the non-vanishing divergence of $I(M^4)$ so that a connection with two views about massivation is obtained. Does the Chern-Simons term come from the Euclidean or Minkowskian region?

I have proposed two models for the generation of matter-antimatter asymmetry. In both models, CP breaking by M^4 Kähler form is essential. Classical electric field induces CP breaking. CP takes self-dual (E,B) to anti-self-dual $(-E,B)$ and self-duality of $J(M^4)$ does not allow CP as a symmetry.

1. In the first model the electric part of $J(M^4)$ would induce a small CP breaking inside cosmic strings thickened to flux tubes inducing in turn small matter-antimatter asymmetry outside cosmic strings. After annihilation this would leave only matter outside the cosmic strings.

2. In the simplest variant of TGD only quarks are fundamental particles and leptons are their local composites in CP_2 scale [L106, L130].

   Both quarks and antiquarks are possible but antiquarks would combine leptons as almost local 3-quark composites and presumably realized CP_2 type extremals with the 3 antiquarks associated with the partonic orbit. I should vanish identically for the DEs representing quarks and leptons but not for antiquarks and antileptons.

   Could the number of DEs with vanishing I be smaller for antiquarks than for quarks by CP breaking and could this induce leptonization of antiquarks and favor baryons instead of antileptons? Could matter-antimatter asymmetry be induced by the interior of DE alone or by its interaction with the Minkowskian space-time region outside DE.

In the standard model also charged weak currents are allowed. Does TGD allow their space-time counterparts? CP_2 allows quaternionic structure in the sense that the conformally invariant Weyl tensor has besides $W_3 = J(CP_2)$ also charged components $W_\pm$, which are however not covariantly constant [L2]. One can assign to $W_\pm$ analogs of Kähler currents as covariant divergences and also the analogs of instanton currents. These currents could realize a classical space-time analog of current algebra.

Chapter 15

Quantum Hall effect and Hierarchy of Planck Constants

15.1 Introduction

Quantum Hall effect [D112, D120, D31] occurs in 2-dimensional systems, typically a slab carrying a longitudinal voltage V causing longitudinal current j. A magnetic field orthogonal to the slab generates a transversal current component j_T by Lorentz force. j_T is proportional to the voltage V along the slab and the dimensionless coefficient is known as transversal conductivity. Classically the coefficients is proportional ne/B, where n is 2-dimensional electron density and should have a continuous spectrum. The finding that came as surprise was that the change of the coefficient as a function of parameters like magnetic field strength and temperature occurred as discrete steps of same size. In integer quantum Hall effect the coefficient is quantized to $2\nu\alpha$, $\alpha = e^2/4\pi$, such that ν is integer.

Later came the finding that also smaller steps corresponding to the filling fraction $\nu = 1/3$ of the basic step were present and could be understood if the charge of electron would have been replaced with $\nu = 1/3$ of its ordinary value. Later also QH effect with wide large range of rational filling fractions of form $\nu = k/m$ was observed.

The observed fractions are not arbitrary but obey quite precise selection rules. This led to the notion of composite fermion (see `http://tinyurl.com/ycotdnyh`) as a bound state of electron and magnetic vortices carrying electron at their boundaries and FQHE reduces to QHE for these effective particles in an effective magnetic field than the original field and reduced by the binding of the magnetic vortices with the electron. Besides quasiparticles also corresponding holes contribute to FQHE.

What I see as a general problem of the composite model is the nature of the bound states. How both the number of vortices per electron and the number of electrons per vortex can be larger than one?

The composite model fails to explain only the observations for $\nu = 5/2$ and $\nu = 7/2$ (these values of ν belong to the spectrum but the these phases do not behave as predicted). The conjecture is that in these cases electron carrying magnetic vortices form Cooper pair like bound states. Non-Abelian braid statistics assigned with these phases would be essential for topological quantum computation but it has not been established convincingly yet [D36] (see `http://tinyurl.com/y8ahwh3x`).

Also the well-established charge fractionization should be understood. Whether fractional braid statistics is realized is still an open question. In these issues TGD might provide some new insights.

The phenomenology of FQHE is described in an extremely lucid way in the Nobel lecture (see `http://tinyurl.com/y8mvdxpk`) of Horst L. Stormer [D83]. As a matter fact, I regret that I did not read it for years ago!

15.1.1 Abelian And Non-Abelian Anyons

The model explaining FQHE is based on pseudo particles known as anyons identifiable as magnetic vortices [A25] , [D112]. According to the general argument of [D133] anyons have a fractional charge νe. The braid statistics of anyon is believed to be fractional so that in the general case anyons are neither bosons nor fermions. Non-fractional statistics is absolutely essential for the vacuum degeneracy used to represent logical qubits.

In the case of Abelian anyons the gauge potential corresponds to the vector potential of the divergence free velocity field or equivalently of incompressible anyon current. For Abelian anyons the field theory defined by Chern-Simons action is free field theory and in well-defined sense trivial although it defines knot invariants. For non-Abelian anyons situation would be different. They would carry non-Abelian gauge charges possibly related to a symmetry breaking to a discrete subgroup H of gauge group [A25] each of them defining an incompressible hydrodynamical flow. According to [B14] the anyons associated with the filling fraction $\nu = 5/2$ are a good candidate for non-Abelian anyons and in this case the charge of electron is reduced to $Q = e/4$ rather than being $Q = \nu e$ [D47]. This finding favors non-Abelian models [D31].

Non-Abelian anyons [D112, D113] are always created in pairs since they carry a conserved topological charge. In the model of [B14] this charge should have values in 4-element group Z_4 so that it is conserved only modulo 4 so that charges +2 and -2 are equivalent as are also charges 3 and -1. The state of n anyon pairs created from vacuum can be shown to possess 2^{n-1}-dimensional vacuum degeneracy [D114]. When two anyons fuse the 2^{n-1}-dimensional state space decomposes to 2^{n-2}-dimensional tensor factors corresponding to anyon Cooper pairs with topological charges 2 and 0. The topological "spin" is ideal for representing logical qubits. Since free topological charges are not possible the notion of physical qubit does not make sense (note the analogy with quarks). The measurement of topological qubit reduces to a measurement of whether anyon Cooper pair has vanishing topological charge or not.

15.1.2 TGD Based View About Fqhe

In this chapter I try to formulate more precisely the recent TGD based view about fractional quantum Hall effect (FQHE) (see `http://tinyurl.com/y8mvdxpk`) . This view is much more realistic than the original rough scenario, which neglected the existing rather detailed understanding. The spectrum of ν, and the mechanism producing it is the same as in composite fermion approach. The new elements relate to the not so well-understood aspects of FQHE, namely charge fractionization, the emergence of braid statistics, and non-abelianity of braid statistics.

1. The starting point is composite fermion model so that the basic predictions are same. Now magnetic vortices correspond to (Kähler) magnetic flux tubes carrying unit of magnetic flux. The magnetic field inside flux tube would be created by de-localized electron at the boundary of the vortex. One can raise two questions.

   Could the boundary of the macroscopic system carrying anyonic phase have identification as a macroscopic analog of partonic 2-surface serving as a boundary between Minkowskian and Euclidian regions of space-time sheet? If so, the space-time sheet assignable to the macroscopic system in question would have Euclidian signature, and would be analogous to blackhole or to a line of generalized Feynman diagram.

   Could the boundary of the vortex be identifiable a light-like boundary separating Minkowskian magnetic flux tube from the Euclidian interior of the macroscopic system and be also analogous to wormhole throat? If so, both macroscopic objects and magnetic vortices would be rather exotic geometric objects not possible in general relativity framework.

2. Taking composite model as a starting point one obtains standard predictions for the filling fractions. One should also understand charge fractionalization and fractional braiding statistics. Here the vacuum degeneracy of Kähler action suggests the explanation. Vacuum degeneracy implies that the correspondence between the normal component of the canonical momentum current and normal derivatives of embedding space coordinates is 1- to-n. These kind of branchings result in multi-furcations induced by variations of the system parameters and the scaling of external magnetic field represents one such variation.

3. At the orbits of wormhole throats, which can have even macroscopic M^4 projections, one has $1 \to n_a$ correspondence and at the space-like ends of the space-time surface at light-like boundaries of causal diamond one has $1 \to n_b$ correspondence. This implies that at partonic 2-surfaces defined as the intersections of these two kinds of 3-surfaces one has $1 \to n_a \times n_b$ correspondence. This correspondence can be described by using a local singular n-fold covering of the embedding space. Unlike in the original approach, the covering space is only a convenient auxiliary tool rather than fundamental notion.

4. The fractionalization of charge can be understood as follows. A de-localization of electron charge to the n sheets of the multi-furcation takes place and single sheet is analogous to a sheet of Riemann surface of function $z^{1/n}$ and carries fractional charge $q = e/n$, $n = n_a n_b$. Fractionalization applies also to other quantum numbers. One can have also many-electron stats of these states with several de-localized electrons: in this case one obtains more general charge fractionalization: $q = \nu e$.

5. Also the fractional braid statistics can be understood. For ordinary statistics rotations of M^4 rotate entire partonic 2-surfaces. For braid statistics rotations of M^4 (and particle exchange) induce a flow braid ends along partonic 2-surface. If the singular local covering is analogous to the Riemann surface of $z^{1/n}$, the braid rotation by $\Delta\Phi = 2\pi$, where Φ corresponds to M^4 angle, leads to a second branch of multi-furcation and one can give up the usual quantization condition for angular momentum. For the natural angle coordinate Φ of the n-branched covering $\Delta\Phi = 2/pi$ corresponds to $\Delta\Phi = n \times 2\pi$. If one identifies the sheets of multi-furcation and therefore uses Φ as angle coordinate, single valued angular momentum eigenstates become in general n-valued, angular momentum in braid statistics becomes fractional and one obtains fractional braid statistics for angular momentum.

6. How to understand the exceptional values $\nu = 5/2, 7/2$ of the filling fraction? The non-abelian braid group representations (see `http://tinyurl.com/y796qycq`) [D113] can be interpreted as higher-dimensional projective representations of permutation group: for ordinary statistics only Abelian representations are possible. It seems that the minimum number of braids is $n > 2$ from the condition of non-abelianity of braid group representations. The condition that ordinary statistics is fermionic, gives $n > 3$. The minimum value is $n = 4$ consistent with the fractional charge $e/4$.

   The model introduces Z_4 valued topological quantum number characterizing flux tubes. This also makes possible non-Abelian braid statistics. The interpretation of this quantum number as a Z_4 valued momentum characterizing the four de-localized states of the flux tube at the sheets of the 4-furcation suggests itself strongly. Topology would corresponds to that of 4-fold covering space of embedding space serving as a convenient auxiliary tool. The more standard explanation is that $Z_4 = Z_2 \times Z_2$ such that Z_2:s correspond to the presence or absence of neutral Majorana fermion in the two Cooper pair like states formed by flux tubes.

   What remains to be understood is the emergence of non-abelian gauge group realizing non-Abelian fractional statistics in gauge theory framework. TGD predicts the possibility of dynamical gauge groups [K29, K122, K91] and maybe this kind of gauge group indeed emerges. Dynamical gauge groups emerge also for stacks of N branes and the n sheets of multi-furcation are analogous to the N sheets in the stack for many-electron states.

The genuinely new element to the existing theory of FQHE are multi-furcations of partonic 2-surfaces and their second quantization. This notion leads to an explanation of the fractional charges, fractional braid statistics, and existence of Z_n valued topological quantum number in terms of many-sheeted space-time and mulfi-furcations of preferred extremals of Kähler action. One ends up also to a concrete geometric realization for the bound states of electron and flux quanta and geometric understanding of how n flux quanta "split" out from the magnetic field experienced by the electron. The rather radical "almost prediction" is that partonic 2-surfaces and their light-like orbits serving as boundaries between Euclidian and Minkowskian regions of space-time sheet would be realized even in macroscopic scales. Anyonic system would be in well-defined sense an elementary particle like object.

The first two sections of the chapter give brief summaries about FQHE and existing theories of FQHE. The third section represents a view about the effective hierarchy of Planck constants assignable to multi-furcations associated with Kähler action and the recent simplifications of this picture. The last section summarizes the TGD inspired model of FQHE, a model for flux tubes, a microscopic description for the 2-D surface representing the boundary of the anyonic system and with electrons attached to this surface. Here the TGD based view about elementary particles is in active role.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

15.2 Fractional Quantum Hall Effect

15.2.1 Basic Facts About FQHE

15.2.2 A Simple Model For Fractional Quantum Hall Effect

Recall first the basic facts. Quantum Hall effect (QHE) [D112, D6, D120] is an essentially 2-dimensional phenomenon and occurs at the end of current carrying region for the current flowing transversally along the end of the wire in external magnetic field along the wire. For quantum Hall effect transversal Hall conductance characterizing the 2-dimensional current flow is dimensionless and quantized and given by

$$\sigma_{xy} = 2\nu\alpha_{em} ~,$$

ν is so called filling factor telling the number of filled Landau levels in the magnetic field. In the case of integer quantum Hall effect (IQHE) ν is integer valued. For fractional quantum Hall effect (FQHE) ν is rational number.

The formula for the quantized Hall conductance is given by

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} ~, \\ \nu &= \frac{n}{m} ~. \end{aligned} \tag{15.2.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15...,\ 2/3, 3/5, 4/7, 5/9, 6/11, 7/13...,$ $5/3, 8/5, 11/7, 14/9...4/3, 7/5, 10/7, 13/9...,\ 1/5, 2/9, 3/13...,\ 2/7, 3/11...,\ 1/7....$ with odd denominator have been observed [D6]. Only fractions smaller than 1 are listed because the integer part of ν should not matter since it represents full Landau levels. Also $\nu = 1/2$, $\nu = 5/2$, $7/2$ states with even denominator have been observed. $\nu = 1/2$ can be understood easily in the existing theory. One might think that $\nu = 5/2 = 2 + 1/2$ and $\nu = 7/2 = 3 + 1/2$ would reduce to $\nu = 1/2$. This not however the case experimentally and these values of ν represent an unsolved problem of anyon physics.

The following gives a brief summary about the evolution of the understanding of FQHE.

1. Laughlin introduced his many-electron wave wave function predicting fractional quantum Hall effect for filling fractions $\nu = 1/m$ [D120]. The model of Laughlin [D120] cannot explain all observed filling fractions.

2. The best existing model proposed originally by Jain [D94] is based on the notion of composite fermion. These would result as bound states of electron and even number of magnetic flux quanta [D94]. Electrons remain integer charged but due to the effective magnetic field electrons appear to have fractional charges. Composite fermion picture predicts all the observed fractions and also their relative intensities and the order in which they appear as the quality of sample improves.

3. The description of the magnetic flux tubes led to the notion of anyon introduced by Wilzeck [D112]. Anyon has been compared to a vortex like excitation of a dense 2-D electron plasma formed by the current carriers. ν is inversely proportional to the magnetic flux and the fractional filling factor can be also understood in terms of fractional magnetic flux.

4. The starting point of the quantum field theoretical models is the effective 2-dimensionality of the system implying that the projective representations for the permutation group of n objects are representations of braid group allowing fractional statistics. This is due to the

non-trivial first homotopy group of 2-dimensional manifold containing punctures. Quantum field theoretical models allow to assign to the anyon-like states also magnetic charge, fractional spin, and fractional electric charge.

Topological quantum computation [K5, K4] , [B14], [C45] is one of the most fascinating applications of FQHE. It relies on the notion of braids with strands representing the orbits of of anyons. The unitary time evolution operator coding for topological computation is a representation of the element of the element of braid group represented by the time evolution of the braid. It is essential that the group involved is non-Abelian so that the system remembers the order of elementary braiding operations (exchange of neighboring strands). There is experimental evidence that $\nu = 5/2$ anyons possessing fractional charge $Q = e/4$ are non-Abelian [D31, D47].

Before continuing, it is good to represent both classical view about QHE effect and simple quantum explanation for IQHE effect.

1. Consider first the classical explanation. Electrons are assumed to drift in the orthogonal electric and magnetic fields with drift velocity $v = E \times B/B^2$ having magnitude $v = E/B$ It is easy to see that this solves Newtons equation of motion identically. Here the 2-D current transversal Hall current can be written as $j = e\rho v$, where ρ is 2-D electron density obtained by averaging in the direction of the electric field. This can be expressed as $j = e(N/S)(E/B)$, where one concludes that the Hall conductivity is given by

$$\sigma_{xy} = \frac{\rho}{B} = e^2\frac{N}{\Phi} \quad , \quad \Phi = eBS = e\int BdS \quad .$$

Using elementary flux quantum as a unit of magnetic flux, this says that Hall conductivity equals to the ratio of electrons per elementary flux quantum. To proceed further one must use quantization of electron's states in the magnetic field to concluded that N equals to integer multiple of $h\Phi$.

2. Consider next a quantum explanation. Choose the coordinates of the current currying slab so that x varies in the direction of Hall current and y in the direction of the main current. For IQHE the value of Hall conductivity is given by $\sigma = j_y/E_x = n_eev/vB = n_ee/B = Ne^2/heBS = Ne^2/mh$, were m characterizes the value of magnetized flux and N is the total number of electrons in the current. In the Landau gauge $A_y = xB$ one can assume that energy eigenstates are momentum eigenstates in the direction of current and harmonic oscillator Gaussians in x-direction in which Hall current runs. This gives

$$\Psi \propto exp(iky)H_n(x+kl^2)exp(-\tfrac{(x+kl^2)^2}{2l^2}) \quad , \quad l^2 = \tfrac{\hbar}{eB} \quad . \tag{15.2.2}$$

Only the states for which the oscillator Gaussian differs considerably from zero inside slab are important so that the momentum eigenvalues are in good approximation in the range $0 \leq k \leq k_{max} = L_x/l^2$. Using $N = (L_y/2\pi)\int_0^{k_{max}} dk$ one obtains that the total number of momentum eigenstates associated with the given value of n is $N = eBdL_xL_y/h = n$. If ν Landau states are filled, the value of σ is $\sigma = \nu e^2/h$, where ν is the integer valued filling fraction.

The understanding of the thermal stability is not trivial. The original FQHE was observed in 80 mK temperature corresponding roughly to a thermal energy of $T \sim 10^{-5}$ eV. For graphene the effect is observed at room temperature. Cyclotron energy for electron is (from $f_e = 6\times 10^5$ Hz at $B = .2$ Gauss) of order thermal energy at room temperature in a magnetic field varying in the range 1-10 Tesla. This raises the question why the original FQHE requires such a low temperature.

15.2.3 The Model Of FQHE Based On Composite Fermions

The model of FQHE based on omposite fermions (see `http://tinyurl.com/y9vwmjy5`) produces FQHE as integer QHE for effective particles - composite fermions. This phenomenological picture is described with enjoyable clarity in the Nobel lecture of Nobel lecture (see `http://tinyurl.com/y8mvdxpk`) of Horst L. Stormer [D83].

The empirical inspiration for the model is the observation that in strong enough magnetic fields electrons behave in an unexpected manner. For instance, they seem to respond only to effective magnetic field much weaker than the actual field. The difference in field strengths corresponds to an integer number of magnetic flux quanta multiplied by 2-D electron number density. It would seem that these flux quanta somehow separate from the external magnetic field and somehow combine with the electrons to form bound states, which become the basic dynamical units interacting with the external magnetic field. They of course have different mass.

From the experimental data one can conclude that the flux quanta behave like fermions. Most naturally they would carry a rotating electron current concentrated near their boundaries and serving as a source of a magnetic field concentrated around flux quantum or better to say, separating a magnetic field from incoming magnetic field outside the flux quantum. By the conservation of magnetic flux the external magnetic field is reduced correspondingly. The number of flux quanta per electron is integer valued. Since flux quanta behave like fermions, the number of the flux quanta per electron is even for fractional quantum Hall effect. For odd values of flux quanta one obtains composite bosons and something totally different.

The basic formula for the filling fraction is easy to deduce by using the assumption that FQHE is IQHE in effective magnetic field B_{eff} [D94] with even number $2p$ flux quanta subtracted. B_{eff} is given by

$$B_{eff} = B - 2pB_1 \ , \ B_1 = \rho\Phi_0 \ , \ \Phi_0 = h/e \ . \tag{15.2.3}$$

Here B is the external magnetic field, $2p$ the even number of flux quanta per electron, and Φ_0 the elementary flux quantum - twice the flux quantum in super-conductors because the charge carriers are now electrons rather than Cooper pairs.

The integer QHE for B_{eff} gives $\nu_{eff} = \rho\phi_0/B_{eff} = B_1/B_{eff} = n$ saying that n Landau levels are filled. This translates FQHE for B with ν given by completely analogous formula $\nu = B_1/B$. From $\nu_{eff} = 1/[(B/B_1) - 2p] = n = 1/(1/\nu) - 2p$ one obtains

$$\nu = \frac{\nu_{eff}}{1+2p\nu_{eff}} = \frac{n}{1+2pn} \ . \tag{15.2.4}$$

The formula is amazingly simple and consistent with all experimental findings hitherto. Note that at the limit $n \to \infty$ the formula gives filling fractions $1/2p$.

My understanding is that charge fractionalization is motivated by a paradox created by the flux quantum picture. Classically the number of electrons per flux quantum is higher than one since the generation of flux quantum requires at least one electron per flux quantum. How it is then possible that the number of flux quanta per electron given by ν is higher than one?

What this fractionalization actually means geometrically is not easy to visualize and might require new physics. The solution of the paradox might also require a de-localization of some kind. The number of electrons in the center and at the boundary of flux quantum is fractional. This could might be understood in terms of de-localization of electron wave functions at several flux quanta. In TGD framework electron is string like object defined by Kähler magnetic flux tube with wormhole contacts at its ends and could have rather long length: could it be that also electron charge is de-localized and shared between the two wormhole ends?

15.3 About Theories Of Quantum Hall Effect

The most elegant models of quantum Hall effect are in terms of anyons regarded as singularities due to the symmetry breaking of gauge group G down to a finite sub-group H, which can be also non-Abelian. Concerning the description of the dynamics of topological degrees of freedom topological quantum field theories based on Chern-Simons action are the most promising approach.

15.3.1 Quantum Hall Effect As A Spontaneous Symmetry Breaking Down To A Discrete Subgroup Of The Gauge Group

The system exhibiting quantum Hall effect is effectively 2-dimensional. Fractional statistics suggests that topological defects, anyons, allowing a description in terms of the representations of the homotopy group of $((R^2)^n - D)/S_n$. The gauge theory description would be in terms of spontaneous symmetry breaking of the gauge group G to a finite subgroup H by a Higgs mechanism [A25] , [D112]. This would make all gauge degrees of freedom massive and leave only topological degrees of freedom. What is unexpected that also non-Abelian topological degrees of freedom are in principle possible. Quantum Hall effect is Abelian or non-Abelian depending on whether the group H has this property.

In the symmetry breaking $G \to H$ the non-Abelian gauge fluxes defined as non-integrable phase factors $Pexp(i \oint A_\mu dx^\mu)$ around large circles (surrounding singularities (so that field approaches a pure gauge configuration) are elements of the first homotopy group of G/H, which is H in the case that H is discrete group and G is simple. An idealized manner to model the situation [D112] is to assume that the connection is pure gauge and defined by an H-valued function which is many-valued such that the values for different branches are related by a gauge transformation in H. In the general case a gauge transformation of a non-trivial gauge field by a multi-valued element of the gauge group would give rise to a similar situation.

One can characterize a given topological singularity magnetically by an element in conjugacy class C of H representing the transformation of H induced by a 2π rotation around singularity. The elements of C define states in given magnetic representation. Electrically the particles are characterized by an irreducible representations of the subgroup of $H_C \subset H$ which commutes with an arbitrarily chosen element of the conjugacy class C.

The action of $h(B)$ resulting on particle A when it makes a closed turn around B reduces in magnetic degrees of freedom to translation in conjugacy class combined with the action of element of H_C in electric degrees of freedom. Closed paths correspond to elements of the braid group $B_n(X^2)$ identifiable as the mapping class group of the punctured 2-surface X^2 and this means that symmetry breaking $G \to H$ defines a representation of the braid group. The construction of these representations is discussed in [D112] and leads naturally via the group algebra of H to the so called quantum double $D(H)$ of H, which is a quasi-triangular Hopf algebra allowing non-trivial representations of braid group.

Anyons could be singularities of gauge fields, perhaps even non-Abelian gauge fields, and the latter ones could be modelled by these representations. In particular, braid operations could be represented using anyons.

15.3.2 Witten-Chern-Simons Action And Topological Quantum Field-Theories

The Wess-Zumino-Witten action used to model 2-dimensional critical systems consists of a 2-dimensional conformally invariant term for the chiral field having values in group G combined with 2+1-dimensional term defined as the integral of Chern-Simons 3-form over a 3-space containing 2-D space as its boundary. This term is purely topological and identifiable as winding number for the map from 3-dimensional space to G. The coefficient of this term is integer k in suitable normalization. k gives the value of central extension of the Kac-Moody algebra defined by the theory.

One can couple the chiral field $g(x)$ to gauge potential defined for some subgroup of G_1 of G. If the G_1 coincides with G, the chiral field can be gauged away by a suitable gauge transformation and the theory becomes purely topological Witten-Chern-Simons theory. Pure gauge field configuration represented either as flat gauge fields with non-trivial holonomy over homotopically non-trivial paths or as multi-valued gauge group elements however remain and the remaining degrees of freedom correspond to the topological degrees of freedom.

Witten-Chern-Simons theories are labelled by a positive integer k giving the value of central extension of the Kac-Moody algebra defined by the theory. The connection with Wess-Zumino-Witten theory come from the fact that the highest weight states associated with the representations of the Kac-Moody algebra of WZW theory are in one-one correspondence with the representations R_i possible for Wilson loops in the topological quantum field theory.

In the Abelian case case 2+1-dimensional Chern-Simons action density is essentially the inner product $A \wedge dA$ of the vector potential and magnetic field known as helicity density and the theory in question is a free field theory. In the non-Abelian case the action is defined by the 3-form

$$\frac{k}{4\pi} Tr\left(A \wedge (dA + \frac{2}{3} A \wedge A)\right)$$

and contains also interaction term so that the field theory defined by the exponential of the interaction term is non-trivial.

In topological quantum field theory the usual n-point correlation functions defined by the functional integral are replaced by the functional averages for $Diff^3$ invariant quantities defined in terms of non-integrable phase factors defined by ordered exponentials over closed loops. One can consider arbitrary number of loops which can be knotted, linked, and braided. These quantities define both knot and 3-manifold invariants (the functional integral for zero link in particular). The perturbative calculation of the quantum averages leads directly to the Gaussian linking numbers and infinite number of perturbative link and not invariants.

The experience gained from topological quantum field theories defined by Chern-Simons action has led to a very elegant and surprisingly simple category theoretical approach to the topological quantum field theory [A9, A29] allowing to assign invariants to knots, links, braids, and tangles and also to 3-manifolds for which braids as morphisms are replaced with cobordisms. The so called modular Hopf algebras, in particular quantum groups $Sl(2)_q$ with q a root of unity, are in key role in this approach. Also the connection between links and 3-manifolds can be understood since closed, oriented, 3-manifolds can be constructed from each other by surgery based on links [K12].

Witten's article [A16] "Quantum Field Theory and the Jones Polynomial" is full of ingenious constructions, and for a physicist it is the easiest and certainly highly enjoyable manner to learn about knots and 3-manifolds. For these reasons a little bit more detailed sum up is perhaps in order.

1. Witten discusses first the quantization of Chern-Simons action at the weak coupling limit $k \rightarrow \infty$. First it is shown how the functional integration around flat connections defines a topological invariant for 3-manifolds in the case of a trivial Wilson loop. Next a canonical quantization is performed in the case $X^3 = \Sigma^2 \times R^1$: in the Coulomb gauge $A_3 = 0$ the action reduces to a sum of $n = dim(G)$ Abelian Chern-Simons actions with a non-linear constraint expressing the vanishing of the gauge field. The WCW consists thus of flat non-Abelian connections, which are characterized by their holonomy groups and allows Kähler manifold structure.

2. Perhaps the most elegant quantal element of the approach is the decomposition of the 3-manifold to two pieces glued together along 2-manifold implying the decomposition of the functional integral to a product of functional integrals over the pieces. This together with the basic properties of Hilbert of complex numbers (to which the partition functions defined by the functional integrals over the two pieces belong) allows almost a miracle like deduction of the basic results about the behavior of 3-manifold and link invariants under a connected sum, and leads to the crucial skein relations allowing to calculate the invariants by decomposing the link step by step to a union of unknotted, unlinked Wilson loops, which can be calculated exactly for $SU(N)$. The decomposition by skein relations gives rise to a partition function like representation of invariants and allows to understand the connection between knot theory and statistical physics [A31]. A direct relationship with conformal field theories and Wess-Zumino-Witten model emerges via Wilson loops associated with the highest weight representations for Kac Moody algebras.

3. A similar decomposition procedure applies also to the calculation of 3-manifold invariants using link surgery to transform 3-manifolds to each other, with 3-manifold invariants being defined as Wilson loops associated with the homology generators of these (solid) tori using representations R_i appearing as highest weight representations of the loop algebra of torus. Surgery operations are represented as mapping class group operations acting in the Hilbert space defined by the invariants for representations R_i for the original 3-manifold. The outcome is explicit formulas for the invariants of trivial knots and 3-manifold invariant of S^3 for $G = SU(N)$, in terms of which more complex invariants are expressible.

4. For $SU(N)$ the invariants are expressible as functions of the phase $q = exp(i2\pi/(k+N))$ associated with quantum groups [K12]. Note that for $SU(2)$ and $k = 3$, the invariants are expressible in terms of Golden Ratio. The central charge $k = 3$ is in a special position since it gives rise

to $k+1=4$-vertex representing naturally 2-gate physically. Witten-Chern-Simons theories define universal unitary modular functors characterizing quantum computations [B18].

15.3.3 Chern-Simons Action For Anyons

In the case of quantum Hall effect the Chern-Simons action has been deduced from a model of electrons as a 2-dimensional incompressible fluid [D120]. Incompressibility requires that the electron current has a vanishing divergence, which makes it analogous to a magnetic field. The expressibility of the current as a curl of a vector potential b, and a detailed study of the interaction Lagrangian leads to the identification of an Abelian Chern-Simons for b as a low energy effective action. This action is Abelian, whereas the anyonic realization of quantum computation would suggest a non-Abelian Chern-Simons action.

Non-Abelian Chern-Simons action could result in the symmetry breaking of a non-Abelian gauge group G, most naturally electro-weak gauge group, to a non-Abelian discrete subgroup H [A25] so that states would be labelled by representations of H and anyons would be characterized magnetically H-valued non-Abelian magnetic fluxes each of them defining its own incompressible hydro-dynamical flow.

15.3.4 Topological Quantum Computation Using Braids And Anyons

By the general mathematical results braids are able to code all quantum logic operations [B3]. In particular, braids allow to realize any quantum circuit consisting of single particle gates acting on qubits and two particle gates acting on pairs of qubits. The coding of braid requires a classical computation which can be done in polynomial time. The coding requires that each dancer is able to remember its dancing history by coding it into its own state.

The general ideas are following.

1. The ground states of anyonic system characterize the logical qubits, One assumes non-Abelian anyons with Z_4 -valued topological charge so that a system of n anyon pairs created from vacuum allows 2^{n-1}-fold anyon degeneracy [D114]. The system is decomposed into blocks containing one anyonic Cooper pair with $Q_T \in \{2,0\}$ and two anyons with such topological charges that the net topological charge vanishes. One can say that the states $(0,1-1)$ and $(0,-1,+1))$ represent logical qubit 0 whereas the states $(2,-1,-1)$ and $(2,+1,+1)$ represent logical qubit 1. This would suggest 2^2-fold degeneracy but actually the degeneracy is 2-fold.

   Free physical qubits are not possible and at least four particles are indeed necessarily in order to represent logical qubit. The reason is that the conservation of Z^4 charge would not allow mixing of qubits 1 and 0, in particular the Hadamard 1-gate generating square root of qubit would break the conservation of topological charge. The square root of qubit can be generated only if 2 units of topological charge is transferred between anyon and anyon Cooper pair. Thus qubits can be represented as entangled states of anyon Cooper pair and anyon and the fourth anyon is needed to achieve vanishing total topological charge in the batch.

2. In the initial state of the system the anyonic Cooper pairs have $Q_T=0$ and the two anyons have opposite topological charges inside each block. The initial state codes no information unlike in ordinary computation but the information is represented by the braid. Of course, also more general configurations are possible. Anyons are assumed to evolve like free particles except during swap operations and their time evolution is described by single particle Hamiltonians.

   Free particle approximation fails when the anyons are too near to each other as during braid operations. The space of logical qubits is realized as k-code defined by the 2^{n-1} ground states, which are stable against local single particle perturbations for $k=3$ Witten-Chern-Simons action. In the more general case the stability against n-particle perturbations with $n<[k/2]$ is achieved but the gates would become $[k/2]$-particle gates (for $k=5$ this would give 6-particle vertices).

3. Anyonic system provides a unitary modular functor as the S-matrix associated with the anyon system whose time evolution is fixed by the pre-existing braid structure. What this means that the S-matrices associated with the braids can be multiplied and thus a unitary representation for the group formed by braids results. The vacuum degeneracy of anyon system makes this

representation non-trivial. By the NP complexity of braids it is possible to code any quantum logic operation by a particular braid [B29]. There exists a powerful approximation theorem allowing to achieve this coding classically in polynomial time [B3]. From the properties of the R-matrices inducing gate operations it is indeed clear that two gates can be realized. The Hadamard 1-gate could be realized as 2-gate in the system formed by anyon Cooper pair and anyon.

4. In [B14] the time evolution is regarded as a discrete sequence of modifications of single anyon Hamiltonians induced by swaps [B30]. If the modifications define a closed loop in the space of Hamiltonians the resulting unitary operators define a representation of braid group in a dense discrete sub-group of $U(2^n)$. The swap operation is 2-local operation acting like a 2-gate and induces quantum logical operation modifying also single particle Hamiltonians. What is important that this modification maps the space of the ground states to a new one and only if the modifications correspond to a closed loop the final state is in the same code space as the initial state. What time evolution does is to affect the topological charges of anyon Cooper pairs representing qubits inside the 4-anyon batches defined by the braids.

   In quantum field theory the analog but not equivalent of this description would be following. Quite generally, a given particle in the final state has suffered a unitary transformation, which is an ordered product consisting of two kinds of unitary operators. Unitary single particle operators $U_n = Pexp(i\int_{t_n}^{t_{n+1}} H_0 dt)$ are analogs of operators describing single qubit gate and play the role of anyon propagators during no-swap periods. Two-particle unitary operators $U_{swap} = Pexp(i\int H_{swap}dt)$ are analogous to four-particle interactions and describe the effect of braid operations inducing entanglement of states having opposite values of topological charge but conserving the net topological charge of the anyon pair. This entanglement is completely analogous to spin entanglement. In particular, the braid operation mixes different states of the anyon. The unitary time development operator generating entangled state of anyons and defined by the braid structure represents the operation performed by the quantum circuit and the quantum measurement in the final state selects a particular final state.

5. Formally the computation halts with a measurement of the topological charge of the left-most anyon Cooper pair when the outcome is just single bit. If decay occurs with sufficiently high probability it is concluded that the value of the computed bit is 0, otherwise 1.

15.4 Quantum Hall Effect, Charge Fractionalization, And Hierarchy Of Planck Constants

The proportionality $\sigma_{xy} \propto \alpha_{em} \propto 1/\hbar$ suggests an explanation of FQHE [D112, D6, D120] in terms of the hierarchy of Planck constants. The idea was that perhaps filling factors and magnetic fluxes are actually integer valued but the value of Planck constant defining the unit of magnetic flux is changed from its standard value - to its rational multiple in the most general case. This naïve guess turned out be incorrect.

A careful study of what was known about FQHE much before 2005 (see for instance [D83]) - in particular understanding of the notion of composite fermion - would have demonstrated that FQHE is basically IQHE for composite fermions so that fractionization cannot be due to the integer values of Planck constant or of effective Planck constant. In fact, accepting that composite fermion description one has only to explain what really happens in charge fractionization and how braid statistics emerges. One should of course also have a concrete description for the bound states of electron and flux tubes.

In the picture using multi-sheeted covering of embedding space as an auxiliary tool, the phase transition corresponds to the leakage of 3-surface from a given 8-D page to another one in the Big Book having local singular coverings of $CD \times CP_2$ as pages. This auxiliary tool is not absolutely necessary since multi-furcations of preferred extremals of Kähler action is the fundamental notion and one can see FQHE as a function of external magnetic field as a hierarchy of multi-furcations of preferred extremals. In the following this view is adopted since this minimizes the number un-necessary assumptions.

One particular assumption of this kind in the previous approach was that the singular coverings are products of those for CD and CP_2. The coverings has product structure in the sense that the number of sheets is product of two integers but this does not require that these integers could be assigned with singular coverings of CD and CP_2.

The proposed general principle governing the transition to large $\hbar$ phase states that Nature loves lazy theoreticians: if perturbation theory fails to converge, a phase transition increasing the effective value of Planck constant occurs and guarantees the convergence. The killer test for the hypothesis is to find whether higher order perturbative QED corrections in powers of α_{em} are reduced from those predicted by QED in QHE phase.

At the level of preferred extremals of Kähler action these phase transitions corresponds to multi-furcations and their presence is unavoidable due to the enormous vacuum degeneracy of Kähler action which makes also ordinary path integral quantization impossible and also implies 4-D spin glass degeneracy as a basic aspect of the dynamics.

In this section the most recent view about the relationship between dark matter hierarchy, effective hierarchy of Planck constants, and FQHE is discussed. Besides explanations for charge fractionization and fractional exchange statistics also a models for the magnetic flux quanta and the macroscopic 2-surface carrying the anyonic phase are proposed. All these models rely on the notion of many-sheeted space-time and the notion of multi-furcations for a preferred extremal of Kähler action implying also the effective hierarchy of Planck constants.

15.4.1 General Description Of The Anyonic Phase

It is appropriate to start with a general description of the anyonic phase in TGD framework. This involves two highly non-trivial new physics elements.

1. The first element corresponds to the description of electrons as pairs of Kähler magnetic flux tubes connecting two wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. 18.3** in the appendix of this book) such that one obtains closed flux tube carrying monopole flux. This description applies to all elementary particles. The "upper" wormhole throat of the second end of this flux tube structure by definition contains electron's quantum numbers and they are assignable to the end of braid strand. This strand continues along the light-like end of the wormhole throat as well as along space-like braid strand assignable to the end of space-time at either end of causal diamond (CD).

   One can imagine a de-localization of electron's quantum numbers in the sense that the state superposition of flux tubes with electron's quantum numbers at either end. This might allow to understand the paradoxical aspects of FQHE in composite fermion description (number of flux quanta per electron large than one and number of electrons per flux quanta larger than one).

2. Second element corresponds to the assumption that wormhole contacts, which have induced metric with Euclidian signature can have M^4 projection which has macroscopic size. All macroscopic objects could correspond to macroscopic wormhole contacts and be analogous to black-holes.

3. Also the nanoscopic magnetic flux quanta with Minkowskian signature of metric and appearing in the composite fermion model of FQHE would have as their boundaries wormhole contacts, now with cylindrical M^4 projection.

4. The natural interpretation is that the generation of flux tubes changes the topology of the macroscopic boundary. It would describe the leakage of a Minkowskian region with magnetic field to Euclidian region occurring also in super-conductivity. Depending on the character of super-conductivity the penetration can take as flux tubes or as complex flux sheets. Flux quanta are long Minkowskian flux tubes connecting opposite sides of the boundary. Single flux tube boundary is a mesoscopic wormhole throat with tubular geometry - like a cave eaten by an worm in apple - and changes its topology by adding a handle.

5. This leads to the vision that macroscopic objects are obtained simply by somehow gluing elementary particles to the two throats of macroscopic wormhole contact along their second end. One can also imagine that Minkowskian flux tube like regions get branched and that there are Minkowskian islands connected by the flux tube Minkowskian flux quanta.

6. The flux tubes define space-like braids with effectively 1-D strands whereas the braids associated with electrons at the light-like orbit of the partonic 2-surface representing macroscopic

boundary define time-like braids with literally 1-D braid strands. The space-like braids defined by magnetic flux tubes are in key role in TGD inspired quantum biology [K4].

Geometric description of the condensation of electrons to the anyonic 2-surface

There is a strong temptation to interpret the macroscopic 2-surface at which the anyonic phase resides as a partonic 2-surface or rather pair of parallel partonic 2-surfaces within distance of CP_2 size associated with macroscopic wormhole contact connecting two space-time sheets. The first space-time sheet would carry the external magnetic field with flux quanta subtracted and the other one the flux quanta.

The rather radical conceptual implication would be that the interior of this boundary surface - more precisely the space-time sheet corresponding to the interior of the entire macroscopic system - has Euclidian signature of metric, and is in several aspects analogous to blackhole interior and indeed proposed to replace blackhole in TGD Universe. In many-sheeted space-time this does not lead to any obvious problems and would say only that entire macroscopic system in this length scale behaves as a line of a generalized Feynman diagram.

Electrons can in some sense condense at this pair of space-time sheets. The simplest view would be that electronic flux tube pair attaches to this surface along its second wormhole contact. Another wormhole contact remains at the Minkowskian side. The two wormhole throats at the second end of electron attach to the macroscopic wormhole throats and the flux turns back through the macroscopic wormhole contact. This allows to have ordinary many-electron state - or rather, boundary state.

If one tries to add electrons as braid strands to the light-like orbit of the upper macroscopic partonic 2-surface, one obtains quite different state. This state has nothing to do with ordinary many-electron state but is more like super-conformal excitation of a primary state containing only single fermionic braid strand and its propagator as particle would be of form $1/p^N$, N large. In conformal theory conformal descendant of a primary field would be the analogy.

I have proposed that this kind of macroscopic and even astroscopic structures emerge naturally in TGD framework. so tht anyons could be important even in astrophysics.

Possible solution of the paradox

It has been already noticed that FQHE leads to what looks like a paradox - at least for an outsider to condensed matter physics like me. The number of flux tubes per electron is larger than 1 on one hand and the number of electrons per flux tube is larger than 1 on one hand.

The bi-locality of the electrons might solve the paradox. If the charge of free electron is de-localized to its both ends, electron can be said to reside at the both ends of its monopole flux tube.

Consider what the following two statements could mean. *Electron current generates the magnetic field inside flux quantum. Electron resides at the center of the flux quantum.*

1. Suppose first that electron is associated with either wormhole end of its monopole flux tube, call it E. If the electronic charge is always at the Minkowskian end of E, then two statements could be special cases of a more general statements E would connect second electron wormhole in the Minkowskian interior of the mesoscopic magnetic flux quantum - call it M - to electron wormhole fused to the boundary of M. The location of interior wormhole would be center of flux quantum or a point near to its boundary in the two cases respectively. It seems that the paradox remains unsolved in this picture.

2. Suppose that electron corresponds to a superposition of states for which charge is associated with either upper end of the flux tube perhaps having length of order Compton length. If the electronic charge is de-localized and shared between ends of E, one cannot anymore say that the electron is either at the center or at the boundary. Paradox would disappear since quantum logic would not allow its formulation.

What happens to electron in external magnetic fields in FQHE?

What happens in external magnetic field when $2p$ flux quanta are formed? The first challenge is to construct a concrete model for what happens to electron as a geometric object in this process.

1. Assume that electron's "upper" space-time sheet by definition containing its quantum numbers suffers a $2p$-furcation. Each sheet of multi-furcation corresponds to flux quantum Φ_0. Electron near the center of flux quantum is de-localized at the sheets of the multi-furcation to "plane wave" like state. The corresponding conserved momentum defined modulo $2p$ defines a topological quantum number making in turn possible non-Abelian braid group representations. Intuitively it is clear that if one identifies electron's charge as that associated with single branch of the covering, charge fractionalization takes place.
2. Conservation of the magnetic flux requires that the lower sheet carries a reduced magnetic field $B_{eff} = B - \rho 2p\Phi_0$. Since electron experiences only this field one obtains IQHE in B_{eff} so that the basic formula for ν follows.
3. The flux of the magnetic flux quanta at the upper sheet must return back along the lower sheet and this leads to the replacement of B with B_{eff}. Also the fluxes assignable to electrons must return back to the lower sheet and this would take place at the boundaries of flux sheets representing second wormhole throat end of electron.

15.4.2 Basic Aspects Of FQHE

The following gives a brief summary about how one might understand basic aspects of FQHE in TGD framework.

The identification of composite fermions

The basic aspects of FQHE can be understood in terms of composite fermions identified as bound states of electron and $2p$ magnetic flux tubes with magnetic field generated by electrons flowing around its boundary. The electrons are at the center of flux tube to minimize Coulomb repulsion. This picture is however somewhat problematic since it seem to be in conflict with $\nu < 1$ stating that the number of electrons per flux tube is smaller than 1. It has been already proposed that the TGD inspired identification of electron as a bi-local object consisting of two wormhole contacts attaching along its neutral wormhole contact to the cylindrical flux tube representing the magnetic flux quantum resolves the problem. Note that this requires that electron's geometric size is given by flux tube radius and can be large.

The formation of anyons - that is flux tubes would mean a topological transition changing the spherical (say) topology of the space-time sheet representing the macroscopic system- to sphere with handles with handle addition representing as drilling of wormhole connecting the opposite sides of the surface. In this process electrons de-localized at the spherical surfaces would be de-localized so that they would be de-localized also at the flux tube boundaries representing part of the macroscopic wormhole contact.

Charge fractionalization

Since the system is extremely non-linear, the increase of the external magnetic field is expected to lead to a series of multi-furcations meaning that the upper space-time sheet associated with electrons and attached to the upper anyonic 2-surface suffers a multi-furcation. The natural reason for the multi-furcation is that it allows to keep the local magnetic field strength at the flux quantum below critical value. Without multi-furcation this field strength would be proportional to $2p$. Once the first multi-furcation has taken place leading to the generation of the flux tubes, the subsequent multi-furcations only add the number of branches of the multi-furcation of the flux tube. Electron de-localizes to this n-branched structure and single branch carries fractional charge e/n. Also other quantum numbers are fractional.

One should demonstrate convincingly that the fractional charges identified in this sense correspond to measured fractional charges.

Fractional exchange statistics

Also the fractional braid statistics can be understood. For ordinary statistics rotations of M^4 rotate entire partonic 2-surfaces. For braid statistics rotations of M^4 (and particle exchange) induce a flow braid ends along partonic 2-surface. If the singular local covering is analogous to the Riemann surface of $z^{1/n}$, the rotation of 2π leads to a second branch of multi-furcation. For the natural angle coordinate of the n-branched covering its variation of $2/pi$ corresponds to a variation $n2\pi$ of M^4 angle coordinate, and a rotation by 2π in M^4 to a rotation of $2\pi/n$ in at space-time level and phase factor $exp(i2\pi)$ is mapped to $exp(i2\pi/n)$: one has fractional exchange statistics for angular momentum.

Quantum groups relate closely to the fractional statistics and the quantum phase $q = exp(i2\pi/n)$ characterizes the statistics. Quantum groups realize particles exchange as braiding and one can formulate statistics in terms of braid group representations. What is remarkable that also genuinely non-Abelian higher-dimensional braid group representations are possible and these representations are conjectured to be associated with the anomalously behaving filling fractions $\nu = 5/2, 7/2$ allowed also by the standard rules when the entire external magnetic field is transformed to flux quanta. Also the limit $n \to \infty$ gives $\nu = 1/2p$, given $\nu = 1/2$ for $p = 1$.

How non-Abelian gauge group is generated?

The emergence of Abelian braid statistics is explained in terms of the velocity field of electrons defining effectively Abelian gauge potential giving rise to Chern-Simons term defining a topological QFT. This requires that the electron flow is incompressible.

In the case of non-Abelian braid statistics a non-Abelian gauge group is needed to define Chern-Simons action. The challenge is to understand the physical origin of this gauge symmetry and to my best knowledge this problem is not well-understood.

In TGD framework Kähler action reduces to Abelian Chern-Simons terms for preferred extremals so that non-Abelian Chern-Simons term and corresponding gauge group should be generated dynamically. The study of the preferred extremals of Kähler action and solutions of Kähler-Dirac action indeed leads to a mechanism generating not only electro-weak gauge symmetries dynamically but also a larger gauge group [K122]. What might happen is follows. The core part of the dynamical gauge group would be $U(n)$ acting in the space of modes of the Kähler-Dirac operator. Its action commutes with electroweak and other quantum numbers. By taking the n^2 generators of $U(n)$ and the 4 generators of electroweak $U(2)$, and forming their tensor products, one would obtain $4n^2$ generators having interpretation as generators of $U(2n)$. The non-Abelian Chern-Simons term would be associated with $U(n)$.

The stack of N branes very near to each other gives rise to a dynamical gauge group $U(N)$ in M-theory context. This encourages to think that the n-furcation giving rise to n space-time branches gives rise to a dynamical gauge group $U(2)$ for $n = 4$: $SU(2)$ is the minimal requirement for non-trivial braid statistics.

Understanding the origin of braid statistics

Braid statistics requires a 2-dimensional system: plane with punctures in the simplest situation. The non-trivial homotopy allows non-trivial braid statistics since particle exchange as a homotopy need not be reducible to trivial one. The problem is that space is 3-dimensional. Isn't the idealization of 3-D system as 2-D system acceptable if it has so drastic implications as fractional statistics? Could braid statistics for anyons be a signature of something much deeper?

In TGD framework this would be the case. In many-sheeted space-time induced spinor fields are localized to 2-D string world sheets. The strings connecting partonic 2-surfaces have ends at partonic 2-surfaces, and one can perform braiding for the ends.

1. The first reason for the localization at string world sheets is the condition that em charge is well-defined for the spinor modes. This demands that the induced classical W boson fields vanish.
2. Also the condition that octonionic and ordinary spinor structures of embedding space are equivalent inside the domains where induced spinor fields are non-vanishing can be satisfied if spinor modes are localized at string world sheets.

The Dirac action contains also a 1-D boundary term localized at the boundary of string world sheet at the orbits of partonic 2-surfaces and its bosonic counterpart which is length of this boundary. Field equation imply that fermion propagates with light-like momentum along piece of light-like geodesic. This is crucial for the generalization of twistorialization from 4-D to 8-D context [K111].

The 2-D character of string world sheets and of partonic 2-surfaces allows braid statistics. One can indeed modify the anti-commutation relations of fundamental fermions so that they realize braid statistics with quantum phase $q = exp(i2\pi/n)$ [K122].

Some problems of composite model

Composite model as at least the following not so well understood aspects.

1. The flux quanta must be assumed to behave like fermions. What gives them the fermionic statistics and maybe also fermion number?
2. How both the number of flux quanta per electron and the number of electrons per flux quantum can be larger than one?
3. How to understand charge fractionization. How general phenomenon the fractionization is?

Could TGD based model provide deeper justification for the com-posite model?

1. Composite model as starting point. Flux quanta now realized as magnetic flux tubes. An interesting possibility is that flux quanta correspond to mono- pole fluxes for which the transversal section of the flux tube is closed 2-surface rather than disk or annulus.
2. Interesting possibility is that the underlying 2-D system corresponds to a partonic 2-surface of macroscopic size at which electrons and accompanying flux tubes are attached. This kind of surfaces are proposed to appear even in astrophysical scales in TGD Universe and carry dark matter. This would give first a principle justification for braid statistics.
3. Could the braid statistics have justification in terms of hierachy of Planck constants? The proposal is that $h_{eff} = n \times h$ corresponds to a formation of effective n-sheeted covering of embedding space. The original proposal was stronger. M^4 (CP_2) could be covered n_1 (n_2) times and one would have $n = n_1 \times n_2$. This means that ordinary rotations and color rotations in Cartan algebra induce only a phase correspond to $2\pi/n_1$ ($2\pi/n_2$). This would bring in various kinds of fractionizations. This option seems however un-necessarily strong and the product formulas $n = n_1 n_2$ is somewhat questionable.
4. A delocalization of em charge to n sheets implies $1/n$ fractionization.
5. Non-abelian braid statistics is possible only for $n > 4$ and $n = 4$ would be minimal value of n.
6. What gives for the flux tube fermionic statistics? One possibility is based on the fact that a magnetic flux tube carrying Kähler magnetic flux equal to Kähler electric flux at its end is dyon with minimal magnetic charge and odd electric charge. By a well-known argument dyons obey fermionic statistics (`http://tinyurl.com/ybmld3hw`) [B6]. The objection is that in TGD physical fermions are obtained by adding "ur-fermions" at dyonic wormhole throats. Does this mean that fermions behave as bosons in scales longer than flux tube length and as fermions only at wormhole throats? This need not be the case since the two flux tube portions both would behave like fermion so that spin statistics would be correct since flux tubes are necessarily closed albeit in sense of many-sheeted space-time.
7. A solution of the problem consistent with basic TGD could be that the dyonic flux tube assignable to elementary particle defines only a classical space-time correlate for fermion.
8. An alternative explanation would be that the flux tube contains two parts located at parallel space-time sheets connected by wormhole contacts at the ends of the flux tubes so that a closed flux tube results (no Dirac magnetic monopoles in TGD). One would have two flux tube portions of this kind and statistics would be bosonic. The appearance of monopole fluxes as pairs in FQHE would conform with this picture about electron.
9. Another possibility is that covariantly constant right handed neutrino assignable to the flux tube gives rise to fermion number without contributing to four-momentum. The first geometric explanation would only define space-time correlate for spin 1/2. Note that this is consistent with the assumption that neutrino pairs neutralizes the weak isospin of electron. For larger h_{eff} the fractionization of weak isospin would be required.

15.5 Quantization Of Conductance In Neutral Matter As Evidence For Many-Sheeted Space-Time?

We are living really interesting times. Experimental sciences are producing with accelerating pace new discoveries challenging the existing theories and it is difficult to avoid the impression that a revolution is going on in physics and also in biology and neuroscience. It is a pity that colleagues do not seem to even realize what is going on. One example of fascinating experimental findings is described in an article published in Nature (`http://tinyurl.com/ybk5rkfl`) [D54].

The article reports quantization of conductance in neutral matter. In quantum Hall effect conductances is quantized in multiples of e^2/h. Now the however is in multiples of $1/h$. Looks strange! This is due to the fact that voltage is not present now: particles are neutral and electric field is replaced with the gradient of chemical potential and electric current with particle current. Hence elementary charge e is replaced with the unit for particle number which is just 1 rather than e. Hence the quantisation as multiples of $1/h$ but in complete analogy with Quantum Hall Effect (QHE).

What comes to my innocent in mind is that the effect is mathematically like QHE and that there is also fractional variant of it as in the case of QHE. In QHE magnetic field and cyclotron states at flux quanta of this field are in key role. But in the situation considered they are not present if we live in the standard model world.

What is the situation in TGD?

1. In many-sheeted space-time all classical electroweak fields are present as long range fields at given sheet. This has been one of they key interpretational problems of TGD from the beginning. In particular, Kähler electric and magnetic fields are always associated with non-vacuum extremals although ordinary electric field can vanish. Note that classical electro-weak fields affect the dynamics indirectly by forcing fermions to the string world sheets! They are clever power holders!
2. This has inspired the hypothesis that induced spinor fields describing fundamental fermions are localized at string world sheets at which only em fields are non-vanishing [K122]. This assumption guarantees that electromagnetic charge is well-defined quantum number for the modes of spinor field and thus also conserved. Classical Z^0 fields could be present below weak scale also at string world sheets. Weak scale is scaled up to macroscopic scale for large values of $h_{eff} = n \times h$ and this could explain the large parity breaking effects in living matter but also just the fact that fermionic fields are not where weak fields are, could explain the parity breaking effects.
3. At GRT-gauge theory limit the sheets of many-sheeted space-time are replaced with single one and interpreted as region of Minkowski space slightly curved and carrying gauge fields: now space-time is not regarded as a surface anymore. Only classical em field effectively present above weak scale since other electroweak gauge potentials associated with space-time sheets sum up to something which is zero on average at GRT limit.

These observations lead to ask whether the quantization of conductivity for neutral particles be a direct signature of many-sheeted space-time? Could the experiments probe physics at single sheet of many sheeted space-time? Could the needed magnetic and electric fields correspond to classical Z^0 fields, which can be present at string world sheets below weak scale now scaled up by h_{eff}/h.

If this approach is on the correct track then the thermodynamical description in terms of chemical potential cannot be fundamental (the gradient of the chemical potential replaces that of electric potential in this description). Leaving the realm of standard model, one could however wonder whether the thermodynamical description using chemical potentials (chemistry is by definition effective theory!) is really fundamental in quantum regime and whether it could reduce to something more fundamental which standard model can describe only phenomenologically.

1. I have considered two alternative models of cell membrane in zero energy ontology [K86] as a generalisation of thermodynamics as square root of thermodynamics with probability densities interpreted as square roots of thermodynamical weights which are exponentials of thermal energies. These models can be also combined. Both are characterized by a large value of $h_{eff} = h_{gr}$.

2. In the first model of the cell membrane Josephson energy determined by the voltage over the cell membrane is generalized by adding to it the difference of cyclotron energies at flux tubes at the two different sides of the membrane and the magnetic fields at flux tubes appear in the formula. This difference of cyclotron energies corresponds to chemical potential and affects the frequency associated with the Josephson current and corresponding energy proportional to h_{eff} and therefore above thermal energy.

3. For the second model classical Z^0 fields explaining the large parity breaking effects in living matter are assumed to be present. Chemical potential corresponds to the difference of Z^0 potential over the cell membrane. Could this phase be the phase in which "chemical" conductivity is quantized?

4. For the hybrid of the two models the theory of QHE would generalize by replacing em fields with combinations of em and Z^0 fields. This framework could be used to model also the observed quantization of neutral conductivity as an analog of QHE.

The most obvious objection that the quantum of conductivity for neutral particles is $1/h$ rather than g^2/h, where g is appropriate weak coupling strength does not bite. Experimentalists measure particle currents rather than Z^0 currents ($j = j_Z/g_Z$) and use gradient of chemical potential instead of Z^0 potentials $\mu = g_Z E_Z$). $j_Z = \sigma E_Z$ implies that the quantization of the conductance is in multiples of $1/h$.

15.6 Condensed matter simulation of 4-D quantum Hall effect from TGD point of view

I learned about an interesting experimental work related to the condensed matter simulation of physics in space-times with D=4 spatial dimensions meaning that one would have D=1+4=5-dimensional space-time. The simulation was discussed in popular article "*Leaving Flatland – Quantum Hall Physics in 4D*" (see `http://tinyurl.com/ycoxr48s`).

What was simulated is 4-D quantum Hall effect (QHE). In M-theory D= 1+4 dimensional branes would have 4 spatial dimensions and also 4-D QH would be possible so that the simulation to study this speculative higher-D physics. To avoid misunderstandings it must be emphasized that it has not been demonstrated that 4:th spatial dimension exists as layman might think first.

A condensed matter simulation of a 4-D QHE possible in 1+4-dimensional space-time [D56] (see `http://tinyurl.com/y7nxd5k3`) is in question. Professors Immanuel Bloch (LMU/MPQ) and Oded Zilberberg (ETH Zürich) are the leaders of the team behind the work. Using ultracold atoms trapped in a periodically modulated two-dimensional superlattice potential, the scientists could observe a dynamical version of a novel type of QHE that is predicted to occur in four-dimensional systems.

The theory of the 4-D QHE is discussed in [D129] (see `http://tinyurl.com/y8nk5jp3`). This model assumes that spatial dimensions correspond to 4-sphere but also more general topologies are possible. In the simulation the topology was that of 4-torus.

4-D QH conductivity is proportional to a topological invariant known has second Chern number [D98]- gauge theorists talk about instanton number. This invariant is space-time integral of a quantity quadratic in gauge field so that the effect is non-linear.

2-D QH conductivity is proportional to the first Chern number which is essentially magnetic charge and non-vanishing if the second homology group is non-trivial (space has a non-contractible 2-D surface) and can be identified in the experiment considered as an analog of magnetic flux over torus but in momentum space rather than space-time. In the case of 2-D QHE in the real world the spatial topology is that of a 2-disk, which is compact only if boundary is included: one can define the first Chern class as Gauss-Bonnet invariant in this case. My interpretation is however that one considers Chern number in momentum space for the boundary of Fermi surface and that the effective monopole magnetic field corresponds to the area form of this surface: certainly this should be the case for the simulation.

15.6.1 The ideas of the simulation of 4-D QHE

The basic idea is that one tries to find an ordinary 1+3-D system having a dynamics mathematically equivalent to that of QHE in 4+1-D spacetime. Fig 1 of [D56] (see http://tinyurl.com/y7nxd5k3) illustrates the basic idea.

1. One wants to simulate the topology $(S^1 \times S^1) \times (S^1 \times S^1)$. 2-D QHE would take place at tori $S^1 \times S^1$. The basic observation is that the union $S^1 \times S^1 \cup S^1 \times S^1$ of two tori as 2-D surfaces in 3-space is Cartesian product $(S^1 \times S^1) \times (S^1 \times S^1)$ as far as degrees of freedom are counted. Therefore it might be possible to simulate physics of this system by using two 2-D tori plus suitable coupling between them. This idea is familiar from elementary quantum mechanism where the physics of N-particle system in 3-D space as physics of single particle system in 3N-D space.

   One cannot realize these tori as 2-D surfaces in 3-space. The problem is that magnetic field should be orthogonal to the torus. This would require monopole charge distribution along circle at the center of torus. This is not realizable at space-time level using the known physics. It can be however realized as effective magnetic field in momentum space at the boundary of Fermi surface, where one can define effective magnetic monopole field using the area form.

   I understand that the idea is to get effective torus topology in momentum space by using lattice like structure. The momenta differing by lattice momenta are equivalent: physically this means that wave lengths scale smaller than lattice constant are not detectable. This identification is standard manner to define torus topology. Even the lattice structure is realized in a rather exotic manner - as a photon lattice.

2. From the figure 1 one learns that for the first torus $S^1 \times S^1$ is obtained from a lattice-structure in z- and x-directions by the proposed identifications. The Fourier transform of the electric field E_z of 2-D QHE is in the z-direction and the transversal velocity component to Lorentz force is in x-direction. E_z is created by time varying real magnetic flux in x-direction of ordinary space-time by Faraday's law. Lorentz force in momentum space is caused by fictive circular monopole distribution in momentum space generating magnetic flux Φ_{xz}.

   The plane defined by the center circle of the second second torus is orthogonal to that of the first one. One has $(z, x) \rightarrow (w, y)$. x- and y-axis of the cyclinders are thus orthogonal as also induce orthogonal velocities v_x and v_y in 2-D QHE for these systems.

3. In order to get the analog of 4-D QHE one adds a coupling between the two systems modellable using real magnetic field B_{xw} orthogonal to the fictive magnetic flux Φ_{xz}. This implies additional Lorentz force F_w in the direction of E_w in momentum space. Φ_{yw} induces therefore an additional velocity component parallel to v_y and proportional to both Φ_{xz} and Φ_{yw}. This gives rise to additional 4-D QHE proportional to the second Chern number as the integral of the instanton density in momentum space, which is essentially the product of Φ_{xz} and Φ_{yw} so the second Chern number is product of first Chern numbers (I must admit that I do not understand the details of the argument). This gives rise to QHE conductivity bi-linear in the effective magnetic fluxes and proportional to the second Chern number.

The actual realization of the situation involves quite refined condensed matter physics. The simulation of 2-D QH lattices is in terms of photon crystals creating 2-D periodic potentials to which a gas of ultracold boson atoms is added. As already confessed, I do not understand how the mathematical model for the situation leads to 4-D QHE. "*By implementing a 2D topological charge pump with ultracold bosonic atoms in an angled optical superlattice, we realize a dynamical version of the 4D integer quantum Hall effect*" does not tell much to a non-specialist. One can only admire the abstractness of the theory and skills of experimentalists.

15.6.2 TGD inspired comments about the simulation

The simulation raises several questions. Can one imagine 4 space-like dimensions or even 4+1 dimensions in TGD? Can one emerging a general simulation of imagined higher-D physics in terms of 4-D physics in TGD framework.

Are 4-D space-like regions possible in TGD?

In braneology of M-theory 4-D QHE is in principle possible and it might serve as a signature for the existence of fourth spatial dimension if branes really are there. There are however objections against large fourth space-like dimension.

1. Additional large spatial dimensions would have been probably detected if there are everywhere: for instance, additional conserved component of momentum is implied. This implies that the additional dimension must be small enough. One cannot however exclude regions of space-time, where the additional dimension is large.
2. The dimension 3 for hydrogen atom is very special. In fact, the $1/\hbar^2$ proportionality of the binding energies is crucial in TGD inspired biology, where Planck constant has spectrum: $\hbar_{eff}/\hbar = n$. At the level of chemistry one ends up with valence bond theory in which n characterizes the bonds [L60].

   The binding energy spectrum changes dramatically in other dimensions. In particlar, in dimension $D = 4$ the dependence of binding energies on Planck constant is not a power law as it is in other dimensions [L37] (see `http://tinyurl.com/yam7rbk6`). The energies of the hydrogen atom depend on $\hbar_{eff} = n \times h$ as $\hbar_{eff}^m$, $m = -2 < 0$. Hydrogen atoms in dimension D have Coulomb potential behaving as $1/r^{D-2}$ from Gauss law and the Schrödinger equation predicts for $D \neq 4$ that the energies satisfy $E_n \propto (h_{eff}/h)^m$, $m = 2+4/(D-4)$. For $D = 4$ the formula breaks since in this case the dependence on $\hbar$ is not given by power law. m is negative only for $D = 3$ and one has $m = -2$. There $D = 3$ would be unique dimension in allowing the hydrino-like states [L42]. The temporary reduction of n makes possible bio-catalysis and life in the proposed scenario.

Are 4-D space-like regions possible in TGD?

1. In TGD space-times are 4-D surfaces in $H = M^4 \times CP_2$ picture. Space-time regions with Euclidian signature of metric (time is like fourth spatial coordinate) are predicted and could accompany any system as space-time sheet having same size as the system.
2. $M^8 - H$ duality is now a key piece of TGD and states that one can regard space-times as surfaces in either $H = M^4 \times CP_2$ or M^8 [?]see `http://tinyurl.com/yd43o2n2`). In M^8-picture space-time surfaces are zero loci for $RE(P)$ or $IM(P)$, where P is octonionic polynomial obtained as a continuation of real polynomial. In this picture one obtains also 1+4-D 1+5-D space-time surfaces as singular solutions but it is unclear whether they have any physical meaning since they do not have $M^4 \times CP_2$ counterpart. If the two descriptions are equivalent, 4-D QH effect is not possible.

Is 4-D QHE possible in TGD?

Is 4-D QHE possible in TGD? One can consider the question in two different pictures: $M^8 - M^4 \times CP_2$ duality [L56] states that the descriptions of space-time surfaces as algebraic surfaces in M^8 on one hand, and as surfaces satisfying field equations in $H = M^4 \times CP_2$ are physically equivalent.

1. As noticed, space-time regions with Euclidian signature of metric are predicted but since one has only 4-D space rather than 1+4-D space-time, 4-D QHE is not possible.

   One could however consider the possibility that ZEO makes 4+1-D situation effectively possible. The size of CD increases in each "small" reduction identifiable as an analog of weak measurement since one can say that the active boundary of CD shifts farther away from the stationary passive boundary where the members of state pairs are unaffected [L66] (see `http://tinyurl.com/ycxm2tpd`).

   The proper time parameter telling the distance between the tips of CD corresponds to clock time correlating with experienced time. Clock time is discrete since the increments are discrete for it but one can ask whether it could give rise to effective additional space-time coordinate and for space-like regions of space-time realized as surface inside CD this could make possible 4-D QHE. Perhaps a better manner to see this clock time is as the size scale of space-time surface which changes. One could also consider 4-D QHE in which time is replaced by a size scale.

2. In M^8-picture space-time surfaces are zero loci for real and imaginary parts $RE(P)$ or $IM(P)$ (in quaternionic sense using he decomposition of octonion to two quaternions) of octonionic polynomials P obtained as a continuation of real polynomials. Rather surprisingly, one obtains as singular solutions also 1+4-D and 1+5-D space-time surfaces but it is unclear whether they have any physical meaning since they do not have $M^4 \times CP_2$ counterpart. If the two descriptions are equivalent 4-D QH effect does not seem to be possible.

Other effects involving instanton number

One can of course imagine that there could be other effects involving 4-D instanton number (second Chern number). But can one have non-vanishing instanton number in TGD?

1. The induced color gauge field is proportional to induced Kähler gauge field and the counterpart of color action reduces to Kähler action. So that it seems to enough to consider the situation for the Kähler form (of CP_2) induced to space-time surface.
2. Instanton number is winding number for the map $X^4 \to CP_2$ and requires that the CP_2 projection of the space-time surface is 4-D. Therefore one can locally represent the instanton as a map $CP_2 \to M^4$. The asymptotic regions of M^4 and the boundary of CD are however exceptions. Call these regions just S. Here CP_2 coordinates are constant and M^4 coordinates are the appropriate coordinates near S. The map $M^4 \to CP_2$ can be however multiple-valued such that the branches co-indice in S.

Consider first Minkowskian signature for the induced metric, that is maps representable as graphs $M^4 \to CP_2$ (note that locally also the representation as map $CP_2 \to M^4$ are possible at points where the instanton density is non-vanishing).

1. One must can allow multiple-valued maps $M^4 \to CP_2$. One could see M^4- or CD coordinates as coordinates for CP_2, and CP_2 require at least 3 coordinate patches, which strongly suggests at least 3-fold covering and 3-valuedness except at singular regions in which some sheets co-incide.

   The effective dynamical compactification of the space-time surface requires that the CP_2 coordinates are constant in S. All gauge field components therefore vanish at S. Instanton number is divergence of a topological current and reduces to a sum of surface integrals. The contribution from S vanishes.

   The topological current is proportional to Kähler gauge potential and since Kähler field is monopole field one must take into account the gauge discontinuities at coordinate patches coming from the gauge transformation associated with the transitions between patches. If one has instanton number n, there are $3n$ patches giving a non-vanising contribution and their sum could give a non-trivial instanton number.
2. There are good reasons to expect that the induced gauge fields have $n = 0$ in space-time regions with Minkowskian signature of the induced metric. At least this would be the case for the induced Kähler form. For the twistor lift of Kähler action reducing to a sum of Kähler action and volume term, preferred extremals representing a map of $M^4 \to CP_2$ or $CD \to CP_2$ with winding number n very probably do not exist [L35] (see `http://tinyurl.com/yboog5sr`).
3. At QFT limit one consider only Minkowkian regions so that there would be no instantons in TGD Universe. Note that one would avoid the strong CP problem of QCD, which is due to instantons.

Consider next Euclidian signature of the induced metric.

1. For a non-vanishing value of n the representation as a map $CP_2 \to M^4$ is possible except at the intersections with S unless they are not discrete points. If the intersection with the boundary of CD discrete point or empty, one can have instanton number $n = 1$. One can represent CP_2 as a surface in $H = M^4 \times CP_2$ obtained by putting M^4 coordinates to constant. This solution is however not consistent with the assumption that space-time surfaces have ends at the opposite boundaries of CD.

   Elementary particles have wormhole contacts identifiable as deformed pieces of CP_2 as building bricks. CP_2 type extremal can be indeed deformed so that M^4 projection is a light-like geodesic. The resulting surface has two holes and they should reduce to points at the boundaries of CD. One can of course imagine also more holes. What could the instanton number of CP_2 with punctures be?

2. One could try to use 2-D analogy. Sphere CP_1 with punctures looks like a good analogy for CP_2 with punctures. The first Chern number for sphere with punctures is proportional to Gauss-Bonnet invariant expressible in terms of curvature scalar and corrections from the punctures. The first Chern number becomes proportional to $1 - n/2$, where n is the number of punctures. For two holes, one has vanishing Gauss-Bonnet invariant since one has topologically cylinder allowing flat metric.

   If an analogous formula holds also for CP_2, the second Chern number becomes fractional. CP_2 differs from sphere CP_1 in that it has 3 poles instead of 2. The removal of poles of CP_1 gives a vanishing first Chern number (cylinder). The removal of 3 poles from CP_2 should give vanishing second Chern number. Thus second Chern number would be proportional to $1 - n/3$.

   If CP_2 as surface in $H = M^4 \times CP_2$ allows n-fold coverings, they have instanton number n for the Abelian gauge field defined by the induced Kähler form. Is this possible? Could one have M^4 projection consisting of n light-like geodesics? One can argue that the sheets of n-fold covering defined by the light-like geodesics must be transformable continuously to each other so that the light-like geodesics must co-incide, and one can argue that one has 1-fold covering.

One can say that instanton number for Kähler form plays a fundamental role at the level of particle physics and has highly nontrivial physical implications and that they are directly seen in the scales of elementary particles if they have wormhole contacts as basic building bricks. This physics is however not seen at QFT limit of TGD.

Is the simulation of higher-dimensional physics/mathematic possible in TGD?

The idea of simulation of higher-D physics using 4-D physics is especially natural in TGD using N disjoint space-time surfaces. Time coordinate would be common to all N space-time surfaces, say proper time coordinate for either light-cone associated with CD so that the number of degrees of freedom would be $D = 3N + 1$. For light-line 3-D light-like partonic orbits defining the boundaries between Minkowskian and Euclidian regions the dimension would be $D = 2N + 1$ and for string world sheets it would be $D = N + 1$ so that multi-string states would allow the simulation of physics in any dimension $D \geq 2$.

At the level of embedding space this would correspond to a simulation of physics for surfaces $H^N = (CD \times CP_2)^N$, such that time coordinate is same for all 3-D surfaces and one has effectively $(H_7)^N \times T = (E^3 \times CP_2)^N \times T$ where T denote time axis and E^3 to time= constant section. One can replace E^3 with the hyperbolic space H^3 and M^4 time t with the proper time a future or past directed light-cone.

I have proposed this possibility as a reaction to an objection against TGD. If space-time dimension is $D = 4$, how it is possible for a mathematician to imagine higher dimensions? Doesn't mathematical cognition of higher dimensions require a physical simulation of the higher-D dynamics? The proposed dynamics would indeed allow the physical simulation of the higher-D mathematics.

The simulation is trivial unless there is a non-trivial interaction between the separate space-time surfaces. This could be achieved by coupling them using flux tubes. If the surfaces are space-time sheets on top of each other with respect to CP_2 degrees of freedom, wormhole contacts define this interaction. What is interesting that homologically non-trivial wormhole contacts are basic building bricks of elementary particles. For homologically trivial wormhole contacts the contact is unstable against splitting.

Chapter 16

TGD as it is towards end of 2021

16.1 Introduction

The purpose of this article is to give a rough overall view about Topological Geometrodynamics (TGD) as it is now. It must be emphasized that TGD is only a vision, not a theory able to provide precise rules for calculating scattering amplitudes. A collective theoretical and experimental effort would be needed to achieve this.

It is perhaps good to explain what TGD is not and what it is or hoped to be. The article [L123] gives an overview of various aspects of TGD and is warmly recommended.

1. "Geometro-" refers to the idea about the geometrization of physics. The geometrization program of Einstein is extended to gauge fields allowing realization in terms of the geometry of surfaces so that Einsteinian space-time as abstract Riemann geometry is replaced with sub-manifold geometry. The basic motivation is the loss of classical conservation laws in General Relativity Theory (GRT)(see **Fig. 17.1**). Also the interpretation as a generalization of string models by replacing string with 3-D surface is natural.

   Standard model symmetries uniquely fix the choice of 8-D space in which space-time surfaces live to $H = M^4 \times CP_2$ [L2]. Also the notion of twistor is geometrized in terms of surface geometry and the existence of twistor lift fixes the choice of H completely so that TGD is unique [L65, L85](see **Fig. 17.6**). The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "world of classical worlds" (WCW) - becomes the basic object endowed with Kähler geometry (see **Fig. 17.7**). General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. Given 3-surface fixes the space-time surface almost completely as analog of Bohr orbit (preferred extremal).This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces.

2. Consider next the attribute "Topological". In condensed matter physical topological physics has become a standard topic. Typically one has fields having values in compact spaces, which are topologically non-trivial. In the TGD framework space-time topology itself is non-trivial as also the topology of $H = M^4 \times CP_2$.

   The space-time as 4-surface $X^4 \subset H$ has a non-trivial topology in all scales and this together with the notion of many-sheeted space-time brings in something completely new. Topologically trivial Einsteinian space-time emerges only at the QFT limit in which all information about topology is lost (see **Fig. 17.3**).

   Practically any GCI action has the same universal basic extremals: CP_2 type extremals serving basic building bricks of elementary particles, cosmic strings and their thickenings to flux tubes defining a fractal hierarchy of structure extending from CP_2 scale to cosmic scales, and massless extremals (MEs) define space-time correletes for massless particles. World as a set or particles is replaced with a network having particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

   "Topological" could refer also to p-adic number fields obeying p-adic local topology differing radically from the real topology (see **Fig. 17.10**).

3. Adelic physics fusing real and various p-adic physics are part of the number theoretic vision, which provides a kind of dual description for the description based on space-time geometry and the geometry of "world of classical" orders. Adelic physics predicts two fractal length scale hierarchies: p-adic length scale hierarchy and the hierarchy of dark length scales labelled by $h_{eff} = nh_0$, where n is the dimension of extension of rational. The interpretation of the latter hierarchy is as phases of ordinary matter behaving like dark matter. Quantum coherence is possible in all scales.

   The concrete realization of the number theoretic vision is based on $M^8 - H$ duality (see **Fig. 17.8**). The physics in the complexification of M^8 is algebraic - field equations as partial differential equations are replaced with algebraic equations associating to a polynomial with rational coefficients a X^4 mapped to H by $M^8 - H$ duality. The dark matter hierarchy corresponds to a hierarchy of algebraic extensions of rationals inducing that for adeles and has interpretation as an evolutionary hierarchy (see **Fig. 17.9**).

   $M^8 - H$ duality provides two complementary visions about physics (see **Fig. 17.2**), and can be seen as a generalization of the q-p duality of wave mechanics, which fails to generalize to quantum field theories (QFTs).

4. In Zero energy ontology (ZEO), the superpositions of space-time surfaces inside causal diamond (CD) having their ends at the opposite light-like boundaries of CD, define quantum states. CDs form a scale hierarchy (see **Fig. 18.2** and **Fig. 17.13**).

   Quantum jumps occur between these and the basic problem of standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see **Fig. 17.14**). This has profound thermodynamic implications and the question about the scale in which the transition from classical to quantum takes place becomes obsolete. BSFRs can occur in all scales but from the point of view of an observer with an opposite arrow of time they look like smooth time evolutions.

   In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary of CD and states at it remain unchanged (Zeno effect).

TGD develops by explaining what TGD is and also this work led to considerable progress in several aspects of TGD.

1. The mutual entanglement of fermions (bosons) as elementary particles is always maximal so that only fermionic and bosonic degrees can entangle in QFTs. The replacement of point-like particles with 3-surfaces forces us to reconsider the notion of identical particles from the category theoretical point of view. The number theoretic definition of particle identity seems to be the most natural and implies that the new degrees of freedom make possible geometric entanglement.

   Also the notion particle generalizes: also many-particle states can be regarded as particles with the constraint that the operators creating and annihilating them satisfy commutation/anticommutation relations. This leads to a close analogy with the notion of infinite prime.

2. The understanding of the details of the $M^8 - H$ duality forces us to modify the earlier view. The notion of causal diamond (CD) central to zero energy ontology (ZEO) emerges as a prediction at the level of H. The pre-image of CD at the level of M^8 is a region bounded by two mass shells rather than CD. $M^8 - H$ duality maps the points of cognitive representations as momenta of quarks with fixed mass in M^8 to either boundary of CD in H.

3. Galois confinement at the level of M^8 is understood at the level of momentum space and is found to be necessary. Galois confinement implies that quark momenta in suitable units are algebraic integers but integers for Galois singlet just as in ordinary quantization for a particle in a box replaced by CD. Galois confinement could provide a universal mechanism for the formation of all bound states.

4. There is considerable progress in the understanding of the quantum measurement theory based on ZEO. From the point of view of cognition BSFRs would be like heureka moments and the sequence of SSFRs would correspond to an analysis having as a correlate the decay of 3-surface to smaller 3-surfaces.

16.2 Physics as geometry

The following provides a sketchy representation of TGD based on the vision about physics as geometry which is complementary to the vision of physics as number theory. $M^8 - H$ duality relates these two visions. A longer representation can be found in [L123].

16.2.1 Space-time as 4-surface in $H = M^4 \times CP_2$

1. The energy problem of GRT means that since space-time is curved, one cannot define Poincare charges as Noether charges (see **Fig. 17.1**). If space-time X^4 is a surface in $H = M^4 \times CP_2$, the situation changes. Poincare symmetries are lifted to the level of $M^4 \subset H$.
2. Generalization of the notion of particle is in question: point-like particle $\rightarrow$ 3-surface so that TGD can be seen also as a generalization of string model. String $\rightarrow$ 3-surface. String world sheet $\rightarrow X^4$. The notions of the particle and space are unified.
3. Einstein's geometrization program is extended to standard model interactions. CP_2 codes for standard model symmetries and gauge fields. Isometries $\leftrightarrow$ color SU(3). Holonomies of spinor connection $\leftrightarrow$ electroweak U(2) [L2]. Genus-generation correspondence provides a topological explanation of the family replication phenomenon of fermions [K27]: 3 fermion families are predicted.
4. Induction of spinors structure as projection of components of spinor connection from CP_2 to X^4 is central for the geometrization. The projections of Killing vectors of color isometries yield color gauge potentials. Parallel translation at X^4 using spinor connection of H. Also spinor structure is induced and means projection of gamma matrices.
5. Dynamics for X^4 is determined by an action S consisting of Kähler action plus volume term (cosmological constant) following from the twistor lift of TGD [K111, L85].
6. The dynamics for fermions at space-time level is determined by modified Dirac action determined by S being super-symmetrically related to it. Gamma matrices are replaced with modified gamma matrices determined by the S as contractions of canonical momentum currents with gamma matrices. Preferred extremal property follows as a condition of hermiticity for the modified Dirac operator.

   Second quantized H-spinors, whose modes satisfy free massless Dirac equation in H restricted to X^4: this induces second quantization to X^4 and one avoids the usual problems of quantization in a curved background. This picture is consistent with the modified Dirac equation satisfied by the induced spinors in X^4.

   Only quarks are needed if leptons are 3-quark composites in CP_2 scale: this is possible only if one accepts the TGD view about color symmetries. This also provides a new view about matter antimatter asymmetry [L106, L130]. CP violation is forced by the M^4 part of Kähler form forced by the twistor lift.

Basic extremals of classical action

Practically any GCI action allows the same basic extremals (for basic questions related to classical TGD see **Fig. 17.3**).

1. CP_2 type extremals having light-like geodesic as M^4 projection and Euclidian signature of the induced metric serve as building bricks of elementary particles. If the volume term is absent as it might be at infinite volume limit, the geodesics become light-like curves [L155]. Wormhole contacts connecting two Minkowskian space-time sheets can be regarded as a piece of a deformed CP_2 type extremal. Monopole flux through contact stabilizes the wormhole contact.
2. Massless extremals (MEs)/topological light rays are counterparts for massless modes. They allow superposition of modes with single direction of ligth-like momentum. Ideal laser beam is a convenient analogy here.
3. Cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$ and their thickenings to flux tubes are also a central notion.

QFT limit of TGD

The induced gauge fields and gravitational field are expressible in terms of only 4 H- coordinates. Locally the theory is too simple to be physical.

1. Many-sheeted space-time means that X^4 is topologically extremely complex. CP_2 coordinates are many-valued functions of M^4 coordinates or vice versa or both. In contrast to this, the space-time of EYM theory is topologically extremely simple.
2. Einsteinian space-times have 4-D projection to M^4. Small test particle experiences the sum of the classical gauge potentials associated with various space-time sheets. At QFT limit the sheets are replaced with a single region of M^4 made slightly curved and gauge potentials are defined as the sums of gauge potentials from different space-time sheets having common M^4 projection. Topological complexity and local simplicity are replaced with topological simplicity and local complexity. (see **Fig. 17.3**).

16.2.2 World of classical worlds (WCW)

The notion of WCW emerges as one gives up the idea about quantizing by path integral.

The failure of path integral forces WCW geometry

The extreme non-linearity implies that the path integral for surfaces space-time surfaces fails. A possible solution is generalize Einstein's geometrization program to the level of the entire quantum theory.

1. "World of classical worlds" (WCW) can be identified as the space of 3-surfaces endowe with a metric and spinor structure (see **Fig. 17.7**). Hermitian conjugation must have a geometrization. This requires Kähler structure requiring also complex structure. WCW has Kähler form and metric.
2. WCW spinors are Fock states created by fermionic oscillator operators assignable to spinor modes of H basically [L118]. WCW gamma matrices as linear combinations of fermionic (quark) oscillator operators defining analog of vielbein.

   WCW has also spinor connection and curvature in WCW. correspond The quantum states of world correspond formally to *classical* spinor fields in WCW. Gamma matrices of WCW expressinble in terms of fermionic oscillator operators are also purely classical objects.

Implications of General Coordinate Invariance

General Coordinate Invariance (GCI) in 4-D sense forces to assign to 3-surface X^3 a 4-surface $X^4(X^3)$, which is as unique as possible. This gives rise to Bohr orbitology and quantum classical correspondence (QCC), and holography. Also zero energy ontology (ZEO) emerges.

Quantum states quantum superpositions of space-time surfaces as analogs of Bohr orbits. QCC means that the classical theory is an exact part of quantum theory (QCC).

A solution to the basic paradox of quantum measurement theory emerges [L105]: superposition of deterministic time evolutions is replaced with a new one in state function reduction (SFR): SFR does not force any failure of determinism for individual time evolutions.

WCW Kähler geometry from classical action

WCW geometry is determined by a classical action defining Kähler function $K(X^3)$ for a preferred extremal $X^4(X^3)$ defining the preferred extremal/Bohr orbit [K53] (see **Fig. 17.7**).

1. QCC suggests that the definition of Kähler function assigns a more or less unique 4-surface $X^4(X^3)$ to 3-surface X^3. Finite non-uniqueness is however possible [L155].
2. $X^4(X^3)$ is identified as a *preferred* extremal of some general coordinate invariant (GCI) action forcing the Bohr orbit property/holography/ZEO. This means a huge reduction of degrees of freedom.

   Remark:: Already the notion of induced gauge field and metric eliminates fields as primary dynamical variables and GCI leaves locally only 4 H-coordinates as dynamical variables.

3. Twistor lift [L65, L85] of TGD geometrizes the twistor Grassmann approach to QFTs. The 6-D extremal X^6 of 6-D Kähler action as a 6- surface in the product $T(M^4) \times T(CP_2)$ of twistor spaces of M^4 and CP_2 represents the twistor space of X^4.

   The condition that X^6 reduces to an S^2 bundle with X^4 as base space, forces a dimensional reduction of 6-D Kähler action to 4-D Kähler action + volume term, whose value for the preferred extremal defines the Kähler function for $X^4(X^3)$.

4. The volume term corresponds to a p-adic length scale dependent cosmological constant Λ approach zero at long p-adic length scale so that a solution of the cosmological constant problem emerges. Preferred extremal/Bohr orbit property means a simultaneous extremal property for *both* Kähler action and volume term. This forces X^4 to have a generalized complex structure (Hamilton-Jacobi structure) so that field equations trivialize and there is no dependence on coupling parameters. Universality of dynamics follows and the TGD Universe is quantum critical. In particular, Kähler coupling strength is analogous to a critical temperature and is quantized [L141].

5. Soap film analogy is extremely useful [L155]: the analogs of soap film frames are singular surfaces of dimension $D < 4$. At the frame the space-time surface fails to be a simultaneous extremal of both actions separately and Kähler and volume actions couple to each other. The corresponding contributions to conserved isometry currents diverge but sum up to a finite contribution. The frames define the geometric analogs for the vertices of Feynman diagrams.

WCW geometry is unique

WCW geometry is fixed by the existence of Riemann connection and requires maximal symmetries.

1. Dan Freed [A12] found that loop space for a given Lie group allows a unique Kähler geometry: maximal isometries needed in order to have a Riemann connection. Same expected to be true now [K29, K91].

2. Twistor lift of TGD [L65, L85] means that one can replace X^4 with its twistor space $X^6(X^4)$ in the product $T(M^4) \times T(CP_2)$ of the 6-D twistor spaces $T(M^4)$ and $T(CP_2)$. $X^6(X^4)$ is 6-surface with the structure of S^2 bundle.

   Dimensionally reduced 6-D Kähler action gives sum of 4-D Kähler action and volume term. Twistor space must however have a Kähler structure and only the twistor spaces of M^4,E^4, and CP_2 have Kähler structure [A21]. TGD is unique both physically and mathematically!

Isometries of WCW

What can one say about the isometries of WCW? Certainly, they should generalize conformal symmetries of string models.

1. The crucial observation is that the 3-D light-cone boundary δM^4_+ has metric, which is effectively 2-D. Also the light-like 3-surfaces $X^3_L \subset X^4$ at which the Minkowskian signature of the induced metric changes to Euclidian are metrically 2-D. This gives an extended conformal invariance in both cases with complex coordinate z of the transversal cross section and radial light-coordinate r replacing z as coordinate of string world sheet. Dimensions $D = 4$ for X^4 and M^4 are therefore unique.

2. $\delta M^4_+ \times CP_2$ allows the group symplectic transformations of $S^2 \times CP_2$ made local with respect to the light-like radial coordinate r. The proposal is that the symplectic transformations define isometries of WCW [K29].

3. To the light-like partonic orbits one can assign Kac-Moody symmetries assignable to $M^4 \times CP_2$ isometries with additional light-like coordinate. They could correspond to Kac-Moody symmetries of string models assignable to elementary particles.

   The preferred extremal property raises the question whether the symplectic and generalized Kac-Moody symmetries are actually equivalent. The reason is that isometries are the only normal subgroup of symplectic transformations so that the remaining generators would naturally annihilate the physical states and act as gauge transformations. Classically the gauge conditions would state that the Noether charges vanish: this would be one manner to express preferred extremal property.

A possible problem related to the twistor lift

The twistor lift strongly suggests that the Kähler form of M^4 exists. The Kähler gauge potential would be the sum of M^4 and CP_2 contributions. The definition of M^4 Kähler structure is however not straightforward [L114, L115]. The naive guess would be that J represents an imaginary unit as the square root of -1 represented by the metric tensor. This would give the condition $J^2 = -g$ for the tensor square but this leads to problems.

To understand the situation, notice that the analogs of symplectic/Kähler structures in $M^4 \subset H$ have a moduli space, whose points correspond to what I have called Hamilton-Jacobi structures defined by integrable distributions of orthogonal decompositions $M^4 = M^2(x) \times E^2(x)$: $M^2(x)$ is analogous to string world sheet and Y^2 to partonic 2-surface. This means the presence of slicing by string world sheets $X^2(x)$, where x labels a point of Y^2. $X^2(x)$ is orthogonal to Y^2 at x. One can interchange the roles X^2 ad Y^2 in the slicing.

The induced Kähler form has an analogous decomposition. The decomposition is completely analogous to the decomposition of polarizations to non-physical time-like ones and physical space-like ones. This decomposition allows a natural modification of the definition of the symplectic structure so that the problem caused by $J^2 = -g$ conditions is avoided.

Consider first the problem. The $E^2(x)$ part of M^4 Kähler metric produces no problems since the signature of the metric is Euclidean. For $M^2(x)$ part, the Minkowskian signature produces problems. If one assumes that the $M^2(x)$ part of the Kähler form is non-vanishing, it should be imaginary in order to satisfy $J^2(M^2(x)) = -g(M^2(x))$. This implies that Kähler gauge potential is imaginary and this spoils the hermiticity of the modified Dirac equation [K122]. Also the electric contribution to the Kähler energy is negative.

The solution of the problem turned out to be ridiculously simple and I should have noticed it a long time ago.

1. $M^2(x)$ has a hypercomplex structure, which means that the imaginary unit e satisfies $e^2 = 1$ rather than $e^2 = -1$. Hamilton-Jacobi structure allows one to decompose J locally into two parts $J = J(M^2(x)) + J(E^2(x))$ such that $J^2 = g(M^2(x)) - g(E^2(x))$. This gives $J^4 = g(M^4)$. The Kähler energy of the canonically embedded M^4 is non-vanishing and positive whereas Kähler action vanishes by self-duality. Situation is identical to that in Maxwell's electrodynamics.

2. Kähler action for the canonically embedded M^4 vanishes and it is possible to define also Lagrangian 2-surfaces as surfaces for which the induced Kähler form vanishes. These are of special interest since they would guarantee small CP violation: string world sheets could be examples of these surfaces. Note that since the magnetic part of J induces violation of CP, the violation is vanishing for CP_2 type extremals and cosmic strings and also small for flux tubes.

If the notion of symplectic/canonical transformation generated by Hamiltonian preserving J generalizes, one could generate an infinite number of slicings.

Consider first ordinary symplectic transformations.

1. For the ordinary symplectic transformations, the closedness of the symplectic for J is essential ($dJ = 0$ corresponds to topological half of Maxwell's equations).

2. Second essential element is that symplectic transformation is generated as a flow for some Hamiltonian H: $j_H = i_{dH} J$ or more explicitly: $j^l_H = J^{kl}\partial_l H$. It is essential that one has $i_{j_H} J = -dH$: having a vanishing exterior derivative. In other words, $J_{kl} j^l_H = -\partial_k H$ is a gradient vector field and has therefore a vanishing curl. Together with $dJ = 0$, this guarantees the vanishing of the Lie derivative of J: $d_{j_H} J = d(i_{j_H} J) + i_{j_H} dJ = ddH + dJ(j_H) = 0$ so that J is preserved.

Could one talk about symplectic transformations in M^4?

1. The analogs of symplectic/canonical transformations should map the Hamilton-Jacobi structure to a new one and leave $J(M^2(x))$ and $J(E^2(x))$ invariant. The induced metrics of

X^2 and Y^2 need not be preserved since only the diagonal metric $g_l^k(X^2/Y^2)$ appears in the conditions $J^2 = g(X^2) - g(Y^2)$.

2. The symplectic transformation generated by the Hamiltonian H would be a flow defined by the vector field $j_H = i_{dH}J$ and one would have $i_{j_H}J = -d_1H + d_2H$, where d_1 and d_2 are gradients operators in X^2 and Y^2. Usually one would have $J_{kl}j^l = dH$ satisfying $d^2H = 0$.

   The condition $ddH = 0$ satisfied by the ordinary symplectic transformations is replaced with the condition $d(-d_1H + d_2H) = 0$. This can be written as $-d_1^2H + d_2^2H + [d_2, d_1]H = 0$, and is satisfied. Therefore this part is not a problem.

3. Also the orthogonality of $M^2(x)$ and $E^2(x)$ must be preserved. This is a highly non-trivial condition since the metrics are induced and the symplectic transformations change the slicing and the metrics. An arbitrary Hamiltonian flow f, which depends on the coordinates of Y^2 only, maps Y^2 to itself but takes the tangent space $E^2(x)$ to $E^2(f(x))$. Unless the slicing satisfies special conditions, $E^2(f(x))$ is not orthogonal to $M^2(x)$.

4. The orthogonality is expressed as orthogonality of the projectors $P(X^2)$ and $P(Y^2)$: $P(X^2)P(Y^2) = 0$. This condition must be respected by the Hamiltonian flow. The product involves 4 components giving 4 conditions which turn out to be partial differential equations for Hamiltonian. The naive expectation is that there are very few solutions. The Lie-derivative of the product must therefore vanish:

$$L_{j_H}[P(X^2)P(Y^2)] = L_{j_H}(P(X^2))P(Y^2) + P(X^2))L_{j_H}(P(Y^2)) = 0 \ . \tag{16.2.1}$$

The projector $P_{mn}(X^2)$ can be expressed as

$$P^{mn} = g^{\alpha\beta}\partial_\alpha m^k \partial_\beta m^l \ . \tag{16.2.2}$$

Here $g_{\alpha\beta} = m_{kl}\partial_\alpha m^k \partial_\beta m^l$ is the induced metric of X^2 or Y^2. m_{kl} is Minkowski metric and one can use linear Minkowski coordinates so that m_{kl} is constant.
The Lie derivative of $P^{mn}(X^2) \equiv P$ can be written as

$$L_j P^{mn} = L_j(g^{\alpha\beta})\partial_\alpha m^k \partial_\beta m^l + g^{\alpha\beta})(\partial_r j^k \partial_\alpha m^r \partial_\beta m^l + \partial_r j^l k \partial_\alpha m^r \partial_\beta m^k \ . \tag{16.2.3}$$

The Lie derivative of the induced metric is

$$\begin{aligned} L_j g^{\alpha\beta} &= g^{\alpha\mu} g^{\beta\nu} L_J g_{\mu\nu} \ , \\ L_j g_{\alpha\beta} &= m_{kl}(\partial_\alpha j^k \partial_\beta m^l + \partial_\alpha m^k \partial_\beta j^l \ . \end{aligned} \tag{16.2.4}$$

Although the existence of symplectic transformations in the general case seems implausible, one can construct special slicings for which symplectic transformations are possible.

1. One can start from a trivial slicing defined by $M^2 \times E^2$ decomposition and perform slicings of M^2 and E^2. The orthogonality is trivially true for all slicings of this kind since $Y^2(y)$ is orthogonal to X^2 not only at y but at every point x. Symplectic transformations of M^2 and Y^2 produce new slicings of this kind. Even symplectic flowqs defined by general Hamiltonians respect the orthogonality.

2. Second example is provided by the slicing of the light-one boundary by light-like 2-surfaces Y_v^2 labelled by the value of light-like radial coordinate v with metrics differing by r^2 factor. The surfaces X^2 would be planes $X^2(y)$ orthogonal to Y^2 at y with light-like coordinates u and v. The orthogonality would be preserved by symplectic transformations.

   The open question is whether these slicings are the only possible slicings allowing symplectic transformations. Although the construction of these slicings looks trivial, they are not trivial physically.

16.2.3 Should unitarity be replaced with the Kähler-like geometry of the fermionic state space?

Physical states correspond to WCW spinor fields and in ZEO. WCW spinors at a given point of WCW correspond to pairs of Fock states assignable to the 3-surfaces at the opposite boundaries of CD defining space-time surface. These pairs of many-fermion states in fermionic degrees of freedom define the TGD counterpart of the S-matrix.

Unitary is a natural notion in non-relativistic wave-mechanics but already in quantum field theory it becomes problematic. In the twistor approach to the scattering amplitudes of massless gauge theories both unitarity and locality are problematic. Whether TGD can give rise to a unitary S-matrix has been a continual head-ache. This leads to a heretic question.

Is unitarity possible at all in TGD framework and should it be replaced with some deeper principle? I have considered these questions several times and in [L126] a rather radical solution was proposed. The implications of this proposal for the construction of scattering amplitudes are discussed in [L128].

Assigning an S-matrix to a unitary time evolution works in non-relativistic theory but fails already in the generic QFT and correlation functions replace S-matrix.

1. Einstein's great vision was to geometrize gravitation by reducing it to the curvature of space-time. Could the same recipe work for quantum theory? Could the replacement of the flat Kähler metric of Hilbert space with a non-flat one allow the identification of the analog of unitary S-matrix as a geometric property of Hilbert space? Kähler metric is required to geometrize hermitian conjugation. It turns out that the Kähler metric of a Hilbert bundle determined by the Kähler metric of its base space could replace the unitary S-matrix.

2. An amazingly simple argument demonstrates that one can construct scattering probabilities from the matrix elements of Kähler metric and assign to the Kähler metric a unitary S-matrix assuming that some additional conditions guaranteeing that the probabilities are real and non-negative are satisfied. If the probabilities correspond to the real part of the complex analogs of probabilities, it is enough to require that they are non-negative: complex analogs of probabilities would define the analog of the Teichmüller matrix.

   Teichmüller space parameterizes the complex structures of Riemann surface: could the allowed WCW Kähler metrics - or rather the associated complex probability matrices - correspond to complex structures for some space? By the strong form of holography (SH), the most natural candidate would be Cartesian product of Teichmüller spaces of partonic 2 surfaces with punctures and string world sheets.

3. Under some additional conditions one can assign to Kähler metric a unitary S-matrix but this does not seem necessary. The experience with loop spaces suggests that for infinite-D Hilbert spaces the existence of non-flat Kähler metric requires a maximal group of isometries. Hence one expects that the counterpart of S-matrix is highly unique.

4. In the TGD framework the "world of classical worlds" (WCW) has Kähler geometry allowing spinor structure. WCW spinors correspond to Fock states for second quantized spinors at space-time surface and induced from second quantized spinors of the embedding space. Scattering amplitudes would correspond to the Kähler metric for the Hilbert space bundle of WCW spinor fields realized in zero energy ontology and satisfying Teichmüller condition guaranteeing non-negative probabilities.

5. Equivalence Principle generalizes to the level of WCW and its spinor bundle. In ZEO one can assign also to the Kähler space of zero energy states spinor structure and this strongly suggests an infinite hierarchy of second quantizations starting from space-time level, continuing at the

level of WCW, and continuing further at the level of the space of zero energy states. This would give an interpretation for an old idea about infinite primes as an infinite hierarchy of second quantizations of an arithmetic quantum field theory.

6. There is also an objection. The transition probabilities would be given by $P(A,B) = g^{A,\overline{B}} g_{\overline{B},A}$ and the analogs for unitarity conditions would be satisfied by $g^{A,\overline{B}} g_{\overline{B},C} = \delta^A_C$. The problem is that $P(A,B)$ is not real without further conditions. Can one imagine any physical interpretation for the imaginary part of $Im(P(A,B))$?

In this framework, the twistorial scattering amplitudes as zero energy states define the covariant Kähler metric $g_{A\overline{B}}$, which is non-vanishing between the 3-D state spaces associated with the opposite boundaries of CD. $g^{A\overline{B}}$ could be constructed as the inverse of this metric. The problem with the unitarity would disappear.

This view is developed in detail in [L128] and one ends up with a very concrete and surprisingly simple number theoretic view about scattering amplitudes.

16.2.4 About Dirac equation in TGD framework

Three Dirac equations

In TGD spinors appear at 3 levels:

1. At the level of embedding space $H = M^4 \times CP_2$ the spinor field embedding space $M^4 \times CP_2$spinor fields (quark field) is a superposition of the harmonics of the Dirac operator. In the complexified M^8 having interpretation as complexified octonions, spinors are octonionic spinors. In accordance with the fact that M^8 is analogous to momentum space, the Dirac equation is purely algebraic and its solutions correspond to discrete points analogous to occupied points of Fermi ball.
2. The spinors at the level of 4-surfaces $X^4 \subset H$ are restrictions of the second quantized embedding space spinor field in X^4 so that the problematic second quantization in curved background is avoided. At the level of M^8 the restriction selects the points of M^8 belonging to 4-surface and carrying quark. The simplest manner to realize Fermi statistics is to assume that there is at most a single quark at a given point.
3. The third realization is at the level of the "world of classical worlds" (WCW) assigned to H consisting of 4-surfaces as preferred extremals of the action. Gamma matrices of WCW are expressible as superpositions of quark oscillator operators so that anti-commutation relations are geometrized. The conditions stating super-symplectic symmetry are a generalization of super-Kac-Moody symmetry and of super-conformal symmetry and give rise to the WCW counterpart of the Dirac equation [K91] [L123].
4. What the realization of WCW at the level of M^8 is, has remained unclear. The notion of WCW geometry does not generalize to his level and should be replaced with an essentially number theoretic notion.

   Adelic physics as a fusion of real and p-adic physics suggests a possible realization. Given extension of rationals induces extensions of various p-adic number fields. These can be glued to a book-like structure having as pages real numbers and the extensions of p-adic number fields.

   The pages would intersect along points with coordinates in the extension of rationals. These points form a cognitive representation. The additional condition that the active points are occupied by quarks guarantees that this makes sense also for octonions, quaternions and 4-surface in M^8. The p-adic sector could consist of discrete and finite cognitive representations continued to the p-adic surface and define the counterpart of WCW at the level of M^8?

The relationship between Dirac operator of H and modified Dirac operator

At the level of $X^4 \subset H$, the proposal is that modified Dirac action for the induced spinor fields defines the dynamics somehow. Modified Dirac equation or operator should be also consistent with the second quantization of induced spinor fields performed at the level of H and inducing the second quantization at the level of X^4.

1. The modified gamma matrices Γ^α are defined by the contractions of H gamma matrices Γ_k and canonical momentum currents $T^{k\alpha}$ associated with the action defining space-time surface. The modified Dirac operator $D = \Gamma^\alpha D_\alpha$, where D_α is X^4 projection of the vector defined by the covariant derivative operators of H ($D_\alpha = \partial_\alpha h^k D_k$). Hermiticity requires $D_\alpha \Gamma^\alpha = 0$ implying that classical field equations are satisfied.
2. Can one assume that the modified Dirac equation is satisfied? Or is it enough to assume that this is not the case so that the modified Dirac operator defines the propagator as its inverse as the QFT picture would suggest?

   In fact, the propagators in H allow to compute N-point functions involving quarks and at the level of H the theory is free and the restriction to the space-time surface brings in the interactions. Therefore the notion of space-time propagator is not absolutely necessary. One can however ask whether some weaker condition could be satisfied and provide new insights.

   One can also ask whether the solutions of the modified Dirac equation correspond to external particles, which correspond to space-time surfaces for which the solution of the modified Dirac equation is consistent with the solution of the Dirac equation in H. Are these kinds of space-time surfaces possible?
3. The intuitive picture is that the solutions of the modified Dirac equation correspond to the external particles of a scattering diagram having an interpretation on mass shell states and are possible only for a very special kind of preferred extremals. Intuitively they should correspond to singular surfaces in M^8 and their mapping to H would involve blow-up due to the non-uniqueness of the normal space along lower than 4-D surface. String like objects and CP_2 type extremals would be basic entities of this kind. Could the modified Dirac equation or its weakened form hold true for these surfaces.

The strong form of equivalence of modified Dirac equation and ordinary Dirac equation would mean the equivalence of the actions of two Dirac operators acting on the second quantized induced spinor field.

1. The modified Dirac operator is given by $\Gamma_k T^{\alpha k} \partial_\alpha h^k D_k$ and its action should be same as H Dirac operator $\Gamma^k D_k$. This would require

   $$\Gamma_k T^{\alpha k} \partial_\alpha h^k D_k \Psi \quad = \quad \Gamma^k D_k \Psi \ . \tag{16.2.5}$$

   Not surprisingly, it turns out that this condition is too strong.
2. One can express Γ_k using an overcomplete basis defined by the Killing vector fields j_A^k for H isometries. In the case of M^4 it is enough to use translations by using the identity $\sum_A j_A^k j_A^l = h^{kl}$. This allows to define gamma matrices $\Gamma_A = \Gamma_k j_A^k$ and to write the equation in the form

   $$\Gamma_A T^{A\alpha} \partial_\alpha h^k D_k \Psi \quad = \quad \Gamma_A j_A^k D_k \Psi \ . \tag{16.2.6}$$

   Here $T^{A\alpha}$ is the conserved isometry current associated with the Killing vector j_A^k. Is it possible to satisfy the condition

   $$T^{A\alpha} \partial_\alpha h^k = j_A^k \tag{16.2.7}$$

   or its suitably weakened form?

   The strong form of the condition cannot be satisfied. The left hand side of the equation is determined by the gradients of H coordinates and parallel to X^4 whereas the right hand side also involves the component normal to X^4. Therefore the condition cannot be satisfied in the general case.
3. By projecting the condition to the tangent space, one obtains a weaker condition stating that the tangential parts of two Dirac operators are proportional to each other with a position dependent proportionality factor $\Lambda(x)$:

$$
\begin{array}{rcl}
T^{A\alpha} & = & \Lambda(x)j^{\alpha}_A \\
j^{\alpha}_A & = & j^k_A\partial^{\alpha}h_k = j^k_A h_{kl}g^{\alpha\beta}\partial_{\beta}h^l \ .
\end{array}
\quad (16.2.8)
$$

The conserved isometry current is proportional to the projection of the Killing vector to the tangent space of X^4. $\Lambda(x)$ is proportionality constant depending on the point of X^4. Isometry current is analogous to a Hamiltonian vector field being parallel to the Killing vector field.

4. If the action were a mere cosmological volume term, the isometry currents would be proportional to j^{α} so that the conditions would be automatically satisfied. The contribution to $\Lambda(x)$ is proportional to the p-adic length scale dependent cosmological constant.

   Kähler action receives contributions from both M^4 and CP_2. Both add to $T^{A\alpha}$ a term of form $T^{\alpha\beta}j_{A\beta}$ coming from the variation of the Kähler action with respect to $g_{\alpha\beta}$. $T^{\alpha\beta}$ is the energy momentum tensor with a form similar to that for Maxwell action.

   Besides this, M^4 *resp.* CP_2 contribute a term proportional to $J^{\alpha\beta}J_{kl}\partial_{\beta}h^kj^k_A$ coming from the variation of the Kähler action with respect to $J_{\alpha\beta}$ contributing only to M^4 *resp.* CP_2 isometries. These contributions make the conditions non-trivial. The Kähler contribution to $\Lambda(x)$ need not be constant. Note that the Kähler contributions to the energy momentum tensor vanish if X^4 is (minimal) surface of form $X^2\times Y^2\subset M^4\times CP_2$ so that both X^2 and Y^2 are Lagrangian.

5. The vanishing of the divergence of $T^{A\alpha}$ using the Killing property $D_lj_{Ak}+D_kj_{Al}=$ of j_{Ak} gives

$$
j^{A\alpha}\partial_{\alpha}\Lambda = 0 \ . \quad (16.2.9)
$$

   Λ is constant along the flow lines of $j^{A\alpha}$ and is therefore analogous to a Hamiltonian. The constant contribution from the cosmological term to Λ does not contribute to this condition.

6. An attractive hypothesis, consistent with the hydrodynamic interpretation, is that the proposed condition is true for all preferred extremals. The conserved isometry current along the X^4 projection of the flow line is proportional to the projection of Killing vector: this conservation law is analogous to the conservation of energy density $\rho v^2/2+p$ along the flow line). One can say that isometries as flows in the embedding space are projected to flows along the space-time surface. One could speak of projected or lifted representation.

7. The projection to the normal space does not vanish in the general case. One could however ask whether a weaker condition stating that the second fundamental form $H^k_{\alpha\beta}=D_{\alpha}h^k$, which is normal to X^4, defines the notion of the normal space in terms of data provided by space-time surface. If X^4 is a geodesic submanifold of H, in particular a product of geodesic submanifolds of M^4 and CP_2, one has $H^k_{\alpha\beta}=0$.

Gravitational and inertial representations of isometries

The lift/projection of the isometry flows to X^4 strongly suggests a new kind of representation of isometries as analog of the braid representation considered earlier.

1. Projected/lifted representation would clarify the role of the classical conserved charges and currents and generalize hydrodynamical conservation laws along the flow lines of isometries. In particular, quark lines would naturally correspond to time-like flow lines of time translations. In the case of CP_2 type extremals, quark momenta for the lifted representations would be light-like.

2. The conservation conditions along the flow lines are very strong, and one can wonder if they might provide a new formulation of the preferred extremal property. It is quite possible that the conditions apply only to a sub-algebra. Quantum classical correspondence (QCC) suggests Cartan algebra for which the quantum charges can have well-defined eigen values simultaneously. In accordance with QCC, the choice of the quantization axes would affect the space-time surfaces considered and could be interpreted as a higher level quantum measurement.

3. Projected/lifted representation provides a new insight also to the Equivalence Principle (EP) stating that gravitational and inertial masses are identical. At the level of scattering amplitudes involving isometry charges defined at the level of H, the isometries affect the entire space-time surface, and one could see EP as an almost trivial statement. QCC however forces us to consider EP more seriously.

   I have proposed that QCC could be seen as the identification of the eigenvalues of Cartan algebra isometry charges for quantum states with the classical charges associated with the preferred extremals. EP would follow from QCC: gravitational charges would correspond to the representation of the flows defined by isometries as their projections/lifts to X^4 whereas inertial charges would correspond to the representation at the level of H with isometries affecting the entire space-time surfaces.

4. The lifted/projected/gravitational representation of isometries, which seems possible in 4-D situation, is analogous to braid group representation making sense only in 2-D situation. Indeed, for the many-sheeted space-time surfaces assignable to $h_{eff} > h_0$, it can happen that rotation by 2π leads to a new space-time sheet and that the $SO(2)$ subgroup of the rotation group associated with the Cartan algebra is lifted to n-fold covering. Same can can happen in the case of color rotations. This leads to a fractionation of quantum numbers usually assigned with quantum group representations suggested to correspond to $h_{eff} > h$ [K81].

   Also for the quantum groups, Cartan algebra plays a special role. In the case of the Poincare group, the 2-D nature of braid group representations would correspond to the selection $M^2 \times SO(2)$ as a Cartan subgroup implying effective 2-dimensionality in the case rotation group. Gravitational representations could therefore correspond to quantum group representations.

5. The gravitational representation provides also a new insight on $M^8 - H$ duality. The source of worries has been whether Uncertainty Principle (UP) is realized if a given 4-surface in M^8 is mapped to a single space-time surface in M^8. It seems that UP can be realized both in terms of inertial and gravitational representations.

   (a) In the case of the "inertial" representation of H-isometries at the level of H, one must regard $X^4 \subset H$ representing images of particle-like 4-surface in M^8 analog of Bohr orbit (holography) and map it to an analog of plane wave define as superposition of its translates and by the total momentum associated with the either boundary of CD associated with the particle. The same applies to the transforms to other Cartan algebra generators.
   In a cognitive representation based on extension of rationals, the shifts for Cartan algebra would be discrete: the values of the plane wave would be roots of unity belonging to the extension and satisfy periodic boundary conditions at the boundary of larger CD.
   Periodic boundary conditions pose rather strong conditions on the time evolution by scaling between two SSFRs. The scaling must respect the boundary conditions. If the momenta assignable to the plane waves of massive particles are conserved and h_{eff} is conserved, the scaling must multiply CD size by integers. The iterations of integer scalings, in particular $n = 2$ scalings (period doubling), are in a preferred position.

   (b) If one replaces the inertial representation of isometries with the gravitational representation, the quantum states can be realized at the level of a single space-time surface. One would have two representations: gravitational and inertial -subjective and objective, one might say.

   (c) Gravitational representations make also sense for the super-symplectic group acting at the boundary of light-cone as well as for the Kac-Moody type algebra associated with the isometries of H realized the light-like orbits of partonic 2-surfaces.

16.2.5 Different ways to understand the "complete integrability" of TGD

There are several ways to see how TGD could be a completely integrable theory.

Preferred extremal property

Preferred extremal property requires Bohr orbit property and holography and is an extremely powerful condition.

1. Twistor lift of TGD implies that X^4 in H is simultaneous extremal of volume action and Kähler action. Minimal surface property is counterpart for massless field equations and extremality for Kähler action gives interpretation for massless field as Kähler form as part of induced electromagnetic field.

   The simultaneous preferred extremal property strongly suggests that 2-D complex structure generalizes for 4-D space-time surfaces and so called Hamilton-Jacobi structure [L101] meaning a decomposition of M^4 to orthogonal slicings by string world sheets and orthogonal partonic 2-surfaces would realize this structure.

2. Generalized Beltrami property [L131] implies that 3-D Lorentz force and dissipation for Kähler form vanish. The Kähler form is analogous to the classical Maxwell field. Energy momentum tensor has vanishing divergence, which makes it plausible that QFT limit is analogous to Einstein-Maxwell theory.

   The condition also implies that the Kähler current defines an integrable flow so that there is global coordinate varying along flow lines. This is a natural classical correlate for quantum coherence. Quantum coherence would be always present but broken only by the finite size of the region of the space-time considered.

   Beltrami property plus current conservation implies gradient flow and an interesting question is whether conserved currents define gradient flows: non-trivial space-time topology would allow this at the fundamental level. Beltrami condition is a very natural classical condition in the models of supraphases.

3. The condition that the isometry currents for the Cartan algebra of isometries are proportional to the projections of the corresponding Killing vectors is a strong condition and could also be at least an important aspect of the preferred extremal property.

Supersymplectic symmetry

The third approach is based on the super-symplectic symmetry of WCW. Isometry property would suggest that an infinite number of super-symplectic Noether charges are defined at the boundaries of CD by the action of the theory. They need not be conserved since supersymplectic symmetries cannot be symmetries of the action: if they were, the WCW metric would be trivial.

The gauge conditions for Virasoro algebra and Kac-Moody algebras suggest a generalization. Super-symplectic algebra (SSA) involves only non-negative conformal weights n suggesting extension to a Yangian algebra (this is essential!). Consider the hierarchy of subalgebras SSA_m for which the conformal weights are m-tiples of those of entire algebra. These subalgebras are isomorphic with the entire algebra and form a fractal hierarchy.

Assume that the sub-algebra SSA_m and commutator $[SSA_m, SSA]$ have vanishing classical Noether charges for $m > m_{max}$. These conditions could fix the preferred extremal. One can also assume that the fermionic realizations of these algebras annihilate physical states. The remaining symmetries would be dynamical symmetries.

The generators are Hamiltonians of $\delta M^4_+ \times CP_2$. The symplectic group contains Hamiltonians of the isometries as a normal sub-algebra. Also the Hamiltonians of and one could assume that only the isometry generators correspond to non-trivial classical and quantal Noether charges. Could the actions of SSA and Kac-Moody algebras of isometries be identical if a similar construction applies to Kac-Moody half-algebras associated with the light-like partonic orbits. Super-symplectic symmetry would reduce to a hierarchy of gauge symmetries.

16.3 Physics as number theory

Number theoretic physics involves the combination of real and various p-adic physics to adelic physics [L64, L63], and classical number fields [K107].

16.3.1 p-Adic physics

The motivation for p-adicization came from p-adic mass calculations [K61, K27].

1. p-Adic thermodynamics for mass squared operator M^2 proportional to scaling generator L_0 of Virasoro algebra. Mass squared thermal mass from the mixing of massless states with states with mass of order CP_2 mass.
2. $exp(-E/T) \rightarrow p^{L_0/T_p}$, $T_p = 1/n$. Partition function p^{L_0/T_p}. p-Adic valued mass squared mapped to a real number by canonical identification $\sum x_n p^n \rightarrow \sum x_n p^{-n}$. Eigenvalues of L_0 must be integers for the Boltzmann weights to exist. Conformal invariance guarantees this.
3. p-adic length scale $L_p \propto \sqrt{p}$ from Uncertainty Principle ($M \propto 1/\sqrt{p}$). p-Adic length scale hypothesis states that p-adic primes characterizing particles are near to a power of 2: $p \simeq 2^k$. For instance, for an electron one has $p = M^{127} - 1$, Mersenne prime. This is the largest not completely super-astrophysical length scale.

   Also Gaussian Mersenne primes $M_{G,n} = (1+i)^n - 1$ seem to be realized (nuclear length scale, and 4 biological length scales in the biologically important range 10 nm,2.5 μm).
4. p-Adic physics [K70] is interpreted as a correlate for cognition. Motivation comes from the observation that piecewise constant functions depending on a finite number of pinary digits have a vanishing derivative. Therefore they appear as integration constants in p-adic differential equations. This could provide a classical correlate for the non-determinism of imagination.

Unlike the Higgs mechanism, p-adic thermodynamics provides a universal description of massivation involving no other assumptions about dynamics except super-conformal symmetry which guarantees the existence of p-adic Boltzmann weights.

The number theoretic picture leads to a deeper understanding of a long standing objection against p-adic thermodynamics [K61] as a thermodynamics for the scaling generator L_0 of Super Virasoro algebra.

If one requires super-Virasoro symmetry and identifies mass squared with a scaling generator L_0, one can argue that only massless states are possible since L_0 must annihilate these states! All states of the theory would be massless, not only those of fundamental particles as in conformally invariant theories to which twistor approach applies! This looks extremely beautiful mathematically but seems to be in conflict with reality already at single particle level!

The resolution of the objection is that *thermodynamics* is indeed in question.

1. Thermodynamics replaces the state of the entire system with the density matrix for the subsystem and describes approximately the interaction with the environment inducing the entanglement of the particle with it. To be precise, actually a "square root" of p-adic thermodynamics could be in question, with probabilities being replaced with their square roots having also phase factors. The excited states of the entire system indeed are massless [**?**]
2. The entangling interaction gives rise to a superposition of products of single particle massive states with the states of environment and the entire mass squared would remain vanishing. The massless ground state configuration dominates and the probabilities of the thermal excitations are of order $O(1/p)$ and extremely small. For instance, for the electron one has $p = M_{127} = 2^{127} - 1 \sim 10^{38}$.
3. In the p-adic mass calculations [K61, K27], the effective environment for quarks and leptons would in a good approximation consist of a wormhole contact (wormhole contacts for gauge bosons and Higgs and hadrons). The many-quark state many-quark state associated with the wormhole throat (single quark state for quarks and 3-quark-state for leptons [L130].
4. In M^8 picture [L114, L115], tachyonicity is unavoidable since the real part of the mass squared as a root of a polynomial P can be negative. Also tachyonic real but algebraic mass squared values are possible. At the H level, tachyonicity corresponds to the Euclidean signature of the induced metric for a wormhole contact.

   Tachyonicity is also necessary: otherwise one does not obtain massless states. The super-symplectic states of quarks would entangle with the tachyonic states of the wormhole contacts by Galois confinement.
5. The massless ground state for a particle corresponds to a state constructed from a massive single state of a single particle super-symplectic representation (CP_2 mass characterizes the

mass scale) obtained by adding tachyons to guarantee masslessness. Galois confinement is satisfied. The tachyonic mass squared is assigned with wormhole contacts with the Euclidean signature of the induced metric, whose throats in turn carry the fermions so that the wormhole contact would form the nearby environment.

The entangled state is in a good approximation a superposition of pairs of massive single-particle states with the wormhole contact(s). The lowest state remains massless and massive single particle states receive a compensating negative mass squared from the wormhole contact. Thermal mass squared corresponds to a single particle mass squared and does not take into account the contribution of wormhole contacts except for the ground state.

6. There is a further delicate number theoretic element involved [L140, L155]. The choice of $M^4 \subset M^8$ for the system is not unique. Since M^4 momentum is an M^4 projection of a massless M^8 momentum, it is massless by a suitable choice of $M^4 \subset M^8$. This choice must be made for the environment so that both the state of the environment and the single particle ground state are massless. For the excited states, the choice of M^4 must remain the same, which forces the massivation of the single particle excitations and p-adic massivation.

These arguments strongly suggest that pure states, in particular the state of the entire Universe, are massless. Mass would reflect the statistical description of entanglement using the density matrix. The proportionality between p-adic thermal mass squared (mappable to real mass squared by canonical identification) and the entropy for the entanglement of the subsystem-environment pair is therefore natural. This proportionality conforms with the formula for the blackhole entropy, which states that the blackhole entropy is proportional to mass squared. Also p-adic mass calculations inspired the notion of blackhole-elementary particle analogy [K73] but without a deeper understanding of its origin.

One implication is that virtual particles are much more real in the TGD framework than in QFTs since they would be building bricks of physical states. A virtual particle with algebraic value of mass squared would have a discrete mass squared spectrum given by the roots of a rational, possibly monic, polynomial and M^8-H duality suggests an association to an Euclidean wormhole contact as the "inner" world of an elementary particle. Galois confinement, universally responsible for the formation of bound states, analogous to color confinement and possibly explaining it, would make these virtual states invisible [L156, L157].

16.3.2 Adelic physics

Adelic physics fuses real and various p-adic physics to a single structure [L63].

1. One can combine real numbers and p-adic number fields to a product: number fields would be like pages of a book intersecting along rationals acting as the back of the book.

2. Each extension of rational induces extensions of p-adic number fields and extension of the basic adele. Points in the extension of rationals are now common to the pages. The infinite hierarchy of adeles defined by the extensions forms an infinite library.

3. This leads to an evolutionary hierarchy (see **Fig. 17.9**) . The order n of the Galois group as a dimension of extension of rationals is identified as a measure of complexity and of evolutionary level, "IQ". Evolutionary hierarchy is predicted.

4. Also a hierarchy of effective Planck constants interpreted in terms of phases of ordinary matter is predicted. X^4 decomposes to n fundamental regions related by Galois symmetry. Action is n times the action for the fundamental region. Planck constant h is effectively replaced with $h_{eff} = nh$. Quantum coherence scales are typically proportional to h_{eff}. Quantum coherence in arbitrarily long scales is implied. Dark matter at the magnetic body of the system would serve as controller of ordinary matter in the TGD inspired quantum biology [L194].

   $h_{eff} = nh_0$ is a more general hypothesis. Reasons to believe that h/h_0 could be the ratio R^2/L_p^2 for CP$_2$ length scale R deduced from p-adic mass calculations and Planck length L_P [L141]. The CP_2 radius R could actually correspond to L_P and the value of R deduced from the p-adic mass calculations would correspond to a dark CP_2 radius $\sqrt{h/h_0}l_P$.

16.3.3 Adelic physics and quantum measurement theory

Adelic physics [L63] forces us to reconsider the notion of entanglement and what happens in state function reductions (SFRs). Let us leave the question whether the SFR can correspond to SSFR or BSFR or both open for a moment.

1. The natural assumption is that entanglement is a number-theoretically universal concept and therefore makes sense in both real and various p-adic senses. This is guaranteed if the entanglement coefficients are in an extension E of rationals associated with the polynomial Q defining the space-time surface in M^8 and having rational coefficients.

   In the general case, the diagonalized density matrix ρ produced in a state function reduction (SFR) has eigenvalues in an extension E_1 of E. E_1 is defined by the characteristic polynomial P of ρ.

2. Is the selection of one of the eigenstates in SFR possible if E_1 is non-trivial? If not, then one would have a number-theoretic entanglement protection.

3. On the other hand, if the SFR can occur, does it require a phase transition replacing E with its extension by E_1 required by the diagonalization?

Let us consider the option in which E is replaced by an extension coding for the measured entanglement matrix so that something also happens to the space-time surface.

1. Suppose that the observer and measured system correspond to 4-surfaces defined by the polynomials O and S somehow composed to define the composite system and reflecting the asymmetric relationship between O and S. The simplest option is $Q = O \circ S$ but one can also consider as representations of the measurement action deformations of the polynomial $O \times P$ making it irreducible. Composition conforms with the properties of tensor product since the dimension of extension of rationals for the composite is a product of dimensions for factors.

2. The loss of correlations would suggest that a classical correlate for the outcome is a union of uncorrelated surfaces defined by O and S or equivalently by the reducible polynomial defined by the $O \times S$ [L135]. Information would be lost and the dimension for the resulting extension is the sum of dimensions for the composites. O however gains information and quantum classical correspondence (QCC) suggests that the polynomial O is replaced with a new one to realize this.

3. QCC suggests the replacement of the polynomial O the polynomial $P \circ O$, where P is the characteristic polynomial associated with the diagonalization of the density matrix ρ. The final state would be a union of surfaces represented by $P \circ O$ and S: the information about the measured observable would correspond to the increase of complexity of the space-time surface associated with the observer. Information would be transferred from entangled Galois degrees of freedom including also fermionic ones to the geometric degrees of freedom $P \circ O$. The information about the outcome of the measurement would in turn be coded by the Galois groups and fermionic state.

4. This would give a direct quantum classical correspondence between entanglement matrices and polynomials defining space-time surfaces in M^8. The space-time surface of O would store the measurement history as kinds of Akashic records. If the density matrix corresponds to a polynomial P which is a composite of polynomials, the measurement can add several new layers to the Galois hierarchy and gradually increase its height.

   The sequence of SFRs could correspond to a sequence of extensions of extensions of..... This would lead to the space-time analog of chaos as the outcome of iteration if the density matrices associated with entanglement coefficients correspond to a hierarchy of powers P^k [L116, L134].

Does this information transfer take place for both BSFRs and SSFRs? Concerning BSFRs the situation is not quite clear. For SSFRs it would occur naturally and there would be a connection with SSFRs to which I have associated cognitive measurement cascades [**?**]

1. Consider an extension, which is a sequence of extensions $E_1 \rightarrow ..E_k \rightarrow E_{k+1}.. \rightarrow E_n$ defined by the composite polynomial $P_n \circ .... \circ P_1$. The lowest level corresponds to a simple Galois group having no non-trivial normal subgroups.

2. The state in the group algebra of Galois group $G = G_n$ having G_{n-1} as a normal subgroup can be expressed as an entangled state associated with the factor groups G_n/G_{n-1} and subgroup G_{n-1} and the first cognitive measurement in the cascade would reduce this entanglement. After that the process could but need not to continue down to G_1. Cognitive measurements considerably generalize the usual view about the pair formed by the observer and measured system and it is not clear whether $O - S$ pair can be always represented in this manner as assumed above: also small deformations of the polynomial $O \times S$ can be considered.

   These considerations inspire the proposal the space-time surface assigned to the outcome of cognitive measurement G_k, G_{k-1} corresponds to polynomial the $Q_{k,k-1} \circ P_n$, where $Q_{k,k-1}$ is the characteristic polynomial of the entanglement matrix in question.

16.3.4 Entanglement paradox and new view about particle identity

A brain teaser that the theoretician sooner or later is bound to encounter, relates to the fermionic and bosonic statistics. This problem was also mentioned in the article of Keimer and Moore [D25] discussing quantum materials `https://cutt.ly/bWdTRj0`. The unavoidable conclusion is that both the fermions and bosons of the entire Universe are maximally entangled. Only the reduction of entanglement between bosonic and fermionic states of freedom would be possible in SFRs. In the QFT framework, gauge boson fields are primary fields and the problem in principle disappears if entanglement is between states formed by elementary bosons and fermions.

In the TGD Universe, all elementary particles are composites of fundamental fermions (quarks in the simplest scenario) so that if Fock space the Fock states of fermions and bosons express everything worth expressing, SFRs would not be possible at all!

Remark: In the TGD Universe all elementary particles are composites of fundamental fermions (quarks in the simplest scenario) localized at the points of space-time surface defining a number theoretic discretization that I call cognitive representation. Besides this there are also degrees of freedom associated with the geometry of 3-surfaces representing particles. These degrees of freedom represent new physics. The quantization of quarks takes place at the level of H so that anticommutations hold true over the entire H.

Obviously, something is entangled and this entanglement is reduced. What these entangled degrees of freedom actually are if Fock space cannot provide them?

1. Mathematically entanglement makes sense also in a purely classical sense. Consider functions $\Psi_i(x)$ and $\Psi_j(y)$) and form the superposition $\Psi(x) = \sum_{ij} c_{ij}\Psi_i(x)\Psi_j x)$. This function is completely analogous to an entangled state.

2. Number theoretical physics implies that the Galois group becomes the symmetry group of physics and quantum states are representations of the Galois group [L125, L129]. For an extension of extension of ...., the Galois group has decomposition by normal subgroups to a hierarchy of coset groups.

   The representation of a Galois group can be decomposed to a tensor product of representations of these coset groups. The states in irreps of the Galois group are entangled and the SFR cascade produces a product of the states as a product of representations of the coset groups. Galois entanglement allows us to express the asymmetric relation between observer and observed very naturally. This cognitive SSFR cascade - as I have called it - could correspond to what happens in at least cognitive SFRs.

   If so, then SFR would in TGD have nothing to do with fermions and bosons (consisting of quarks too) since the maximal fermionic entanglement remains. For instance, when one for instance talks about long range entanglement the entanglement that matters would correspond to entanglement between degrees of freedom, which do not allow Fock space description.

In the TGD framework, the replacement of particles with 3-surfaces brings in an infinite number of non-Fock degrees of freedom. Could it make sense to speak about the reduction of entanglement in WCW degrees of freedom? There is no second quantization at WCW level so that one cannot talk about Fock spaces WCW level but purely classical entanglement is possible as observed.

1. In WCW unions of disjoint 3-surfaces correspond to classical many-particle states. One can form single particle wave functions for 3-surfaces with a single component, products of these

single particle wave functions, and also analogs of entangled states as their superposition realized as building bricks of WCW spinor fields.

If one requires that these wave functions are completely symmetric under the exchange of 3-surfaces, maximal entanglement in this sense would be realized also now and SFR would not be possible. But can one require the symmetry? Under what conditions one can regard two 3-surfaces as identical? For point-like particles one has always identical particles but in TGD the situation changes.

2. Here theoretical physics and category theory meet since the question when two mathematical objects can be said to be identical is the basic question of category theory. The mathematical answer is they are isomorphic in some sense. The physical answer is that the two systems are identical if they cannot be distinguished in the measurement resolution used.

16.4 $M^8 - H$ duality

There are several observations motivating $M^8 - H$ duality (see **Fig. 17.8**).

1. There are four classical number fields: reals, complex numbers, quaternions, and octonions with dimensions $1, 2, 4, 8$. The dimension of the embedding space is $D(H) = 8$, the dimension of octonions. Spacetime surface has dimension $D(X^4) = 4$ of quaternions. String world sheet and partonic 2-surface have dimension $D(X^2) = 2$ of: complex numbers. The dimension $D(string) = 1$ of string is that of reals.
2. Isometry group of octonions is a subgroup of automorphism group G_2 of octonions containing $SU(3)$ as a subgroup. $CP_2 = SU(3)/U(2)$ parametrizes quaternionic 4-surfaces containing a fixed complex plane.

Could M^8 and $H = M^4 \times CP_2$ provide alternative dual descriptions of physics (see **Fig. 17.8**)?

1. Actually a complexification $M^8_c \equiv E^8_c$ by adding an imaginary unit i commuting with octonion units is needed in order to obtain sub-spaces with real number theoretic norm squared. M^8_c fails to be a field since $1/o$ does not exist if the complex valued octonionic norm squared $\sum o_i^2$ vanishes.
2. The four-surfaces $X^4 \subset M^8$ are identified as "real" parts of 8-D complexified 4-surfaces X^4_c by requiring that $M^4 \subset M^8$ coordinates are either imaginary or real so that the number theoretic metric defined by octonionic norm is real. Note that the imaginary unit defining the complexification commutes with octonionic imaginary units and number theoretical norm squared is given by $\sum_i z_i^2$ which in the general case is complex.
3. The space H would provide a geometric description, classical physics based on Riemann metric, differential geometric structures and partial differential equations deduced from an action principle. M^8_c would provide a number theoretic description: no partial differential equations, no Riemannian metric, no connections...

   M^8_c has only the number theoretic norm squared and bilinear form, which are real only if M^8_c coordinates are real or imaginary. This would define "physicality". One open question is whether all signatures for the number theoretic metric of X^4 should be allowed? Similar problem is encountered in the twistor Grassmannian approach.
4. The basic objection is that the number of algebraic surfaces is very small and they are extremely simple as compared to extremals of action principle. Second problem is that there are no coupling constants at the level of M^8 defined by action.

   Preferred extremal property realizes quantum criticality with universal dynamics with no dependence on coupling constants. This conforms with the disappearance of the coupling constants from the field equations for preferred extremals in H except at singularities, with the Bohr orbitology, holography and ZEO. $X^4 \subset H$ is analogous to a soap film spanned by frame representing singularities and implying a failure of complete universality.
5. In M^8, the dynamics determined by an action principle is replaced with the condition that the *normal* space of X^4 in M^8 is associative/quaternionic. The distribution of normal spaces is always integrable to a 4-surface.

One cannot exclude the possibility that the normal space is complex 2-space, this would give a 6-D surface [L114, L115]. Also this kind of surfaces are obtained and even 7-D with a real normal space. They are interpreted as analogs of branes and are in central role in TGD inspired biology.

Could the twistor space of the space-time surface at the level of H have this kind of 6-surface as M^8 counterpart? Could M^8-H duality relate these spaces in 16-D M^8_c to the twistor spaces of the space-time surface as 6-surfaces in 12-D $T(M^4)\times T(CP_2)$?

6. Symmetries in M^8 number theoretic: octonionic automorphism group G_2 which is complexified and contains $SO(1,3)$. G_2 contains $SU(3)$ as M^8 counterpart of color $SU(3)$ in H. Contains also $SO(3)$ as automorphisms of quaternionic subspaces. Could this group appear as an (approximate) dynamical gauge group?

   $M^8=M^4\times E^4$ as $SO(4)$ as a subgroup. It is not an automorphism group of octonions but leaves the octonion norm squared invariant. Could it be analogous to the holonomy group $U(2)$ of CP_2, which is not an isometry group and indeed is a spontaneously broken symmetry.

   A connection with hadron physics is highly suggestive. $SO(4)=SU(2)_L\times SU(2)_R$ acts as the symmetry group of skyrmions identified as maps from a ball of M^4 to the sphere $S^3\subset E^4$. Could hadron physics $\leftrightarrow$ quark physics duality correspond to M^8-H duality. The radius of S^3 is proton mass: this would suggest that M^8 has an interpretation as an analog of momentum space.

7. What is the interpretation of M^8? Massless Dirac equation in M^8 for the octonionic spinors must be algebraic. This would be analogous to the momentum space Dirac equation. Solutions would be discrete points having interpretation as quark momenta! Quarks pick up discrete points of $X^4\subset M^8$.

   States turn out to be massive in the M^4 sense: this solves the basic problem of 4-D twistor approach (it works for massless states only). Fermi ball is replaced with a region of a mass shell (hyperbolic space H^3).

   M^8 duality would generalize the momentum-position duality of the wave mechanics. QFT does not generalize this duality since momenta and position are not anymore operators.

16.4.1 Associative dynamics in M^8_c

How to realize the associative dynamics in M^8_c [L114, L115]?

1. Number theoretical vision requires hierarchy of extensions of rationals and polynomials with rational coefficients would realize them. Rational coefficients make possible the interpretation as a polynomial with p-adic argument and therefore number theoretical universality.

   One cannot exclude the possibility that also real argument is allowed and that number theoretic universality and adelization applies only for the space-time surfaces defined by polynomials with rational coefficients.

2. Algebraic physics suggests that X^4 is in some sense a root of a M^8_c valued polynomial. One can continue polynomials P with rational coefficients to M^8_c by replacing the real argument with a complexified octonion.

3. The algebraic conditions should imply that the normal space of X^4 is quaternionic/associative. One can decompose octonions to sums $q_1+I_4q_2$, or "real" and "imaginary" parts q_i, which are quaternions and I_4 is octonion unit orthogonal to quaternions. The condition is that the "real" part of the octionic polynomial vanishes. Complexified 4-D surface whose projection to a real section (M^8 coordinates imaginary or real so that complexified octonion norm squared is real) is 4-D.

4. M^8-H duality requires an additional condition. The normal space contains also a complex plane M^2 which is commutative. This guarantees that normal spaces correspond to a point of CP_2. This is necessary in order to define M^8-H duality mapping X^4 from M^8 to H. M^2 can be replaced with an integrable distribution of M^2s if the assignment of the CP_2 point to tangent space can be made unique. This is the case if the spaces $M^2(x)$ are obtained from $M^2(y)$ by a unique G_2 automorphism $g(x,y)$.

Associativity condition at the level of M^8

Associativity condition for polynomials allows to characterize space-time surfaces in terms of polynomials with rational coefficients and possibly also analytic functions with rational Taylor coefficients at M^8 level. $M^8 - H$ duality would map $X^4 \subset M^8$ to $X^4 \subset H$. In M_c^8 the space-time surfaces could be also seen as graphs of local (complex) G_2 gauge transformations.

Remark: Even non-rational coefficients can be considered. In this case polynomials with rational coefficients would define a unique discretion of WCW and allow p-adicization and adelization.

In the generic case the set of points in the extension of rationals defining cognitive representation is discrete and finite. The surprise was that the "roots"can be solved explicitly and that the discrete cognitive representation is dense so that momentum quantization due to the finite volume of CD must be assumed to obtain finite cognitive representation inside CD. Cognitive representation could be defined by the points which correspond to the 8-momenta solving octonionic Dirac equation. This is excellent news concerning practical applications.

The outcome of a detailed examination of the "roots" of the octonionic polynomial having real part $X = Re_Q(P)$ and imaginary part $Y = Im_Q(P)$ in quaternionic sense, yielded a series of positive and negative surprises and demonstrated the failure of the naive arguments based on dimension counting.

1. Although no interesting associative space-time surfaces are possible, every distribution of normal associative planes (co-associativity) is integrable. Note that the distribution of normal spaces must have an integrable distribution of commutative planes in order to guarantee the existence of $M^8 - H$ duality. Generic arguments fail in the presence of symmetries.
2. Another positive surprise was that Minkowski signature is the only possible option. Equivalently, the image of M^4 as real co-associative subspace of O_c (complex valued octonion norm squared is real valued for them) by an element of local $G_{2,c}$ or its subgroup $SU(3,c)$ gives a real co-associative space-time surface.
3. The conjecture based on naive dimensional counting, which was not correct, was that the polynomials P determine these 4-D surfaces as roots of $Re_Q(P)$. The normal spaces of these surfaces possess a fixed 2-D commuting sub-manifold or possibly their distribution allowing the mapping to H by $M^8 - H$ duality as a whole.

   If this conjecture were correct, strong form of holography (SH) would not be needed and would be replaced with extremely powerful number theoretic holography determining space-time surface from its roots and selection of real subspace of O_c characterizing the state of motion of a particle.
4. One of the cold showers during the evolution of the ideas about $M^8 - H$ duality was that the naive expectation that one obtains complex 4-D surfaces as solutions is wrong. The equations for $Re_Q(P) = 0$ ($ImQ_P = 0$) reduce to roots of ordinary real polynomials defined by the odd (even() parts of P and have interpretation as complex values of 8-D mass squared. These surfaces have complex dimension 7. 4 complex dimensions should be eliminated in order to have a complex 4-D surface, whose real parts would give a real 4-surface X^4. The explanation for the unexpected result comes from the symmetries of the octonionic polynomial implying that generic arguments fail.

How does one obtain 4-D space-time surfaces?

Contrary to the naive expections, the solutions of the vanishing conditions for the $Re_Q(P)$ ($Im_Q(P)$) (real (imaginary) part in quaternionic sense) are 7-D complex mass shells $r^2 = r_{n,1}$ as roots of $P_1(r) = 0$ or $r^2 = r_{n,2}$ of $P_2(r) = 0$ rather than 4-D complex surfaces (for a detailed discussion see [K22]) A solution of both conditions requires that P_1 and P_2 have a common root but the solution remains a 7-D complex mass shell! This was one of the many cold showers during the development of the ideas about $M^8 - H$ duality! It seems that the adopted interpretation is somehow badly wrong. Here zero energy ontology (ZEO) and holography come to the rescue.

1. Could the roots of P_1 or P_2 define only complex mass shells of the 4-D complex momentum space identifiable as M_c^4? ZEO inspires the question whether a proper interpretation of mass

shells could be as pre-images of boundaries of cd:s (intersections of future and past directed light-cones) as pairs of mass shells with opposite energies. If this is the case, the challenge would be to understand how X^4_c is determined if P does not determine it.

Here holography, considered already earlier, suggests itself: the complex 3-D mass shells belonging to X^4_c would only define the 3-D boundary conditions for holography and the real mass shells would be mapped to the boundaries of cds. This holography can be restricted to X^4_R. Bohr orbit property at the level of H suggests that the polynomial P defines the 4-surface more or less uniquely.

2. Let us take the holographic interpretation as a starting point. In order to obtain an X^4_c mass shell from a complex 7-D light-cone, 4 complex degrees of freedom must be eliminated. M^8-H duality requires that X^4_c allows M^4_c coordinates.

   Note that if one has $X^4_c = M^4_c$, the solution is trivial since the normal space is the same for all points and the H image under M^8-H duality has constant $CP_2 = SU(3)/U(2)$ coordinates. X^4_c should have interpretation as a non-trivial deformation of M^4_c in M^8.

3. By M^8-H duality, the normal spaces should be labelled by $CP_2 = SU(3)/U(2)$ coordinates. M^8-H duality suggests that the image $g(p)$ of a momentum $p \in M^4_c$ is determined essentially by a point $s(p)$ of the coset space $SU(3)/U(2)$. This is achieved if M^4_c is deformed by a local $SU(3)$ transformation $p \rightarrow g(p)$ in such a way that each image point is invariant under $U(2)$ and the mass value remains the same: $g(p)^2 = p^2$ so that the point represents a root of P_1 or P_2.

   Remark: I have earlier considered the possibility of G_2 and even $G_{2,c}$ local gauge transformation. It however seems that that local $SU(3)$ transformation is the only possibility since G_2 and $G_{2,c}$ would not respect M^8-H duality. One can also argue that only real $SU(3)$ maps the real and imaginary parts of the normal space in the same manner: this is indeed an essential element of M^8-H duality.

4. This option defines automatically M^8-H duality and also defines causal diamonds as images of mass shells $m^2 = r_n$. The real mass shells in H correspond to the real parts of r_n. The local $SU(3)$ transformation g would have interpretation as an analog of a color gauge field. Since the H image depends on g, it does not correspond physically to a local gauge transformation but is more akin to an element of Kac-Moody algebra or Yangian algebra which is in well-defined half-algebra of Kac-Moody with non-negative conformal weights.

The following summarizes the still somewhat puzzling situation as it is now.

1. The most elegant interpretation achieved hitherto is that the polynomial P defines only the mass shells so that mass quantization would reduce to number theory. Amusingly, I started to think about particle physics with a short lived idea that the d'Alembert equation for a scalar field could somehow give the mass spectrum of elementary particles so that the issue comes full circle!

2. Holography assigns to the complex mass shells complex 4-surfaces for which M^8-H duality is well-defined even if these surfaces would fail to be 4-D co-associative. These surfaces are expected to be highly non-unique unless holography makes them unique. The Bohr orbit property of their images in H indeed suggests this apart from a finite non-determinism [L155]. Bohr orbit property could therefore mean extremely powerful number theoretical duality for which the roots of the polynomial determine the space-time surface almost uniquely. $SU(3)$ as color symmetry emerges at the level of M^8. By M^8-H duality, the mass shells are mapped to the boundaries of CDs in H.

3. Do we really know that X^4_r co-associative and has distribution of 2-D commuting subspaces of normal space making possible M^8-H duality? The intuitive expectation is that the answer is affirmative [A7]. In any case, M^8-H duality is well-defined even without this condition.

4. The special solutions to $P=0$, discovered already earlier, are restricted to the boundary of CD_8 and correspond to the values of energy (rather than mass or mass squared) coming as roots of the real polynomial P. These mass values are mapped by inversion to "very special moments in the life of self" (a misleading term) at the level of H as special values of light-cone

proper time rather than linear Minkowski time as in the earlier interpretation [L98]. The new picture is Lorenz invariant.

Octonionic Dirac equation requires co-associativity

The octonionic Dirac equation allows a second perspective on associativity [L115].

1. Everything is algebraic at the level of M^8 and therefore also the octonionic Dirac equation should be algebraic. The octonionic Dirac equation is an analog of the momentum space variant of ordinary Dirac equation and also this forces the interpretation of M^8 as momentum space.
2. Fermions are massless in the 8-D sense and massive in 4-D sense. This suggests that octonionic Dirac equation reduces to a mass shell condition for massive particle with $q \cdot q = m^2 = r_n$, where $q \cdot q$ is octonionic norm squared for quaternion q defined by the expression of momentum p as $p = I_4 q$, where I_4 is octonion unit orthogonal to q. r_n represents mass shell as a root of P.
3. For the co-associative option, the co-associative octonion p representing the momentum is given in terms of quaternion q as $p = I_4 q$. One obtains $p \cdot p = q\overline{q} = m^2 = r_n$ at the mass shell defined as a root of P. Note that for M^4 subspace the space-like components of p p are proportional to i and the time-like component is real. All signatures of the number theoretic metric are possible.
4. For associative option, one would obtain $qq = m^2$, which cannot be satisfied: q reduces to a complex number $zx + Iy$ and one has analog of equation $z^2 = z^2 - y^2 + 2Ixy = m_n^2$, which cannot be true. Hence co-associativity is forced by the octonionic Dirac equation.

This picture combined with zero energy ontology leads also to a view about quantum TGD at the level of M^8. Local $SU(3)$ element g has properties suggesting a Yangian symmetry assignable to string world sheets and possibly also partonic 2-surfaces. The representation of Yangian algebra using quark oscillator operators would allow to construct zero energy states at representing the scattering amplitudes. The physically allowed momenta would naturally correspond to algebraic integers in the extension of rationals defined by P. The co-associative space-time surfaces (unlike generic ones) allow infinite-cognitive representations making possible the realization of momentum conservation and on-mass-shell conditions.

Hamilton-Jacobi structure and Kähler structure of $M^4 \subset H$ and their counterparts in $M^4 \subset M^8$

The Kähler structure of $M^4 \subset H$, forced by the twistor lift of TGD, has deep physical implications and seems to be necessary. It implies that for Dirac equation in H, modes are eigenstates of only the longitudinal momentum and in the 2 transversal degrees of freedom one has essentially harmonic oscillator states [L147, L140], that is Gaussians determined by the 2 longitudinal momentum components. For real longitudinal momentum the exponents of Gaussians are purely imaginary or purely real.

The longitudinal momentum space $M^2 \subset M^4$ and its orthogonal complement E^2 is in a preferred role in gauge theories, string models, and TGD. The localization of this decomposition leads to the notion of Hamilton-Jacobi (HJ) structure of M^4 and the natural question is how this relates to Kähler structures of M^4. At the level of H spinors fields only the Kähler structure corresponding to constant decomposition $M^2 \oplus E^2$ seems to make sense and this raises the question how the H-J structure and Kähler structure relate. TGD suggests the existence of two geometric structure in M^4: HJ structure and Kähler structure. It has remained unclear whether HJ structure and Kähler structure with covariantly constant self-dual Kähler form are equivalent notions or whether there several H-J structures accompaning the Kähler structure.

In the following I argue that H-J structures correspond to different choices of symplectic coordinates for M^4 and that the properties of $X^4 \subset H$ determined bt $M^- H$ duality make it natural to to choose particular symplectic coordinates for M^4.

Consider first what H-J structure and Kähler structure could mean in H.

1. The H-J structure of $M^4 \subset H$ would correspond to an integrable distribution of 2-D Minkowskian sub-spaces of M^4 defining a distribution of string world sheets $X^2(x)$ and orthogonal distribution of partonic 2-surfaces $Y^2(x)$. Could this decomposition correspond to self-dual covariantly Kähler form in M^4?

   What do we mean with covariant constancy now? Does it mean a separate covariant constancy for the choices of $M^2(x)$ and $Y^2(x)$ or only of their sum, which in Minkowski coordinates could correspond to a constant electric and magnetic fields orthogonal to each other?

2. The non-constant choice of $M^2(x)$ $(E^2(x))$ cannot be covariantly constant. One can write $J(M^4) = J(M^2(x)) \oplus J(E^2(x)$ corresponding to decomposition to electric and magnetic parts. Constancy of $J(M^2(x)$ would require that the gradient of $J(M^2(x)$ is compensated by the gradient of an antisymmetric tensor with square equal to the projector to $M^2(x)$. Same condition holds true for $J(E^2(x))$. The gradient of the antisymmetric tensor would be parallel to itself implying that the tensor is constant.

3. H-J structure can only correspond to a transformation acting on J but leaving $J_{kl}dm^kdm^l$ invariant. One should find analogs of local gauge transformations leaving J invariant. In the case of CP_2, these correspond to symplectic transformations and now one has a generalization of the notion. The M^4 analog of the symplectic group would parameterize various decompositions of $J(M^4)$.

   Physically the symplectic transformations define local choices of 2-D space $E^2(x)$ of transversal polarization directions and longitudinal momentum space M^2 emerging in the construction of extremals of Kähler action.

4. For the simplest Kähler form for $M^4 \subset H$, this decomposition in Minkowski coordinates would be constant: orthogonal constant electric and magnetic fields. This Kähler form extends to its number theoretical analog in M^8. The local $SU(3)$ element g would deform M^4 to $g(M^4)$ and define an element of local CP_2 defining $M^8 - H$ duality. g should correspond to a symplectic transformation of M^4.

Consider next the number theoretic counterparts of H-J- and Kähler structures of $M^4 \subset H$ in $M^4 \subset M^8$.

1. In M^4 coordinates H-J structure would correspond to a constant $M^2 \times E^2$ decomposition. In M^4 coordinates Kähler structure would correspond to constant E and B orthogonal to each other. Symplectic transformations give various representations of this structure as H-J structures.

2. The number theoretic analog of H-J structure makes sense also for $X^4 \subset M^8$ as obtained from the distribution of quaternionic normal spaces containing 2-D commutative sub-space at each point by multiplying then by local unit $I_4(x)$ orthogonal to the quaternionic units $\{1, I_1 = I_2 = I_3\}$ with respect to octonionic inner product. There is a hierarchy of CDs and the choices of these structures would be naturally parameterized by G_2.

   This would give rise to a number theoretically defined slicing of $X^4_c \subset M^8_c$ by complexified string world sheets X^2_c and partonic 2-surfaces Y^2_c orthogonal with respect to the octonionic inner product for complexified octonions.

3. In $M^8 - H$ duality defined by $g(p) \subset SU(3)$ assigns a point of CP_2 to a given point of M^4. $g(p)$ maps the number theoretic H-J to H-J in $M^4 \subset M^8$. The space-time surface itself - that is $g(p)$ - defines these symplectic coordinates and the local $SU(3)$ element g would naturally define this symplectic transformation.

4. For $X^4 \subset M^8$ g reduces to a constant color rotation satisfying the condition that the image point is $U(2)$ invariant. Unit element is the most natural option. This would mean that g is constant at the mass and energy shells corresponding to the roots of P and the mass shell is a mass shell of M^4 rather than some deformed mass shell associated with images under $g(p)$.

   This alone does not yet guarantee that the 4-D tangent space corresponds to M^4. The additional physically very natural condition on g is that the 4-D momentum space at these mass shells is the same. $M^8 - H$ duality maps these mass shells to the boundaries of these cd:s in M^4 (CD= $cd \times CP_2$). This conforms with the identification of zero energy states as pairs of 3-D states at the boundaries of CD.

This generalizes the original intuitive but wrong interpretation of the roots r_n of P as "very special moments in the life of self" [L98].

1. Since the roots correspond to mass squared values, they are mapped to the boundaries of cd with size $L = \hbar_{eff}/m$ by $M^8 - H$ duality in M^4 degrees of freedom. During the sequence of SSFRs the passive boundary of CD remains does not shift only changes in size, and states at it remain unaffected. Active boundary is shifted due to scaling of cd.

   The hyperplane at which upper and lower half-cones of CD meet, is shifted to the direction of geometric future. This defines a geometric correlate for the flow of experienced time.
2. A natural proposal is that the moments for SSFRs have as geometric correlates the roots of P defined as intersections of geodesic lines with the direction of 4-momentum p from the tip of CD to its opposite boundary (here one can also consider the possibility that the geodesic lines start from the center of cd). Also energy shells as roots $E = r_n$ of P are predicted. They decompose to a set of mass shells $m_{n.,k}$ with the same $E = r_n$: similar interpretation applies to them.
3. What makes these moments very special is that the mass and energy shells correspond to surfaces in M^4 defining the Lorentz quantum numbers. SSFRs correspond to quantum measurements in this basis and are not possible without this condition. At $X^4 \subset M^8$ the mass squared would remain constant but the local momentum frame would vary. This is analogous to the conservation of momentum squared in general relativistic kinematics of point particle involving however the loss of momentum conservation.
4. These conditions, together with the assumption that g is a rational function with real coefficients, strongly suggest what I have referred to as preferred extremal property, Bohr orbitology, strong form of holography, and number theoretical holography.

In principle, by a suitable choice of M^4 one can make the momentum of the system light-like: the light-like 8-momentum would be parallel to M^4. I have asked whether this could be behind the fact that elementary particles are in a good approximation massless and whether the small mass of elementary particles is due to the presence of states with different mass squares in the zero state allowed by Lorentz invariance.

The recent understanding of the nature of right-handed neutrinos based on M^4 Kähler structure [L140] makes this mechanism un-necessary but poses the question about the mechanism choosing some particular M^4. The conditions that $g(p)$ leaves mass shells and their 4-D tangent spaces invariant provides this kind of mechanism. Holography would be forced by the condition that the 4-D tangent space is same for all mass shels representing inverse images for very special moments of time.

16.4.2 Uncertainty Principle and $M^8 - H$ duality

The detailed realization of $M^8 - H$ duality involves still uncertainties. The quaternionic normal spaces containing fixed 2-space M^2 (or an integrable distribution of M^2) are parametrized by points of CP_2. One can map the normal space to a point of CP_2.

The tough problem has been the precise correspondence between M^4 points in $M^4 \times E^4$ and $M^4 \times CP_2$ and the identification of the sizes of causal diamonds (CDs) in M^8 and H. The identification is naturally linear if M^8 is analog of space-time but if M^8 is interpreted as momentum space, the situation changes. The option discussed in [L114, L115] maps mass hyperboloids to light-cone proper time =constant hyperboloids and it has turned out that this correspondence does not correspond to the classical picture suggesting that a given momentum in M^8 corresponds in H to a geodesic line emanating from the tip of CD.

$M^8 - H$ duality in M^4 degrees of freedom

The following proposal for M^8-H duality in M^4 degrees of freedom relies on the intuition provided by UP and to the idea that a particle with momentum p^k corresponds to a geodesic line with this direction emanating from the tip of CD.

1. The first constraint comes from the requirement that the identification of the point $p^k \in X^4 \subset M^8$ should classically correspond to a geodesic line $m^k = p^k\tau/m$ ($p^2 = m^2$) in M^8 which in

Big Bang analogy should go through the tip of the CD in H. This geodesic line intersects the opposite boundary of CD at a unique point.

Therefore the mass hyperboloid H^3 is mapped to the 3-D opposite boundary of $cd \subset M^4 \subset H$. This does not fix the size nor position of the CD ($= cd \times CP_2$) in H. If CD does not depend on m, the opposite light-cone boundary of CD would be covered an infinite number of times.

2. The condition that the map is 1-to-1 requires that the size of the CD in H is determined by the mass hyperboloid M^8. Uncertainty Principle (UP) suggests that one should choose the distance T between the tips of the CD associated with m to be $T = \hbar_{eff}/m$.

   The image point m^k of p^k at the boundary of $CD(m, h_{eff})$ is given as the intersection of the geodesic line $m^k = p^k\tau$ from the origin of $CD(m, h_{eff})$ with the opposite boundary of $CD(m, h_{eff})$:

$$m^k = \hbar_{eff} X \frac{p^k}{m^2} \quad , X = \frac{1}{1+p_3/p_0} \quad . \tag{16.4.1}$$

   Here p_3 is the length of 3-momentum.

   The map is non-linear. At the non-relativistic limit ($X \to 1$), one obtains a linear map for a given mass and also a consistency with the naive view about UP. m^k is on the proper time constant mass shell so the analog of the Fermi ball in $H^3 \subset M^8$ is mapped to the light-like boundary of $cd \subset M^4 \subset H$.

3. What about massless particles? The duality map is well defined for an arbitrary size of CD. If one defines the size of the CD as the Compton length $\hbar_{eff}/m$ of the massless particle, the size of the CD is infinite. How to identify the CD? UP suggests a CD with temporal distance $T = 2\hbar_{eff}/p_0$ between its tips so that the geometric definition gives $p^k = \hbar_{eff} p^k/p_0^2$ as the point at the 2-sphere defining the corner of CD. p-Adic thermodynamics [K61]) strongly suggests that also massless particles generate very small p-adic mass, which is however proportional to $1/p$ rather than $1/\sqrt{p}$. The map is well defined also for massless states as a limit and takes massless momenta to the 3-ball at which upper and lower half-cones meet.

4. What about the position of the CD associated with the mass hyperboloid? It should be possible to map all momenta to geodesic lines going through the 3-ball dividing the largest CD involved with T determined by the smallest mass involved to two half-cones. This is because this 3-ball defines the geometric "Now" in TGD inspired theory of consciousness. Therefore all CDs in H should have a common center and have the same geometric "Now".

   $M^8 - H$ duality maps the slicing of momentum space with positive/negative energy to a Russian doll-like slicing of $t \geq 0$ by the boundaries of half-cones, where t has origin at the bottom of the double-cone. The height of the $CD(m, h_{eff})$ is given by the Compton length $L(m, h_{eff}) = \hbar_{eff}/m$ of quark. Each value of h_{eff} corresponds its own scaled map and for $h_{gr} = GMm/v_0$, the size of $CD(m, h_{eff}) = GM/v_0$ does not depend on m and is macroscopic for macroscopic systems such as Sun.

5. The points of cognitive representation at quark level must have momenta with components, which are algebraic integers for the extension of rationals considered. A natural momentum unit is $m_{Pl} = \hbar_0/R$, h_0 is the minimal value of $h_{eff} = h_0$ and R is CP_2 radius. Only "active" points of $X^4 \subset M^8$ containing quark are included in the cognitive representation. Active points give rise to active CD:s $CD(m, h_{eff})$ with size $L(m, h_{eff})$.

   It is possible to assign $CD(m, h_{eff})$ also to the composites of quarks with given mass. Galois confinement suggest a general mechanism for their formation: bound states as Galois singlets must have a rational total momentum. This gives a hierarchy of bound states of bound states of ..... realized as a hierarchy of CDs containing several CDs.

6. This picture fits nicely with the general properties of the space-time surfaces as associative "roots" of the octonionic continuation of a real polynomial. A second nice feature is that the notion of CD at the level H is forced by this correspondence. "Why CDs?" at the level of H has indeed been a longstanding puzzle. A further nice feature is that the size of the largest CD would be determined by the smallest momentum involved.

7. Positive and negative energy parts of zero energy states would correspond to opposite boundaries of CDs and at the level of M^8 they would correspond to mass hyperboloids with opposite energies.

8. What could be the meaning of the occupied points of M^8 containing fermion (quark)? Could the image of the mass hyperboloid containing occupied points correspond to sub-CD at the level of H containing corresponding points at its light-like boundary? If so, $M^8 - H$ correspondence would also fix the hierarchy of CDs at the level of H.

It is enough to realize the analogs of plane waves only for the actualized momenta corresponding to quarks of the zero energy state. One can assign to CD as total momentum and passive *resp.* active half-cones give total momenta $P_{tot,P}$ *resp.* $P_{tot,A}$, which at the limit of infinite size for CD should have the same magnitude and opposite sign in ZEO.

The above description of $M^8 - H$ duality maps quarks at points of $X^4 \subset M^8$ to states of induced spinor field localized at the 3-D boundaries of CD but necessarily delocalized into the interior of the space-time surface $X^4 \subset H$. This is analogous to a dispersion of a wave packet. One would obtain a wave picture in the interior.

Does Uncertainty Principle require delocalization in H or in X^4?

One can argue that Uncertainty Principle (UP) requires more than the naive condition $T = \hbar_{eff}/m$ on the size of sub-CD. I have already mentioned two approaches to the problem: they could be called inertial and gravitational representations.

1. The inertial representations assigns to the particle as a space-time surface (holography) an analog of plane wave as a superposition of space-time surfaces: this is natural at the level of WCW. This requires delocalization space-time surfaces and CD in H.
2. The gravitational representation relies on the analog of the braid representation of isometries in terms of the projections of their flows to the space-time surface. This does not require delocalization in H since it occurs in X^4.

Consider first the inertial representation. The intuitive idea that a single point in M^8 corresponds to a discretized plane wave in H in a spatial resolution defined by the total mass at the passive boundary of CD. UP requires that this plane wave should be realized at the level of H and also WCW as a superposition of shifted space-time surfaces defined by the above correspondence.

1. The basic observation leading to TGD is that in the TGD framework a particle as a point is replaced with a particle as a 3-surface, which by holography corresponds to 4-surface.

   Momentum eigenstate corresponds to a plane wave. Now planewave could correspond to a delocalized state of 3-surface - and by holography that of 4-surface - associated with a particle.

   A generalized plane wave would be a quantum superposition of shifted space-time surfaces inside a larger CD with a phase factor determined by the 4-momentum. M^8-H duality would map the point of M^8 containing an object with momentum p to a generalized plane wave in H. Periodic boundary conditions are natural and would force the quantization of momenta as multiples of momentum defined by the larger CD. Number theoretic vision requires that the superposition is discrete such that the values of the phase factor are roots of unity belonging to the extension of rationals associated with the space-time sheet. If momentum is conserved, the time evolutions for massive particles are scalings of CD between SSFRs are integer scalings. Also iterated integer scalings, say by 2 are possible.
2. This would also provide WCW description. Recent physics relies on the assumption about single background space-time: WCW is effectively replaced with M^4 since 3-surface is replaced with point and CP_2 is forgotten so that one must introduce gauge fields and metric as primary field variables.

As already discussed, the gravitational representation would rely on the lift/projection of the flows defined by the isometry generators to the space-time surface and could be regarded as a "subjective" representation of the symmetries. The gravitational representation would generalize braid group and quantum group representations.

The condition that the "projection" of the Dirac operator in H is equal to the modified Dirac operator, implies a hydrodynamic picture. In particular, the projections of isometry generators are conserved along the lifted flow lines of isometries and are proportional to the projections of Killing vectors. QCC suggests that only Cartan algebra isometries allow this lift so that each choice of quantization axis would also select a space-time surface and would be a higher level quantum measurement.

Exact ZEO emerges only at the limit of CD with infinite size

At the limit when the volume of CD becomes infinite, the sum of the momenta associated with opposite boundaries of CD should automatically vanish and one would obtain ideal zero energy states. The original assumption that ideal zero energy states are possible for finite size of CD, is not strictly true. The situation is the same for quantization in a finite volume.

1. Denote the sum of the total momenta with positive energy associated with passive boundaries of all CDs by $P_{tot,P} =\equiv P_{tot}$. For finite size of CD, $P_{tot,P}$ need not be the same as the total momentum $P_{tot,A}$ associated with the active boundary which can change during the sequence of SSFRs. Denote the difference $P_{tot,P} - P_{tot,A}$ by ΔP.

   This momentum is P_{tot} is large for large CDs, and naturally defines the spatial resolution. Denote by $M^k = nXh_{eff}P^k_{tot}/\cdot P^2_{tot}$, $X = 1/(1 + P_3/P_0)$, the shift defined by P_{tot}. The analogs of plane waves for the sub-CDs should be discretized with this spatial resolution and at the limit of large total mass the discretization improves.

2. The image of X^4 in H for a given mass hyperboloid H^3 should define a geometric analog of a plane wave in WCW for the total momentum $P^k = \sum_i p^k_i$, $p^2_i = m^2$ of H^3, associated with the CD(M) in M^8. It is also possible to include the momenta with different masses since they have images also at the boundaries of all CDs in the Russian doll hierarchy. For $\hbar_{gr}$ there is a common CD for all particle masses with size Λ_{gr}.

   The WCW plane wave would not be a superposition of points but of shifted space-time surfaces. The argument of the plane wave would correspond to the shift of the $X^4 \subset CD(M) \subset H$.

   Maximal spatial resolution is achieved if one shifts the X^4 and corresponding CD(m) in H inside the large CD by nM^k, $M^k = nh_{eff}XP^k_{tot}/\cdot P^2_{tot}$ and forms the WCW spinor field as a superposition of shifted space-time surfaces $X^4(m)$ with $U_n = exp(i\Delta P \cdot nM)$ appearing as plane wave phase factor.

3. At the limit when the size of the largest CD becomes infinite (the mass M defining Λ_{gr} becomes very large), the sum $\sum_n U_n$ obtained as integral over the identical shifted copies of the space-time surfaces is non-vanishing only for $\Delta P = 0$ and one obtains an momentum conserving ideal zero energy state.

These states would be analogs of single particle states as plane waves, with particle replaced with many-quark state inside $CD(m)$. The generalization is obvious: perform the analog of second quantization by forming N-particle states in which one has N $CD(m)$ plane waves.

The revised view about $M^8 - H$ duality and the "very special moments in the life of self"

The polynomial equations allow at M^8 level also highly unique brane-like solutions having the topology of 6-sphere S^6 and intersecting M^4 along $p^0 = E = constant$ hyperplane. These quantizd values of energy E correspond to the roots of the polynomial defining the solution and are algebraic numbers and algebraic integers for monic polynomials of form $P(x) = x^n + p_{n-1}x^{n-1} + ...$

The TGD inspired theory of consciousness motivated the interpretation of these hyperplanes as "very special moments in the life of self": this interpretation [L98] emerged before the realization that M^8 corresponds to momentum space. The images of these planes under M^8-H duality should however allow this interpretation also in the new picture. Is this possible?

To answer the question one must understand what the image of S^6 under $M^8 - H$ duality is.

1. The image must belong to $M^4 \times CP_2$. The 2-D normal space of the point of S^6 is a complex commutative plane of octonions. Since 4-D normal planes of space-time surface containing complex plane correspond to points of CP_2, the natural proposal is that the image now corresponds to point of CP_1 identified as homologically trivial geodesic sub-manifold S^2_G of CP_2 carrying Kähler magnetic charge.

2. The first thing to notice about the H-image of the 3-D $E = constant$ surface $X^3(E) \subset M^4$ is that it is indeed 3-D rather than 4-D. In M^4 the map has the form $m^k = X\hbar_{eff}/m^2$, $X = 1/(1 + p_3/p_0)$ already discussed.

The value of $m^2 = E^2 - p_3^2$ decreases as p_3^2 increases so that the values of light-cone proper time $a = t^2 - r^2$ for the image are larger than $a_{min} = \hbar_{eff}/m$. "Fermi-spheres" $S_F^2(p_3)$ are mapped to 2-spheres $S^2(r) \subset M^4 \subset H$ with an increasing radius $r(t) = \sqrt{t^2 - a_{min}^2}$. 2-sphere is born at $t = a_{min}$ and starts to increase in size and the expansion velocity approaches light velocity asymptotically. This expanding sphere would be magnetically charged.

The sequence a_n of "very special moments in the life of self" in the life of self would mean the birth of this kind of expanding sphere and a_n would correspond to the roots of the polynomial considered identified as quantized energies. The dispersion relation $E = constant$ means that energy does not depend on the momentum: plasmons provide the condensed matter analogy.

3. There are interesting questions to be answered. Do the surfaces $X^3(E)$ intersect the 4-D space-time surface $X^4 \subset H$? At the level of M^8 the intersections of 4-D and 6-D surfaces are 2-D. The proposal is that these 2-surfaces M^8 are mapped to partonic vertices identified as 2-surfaces $X^2 \subset X^4 \subset H$ at which 4-D surfaces representing particles meet. This should happen also for the new identification of $M^8 - H$ duality.

   However, in the generic case the intersections of 3-surfaces and 4-surfaces in H are empty. The recent situation is however not a generic one since the S^6 solutions are non-generic (one would expect only 4-D solutions) and 4-D and 6-D solutions are determined by the same polynomial. Therefore the points to which the 2-spheres contract for $t = a_{min}$ should be mapped to partonic 2-surfaces in H. Single point should correspond to the geodesic sphere S_G^2.

   Does this conform with the view that 4-D CP_2 type extremals in H correspond to "blow-ups" of 1-D line singularities of $X^4 \subset M^8$ for which the quaternionic tangent spaces at singularity are not unique and define 3-D surface as points of CP_2. Now the 2-D normal spaces of S_F^2 would span $S_G^2 \subset CP_2$ and at the limit of S_F^2 contracting to a point, one would have a 2-D singularity having an interpretation as a partonic vertex.

4. Cosmic strings $X^4 = X^2 \times S_G^2 \subset M^4 \times CP_2$ carrying monopole charge are basic solutions of field equations. Could these cosmic strings relate to the images of $X^3(E)$? For instance, could $X^3(E_1)$ and $X^3(E_2)$ correspond to the ends of a cosmic string thickening to a monopole flux tube? Thickening would correspond to the growth of M^4 projection $S^2(r(t))$ of the flux tube having $r(t) = \sqrt{t^2 - a_{min}^2}$. The interpretation would be as a pair of magnetic poles connected by a monopole flux tube. Cosmic strings would be highly dynamical entities if this is the case.

An objection against $M^8 - H$ duality

Objections are the best manner to proceed. $M^8 - H$ duality maps the point M^8 at mass shell m to points of CD corresponding to the Compton length $\hbar_{eff}/m$ obtained as intersection of line with momentum p starting at the center point of CD and intersecting either boundary of CD. Each quaternionic normal space contains a commuting subspace (in octonionic sense) such that the distribution of the latter spaces is integrable. These normal spaces are parameterized by CP_2. This implies a complete localization in CP_2 so that the restriction of the induced quark field does not have well-defined color quantum numbers.

How to circumvent this objection? The proposed identification of string-like and particle-like space-time surfaces suggests a solution to the problem. Consider first CP_2 type extremals.

1. Consider first CP_2 type extremals as analogs of particles proposed to correspond to line singularities of algebraic 4-surfaces in M^8 with the property that the normal co-quaternionic space is not unique and the normal spaces at given point of the line are parametrized by a 3-D surface of CP_2 at each point of the light-like curve. Algebraic geometers speak of blow-up singularity. This kind of singularity is analogous to the tip of a cone.

   For polynomials the M^4 projection is a light-like geodesic. Also the octonionic continuations of analytic functions of real argument with rational Taylor coefficients can define space-time surfaces and in this case more general light-like curves are expected to be possible. This gives rise to a 4-D surface of H, which has the same Euclidean metric and Kähler form as CP_2 and only the induced gamma matrices are different.

2. The induced spinor field as restriction of the second quantized spinor field of H decomposes into modes, which are modes of H d'Alembertian. The modes have well-defined color quantum numbers so that one can speak of color quarks. This would mean that one can speak about colored quarks only inside CP_2 type extremals and possibly also inside string-like objects. This would trivialize the mysteries of quark and color confinement.

   Gluons would correspond to pairs of quark and antiquark associated with distinct wormhole throats or even - contacts. The mass squared for a given mode is well-defined but at the level of H only the right-handed neutrino is massless. Other states have mass of order CP_2 mass.

3. One can argue that the average momenta associated with these kinds of states have M^4 projection parallel to the light-like geodesic so that the momentum is light-like. There are several justifications for the claim.

   (a) The gravitational representation of isometries already discussed as lift/projection of the corresponding flows in H to X^4 restricts the action of M^4 isometries to a light-like geodesic and implies that the states are massless in this sense.

   (b) The claim conforms with an earlier intriguing observation that the restriction of a massive quark propagator to a pair of space-time points with light-like M^4 distance is essentially a massless propagator irrespective of the value of the mass.

   (c) With a suitable choice of $M^4 \subset M^8$ the ground state mass can be chosen to vanish. The reason is that the 8-D momentum is light-like and if M^4 contains the momentum, then also the M^4 mass vanishes. This choice can be made only for a single mode in the superposition. p-Adic thermodynamics would describe the contribution of higher modes in the quantum superposition of states to the mass squared having interpretation as thermal mass squared.

   (d) One can look at the situation also at the space-time level. If one has a light-like curve or a curve consisting of segments, which are light-like geodesic lines, the situation changes. Since the average velocity for this kind of zigzag (zitterbewegung) curve is below light velocity, the intuitive expectation is that this represents the TGD analog of the Higgs mechanism having interpretation as massivation.

   This finding was the original motivation for p-adic thermodynamics. The conditions stating the light-likeness of the projection are nothing but Virasoro conditions. p-Adic thermodynamics involves also the inclusion of supersymplectic symmetries.

   $H(M^4)$ is orthogonal to the space-time surface and has an interpretation as a local acceleration of the space-time surface as an extended particle. The CP_2 part of H was the original proposal for the Higgs field considered in my thesis. Indeed, $H(CP_2)$ behaves like a complex doublet in complex coordinates. The physical interpretation is that the minimal surface property forces zitterbewegung with acceleration $H(M^4) = H(CP_2)$, which in turn means that light-like curve looks in the average sense like time-like geodesic for a massive particle.

   The problem is that the proposed Higgs field vanishes in the interiors of space-time surfaces. However, the general field equations do not imply minimal surface property and also for preferred extremals it fails at singularities analogous to frames of soap films. At these point one can have non-vanishing $H(CP_2)$. 8-D light-likeness suggests that at these points $H(H)$ is light-like.

   What happens to string like-objects corresponding to 2-D singularities such that the normal spaces at a given point correspond to a 2-D surface of CP_2, which in the most general situation can be either complex 2-surface of CP_2 or a minimal Lagrangian 2-manifold? One cannot exclude 1-D singularities associated with surfaces $X^3 \times X^1 \subset M^4 \times CP_2$ for which CP_2 projection is 1-D, presumably a geodesic circle.

   (a) The simplest string-like objects come in 2 variants corresponding to CP_2 projection, which is a geodesic sphere, which can be homologically non-trivial or non-trivial. M^4 projection is in the simplest situation 2-D plane M^2.

   These two options correspond to the reduction of $SU(3)$ to $U(2)$ or $SO(3)$. The interpretation in terms of spontaneous symmetry breaking is highly suggestive. The representations of $SU(3)$ decompose to those of $U(2)$ or $SO(3)$. Color confinement could weaken to that for $U(2)$ or $SO(3)$ so that the total color quantum numbers I_3 and Y would still vanish but color multiplets would allow these kinds of states.

(b) The simplest symmetry breaking to $U(1)$ could correspond to extremals of form $M^3 \times S^1$ and only $U(1)$ confinement would hold true. In the case of M^4 it does not make sense to speak of color quantum numbers.

16.4.3 Generalizations related to $M^8 - H$ duality

It has become clear that $M^8 - H$ duality generalizes and there is a connection with the twistorialization at the level of H.

M^8-H duality at the level of WCW and p-adic prime as the maximal ramified prime of polynomial

The vacuum functional as an exponent of the Kähler function determines the physics at WCW level. $M^8 - H$ duality suggests that it should have a counterpart at the level of M^8 and appear as a weight function in the summation. Adelic physics requires that weight function is a power of p-adic prime and ramified primes of the extension are the natural candidates in this respect.

1. The discriminant D of the algebraic extension defined by a polynomial P with rational coefficients (`https://en.wikipedia.org/wiki/Discriminant`) is expressible as a square for the product of the non-vanishing differences $r_i - r_j$ of the roots of P. For a polynomial P with rational coefficients, D is a rational number as one can see for polynomial $P = ax^2 + bx + c$ from its expression $D = b^2 - 4ac$. For monic polynomials of form $x^n + a_{n-1}x^{m-1} + ...$ with integer coefficients, D is an integer. In both cases, one can talk about ramified primes as prime divisors of D.

   If the p-adic prime $p$is identified as a ramified prime, D is a good candidate for the weight function since it would be indeed proportional to a power of p and have p-adic norm proportional to negative power of p. Hence the p-adic interpretation of the sum over scattering amplitudes for polynomials P is possible if p corresponds to a ramified prime for the polynomials allowed in the amplitude.

   p-Adic thermodynamics [K61] suggest that p-adic valued scattering amplitudes are mapped to real numbers by applying to the Lorentz invariants appearing in the amplitude the canonical identification $\sum x_n p^n \rightarrow \sum x_n p^{-n}$ mapping p-adics to reals in a continuous manner

2. For monic polynomials, the roots are powers of a generating root, which means that D is proportional to a power of the generating root, which should give rise to some power of p. When the degree of the monic polynomial increases, the overall power of p increases so that the contributions of higher polynomials approach zero very rapidly in the p-adic topology. For the p-adic prime $p = M_{127} = 2^{127} - 1 \sim 10^{38}$ characterizing electrons, the convergence is extremely rapid.

   Polynomials of lowest degree should give the dominating contribution and the scattering amplitudes should be characterized by the degree of the lowest order polynomial appearing in it. For polynomials with a low degree n the number of particles in the scattering amplitude could be very small since the number n of roots is small. The sum $x_i + p_i$ cannot belong to the same mass shell for timelike p_i so that the minimal number of roots r_n increases with the number of external particles.

3. $M^8 - H$ duality requires that the sum over polynomials corresponds to a WCW integration at H-side. Therefore the exponent of Kähler function at its maximum associated to a given polynomial should be apart from a constant numerical factor equal to the discriminant D in canonical identification.

   The condition that the exponent of Kähler function as a sum of the Kähler action and the volume term for the preferred extremal $X^4 \subset H$ equals to power of D apart from a proportionality factor, should fix the discrete number theoretical and p-adic coupling constant evolutions of Kähler coupling strength and length scale dependent cosmological constant proportional to inverse of a p-adic length scale squared. For Kähler action alone, the evolution is logarithmic in prime p since the function reduces to the logarithm of D.

$M^8 - H$ duality suggests that the exponent $exp(-K)$ of Kähler function has an M^8 counterpart with a purely number theoretic interpretation. The discriminant D of the polynomial P is the natural guess. For monic polynomials D is integer having ramified primes as factors.

There are two options for the correspondence between $exp(-K)$ at its maximum and D assuming that P is monic polynomial.

1. In the real topology, one would naturally have $exp(-K) = 1/D$. For monic polynomials with high degree, D becomes large so that $exp(-K)$ is large.

2. In a p-adic topology defined by p-adic prime p identified as a ramified prime of D, one would have naturally $exp(-K) = I(D)$, where one has $I(x) = \sum x_n p^n = \sum x_n p^{-n}$.

   If p is the largest ramified prime associated with D, this option gives the same result as the real option, which suggests a unique identification of the p-adic prime p for a given polynomial P. P would correspond to a unique p-adic length scale L_p and a given L_p would correspond to all polynomials P for which the largest ramified prime is p.

   This might provide some understanding concerning the p-adic length scale hypothesis stating that p-adic primes tend to be near powers of integer. In particular, understanding about why Mersenne primes are favored might emerge. For instance, Mersennes could correspond to primes for which the number of polynomials having them as the largest ramified prime is especially large. The quantization condition $exp(-K) = D(p)$ could define which p-adic primes are the fittest ones.

The condition that $exp(-K)$ at its maximum equals to D via canonical identification gives a powerful number theoretic quantization condition.

Space-time surfaces as images of associative surfaces in M^8

$M^8 - H$ duality would provide an explicit construction of space-time surfaces as algebraic surfaces with an associative normal space [L114, L115]. M^8 picture codes space-time surface by a real polynomial with rational coefficients. One cannot exclude coefficients in an extension of rationals and also analytic functions with rational or algebraic coefficients can be considered as well as polynomials of infinite degree obtained by repeated iteration giving rise algebraic numbers as extension and continuum or roots as limits of roots.

$M^8 - H$ duality maps these solutions to H and one can consider several forms of this map. The weak form of the duality relies on holography mapping only 3-D or even 2-D data to H and the strongest form maps entire space-time surfaces to H. The twistor lift of TGD allows to identify the space-time surfaces in H as base spaces of 6-D surfaces representing the twistor space of space-time surface as an S^2 bundle in the product of twistor spaces of M^4 and CP_2. These twistor spaces must have Kähler structure and only the twistor spaces of M^4 and CP_2 have it [A21] so that TGD is unique also mathematically.

An interesting question relates to the possibility that also 6-D commutative space-time surfaces could be allowed. The normal space of the space-time surface would be a commutative subspace of M^8_c and therefore 2-D. Commutative space-time would be a 6-D surface X^6 in M^8.

This raises the following question: Could the inverse image of the 6-D twistor-space of 4-D space-time surface X^4 so that X^6 would be M^8 analog of twistor lift? This requires that $X^6 \subset M^8_c$ has the structure of an S^2 bundle and there exists a bundle projection $X^6 \rightarrow X^4$.

The normal space of an associative space-time surface actually contains this kind of commutative normal space! Its existence guarantees that the normal space of X^4 corresponds to a point of CP_2. Could one obtain the M^8_c analog of the twistor space and the bundle bundle projection $X^6 \rightarrow X^4$ just by dropping the condition of associativity. Space-time surface would be a 4-surface obtained by adding the associativity condition.

One can go even further and consider 7-D surfaces of M^8 with real and therefore well-ordered normal space. This would suggest dimensional hierarchy: $7 \rightarrow 6 \rightarrow 4$.

This leads to a possible interpretation of twistor lift of TGD at the level of M^8 and also about generalization of $M^8 - H$ correspondence to the level of twistor lift. Also the generalization of twistor space to a 7-D space is suggestive. The following arguments representa vision about "how it must be" that emerged during the writing of this article and there are a lot of details to be checked.

Commutative 6-surfaces and twistorial generalization of $M^8 - H$ correspondence

One can generalize the notion of complex 4-surface $X^6_c \subset M^8_c$ to that of complex 6-surface $X^6_c \subset M^8$ with a complexified commutative normal space. The 6-surface would correspond to a surface obtained by a local $SU(3)$ element invariant under $U(1) \times U(1) \subset SU(2)$. In complete analogy with 4-D case, these 6-surfaces would contain 5-D mass shells determined by the roots of P. The space $F = SU(3)/U(1) \times U(1)$ of points is nothing but the twistor space of CP_2!

The deformed M^6 defining $X^6 \subset M^8$ regarded as surface in M^8 suggests an interpretation as an analog of 6-D twistor space of M^4. Maybe one could identify the M^6 as the projective space $C^4/C_\times$ obtained from C^4 by dividing with complex scalings? This would give the twistor space $CP_3 = SU(4)/U(3)$ of M^4. This is not obvious since one has (complexified) octonions rather than C^4 or its hypercomplex analog. This would be analogous to using several (4) coordinate charts glued together as in the case of sphere CP_1.

The map $M^6 \to F$ obtained in this manner would define mapping of the twistor spaces of M^4 and CP_2 to each other. The twistor lift of TGD indeed defines this kind of map. The twistor lift involves the additional assumption that the S^2 fibers of these twistor spaces correspond to each other isometrically. This could correspond to a choice of Hamilton-Jacobi structure defining a local decomposition of $M^6 = M^2 \oplus E^4$ such that M^2 defines the analog of the Riemann sphere for M^6.

It might be also possible to identify the octonionic analog of the projective space $CP_3 = C^4/C_\times$. Could the octonionic M^8 momenta be scaled down by dividing with the momentum projection in the commutative normal space so that one obtains an analog of projective space? Could one use these as coordinates for M^6? The scaled 8-momenta would correspond to the points of the octonionic analog of CP_3. The scaled down 8-D mass squared would have a constant value.

A possible problem is that one must divide either from left or right and results are different in the general case. Could one require that the physical states are invariant under the automorphisms generated $o \to gog^{-1}$, where g is an element of the commutative subalgebra in question?

Physical interpretation of the counterparts of twistors at the level of M^8_c

What about the physical interpretation at the level of M^8_c. The twistor space allows a geometrization of spin so that momentum and spin would combine to a purely geometric entity with 6 components. The active points would correspond to fermions (quarks) with a given momentum and spin.

1. The first thing to notice is that in the twistor Grassmannian approach twistor space provides an elegant description of spin. Partial waves in the fiber S^2 of twistor space representation of spin as a partial wave. All spin values allow a unified treatment.

   The problem is that this requires massless particles. In the TGD framework 4-D masslessness is replaced with its 8-D variant so that this difficulty is circumvented. This kind of description in terms of partial waves is expected to have a counterpart at the level of the twistor space $T(M(^4) \times T(CP_2)$. At level of M^8 the description is expected to be in terms of discrete points of M^8_c.

2. Consider first the real part of $X^6_c \subset M^8_c$. At the level of M^8 the points of X^4 correspond to points. The same must be true also at the level of X^6. Single point in the fiber space S^2 would be selected. The interpretation could be in terms of the selection of the spin quantization axis.

   Spin quantization axis corresponds to 2 diametrically opposite points of S^2. Could the choice of the point also fix the spin direction? There would be two spin directions and in the general case of a massive particle they must correspond to the values $S_z = \pm 1/2$ of fermion spin. For massless particles in the 4-D sense two helicities are possible and higher spins cannot be excluded. The allowance of only spin 1/2 particles conforms with the idea that all elementary particles are constructed from quarks and antiquarks. Fermionic statistics would mean that for fixed momentum one or both of the diametrically opposite points of S^2 defining the same and therefore unique spin quantization axis can be populated by quarks having opposite spins.

3. For the 6-D tangent space of X^6_c or rather, its real projection, an analogous argument applies. The tangent space would be parametrized by a point of $T(CP_2)$ and mapped to this point. The selection of a point in the fiber S^2 of $T(CP_2)$ would correspond to the choice of the

quantization axis of electroweak spin and diametrically opposite points would correspond to opposite values of electroweak spin 1/2 and unique quantization axis allows only single point or pair of diametrically opposite points to be populated.

Spin 1/2 property would hold true for both ordinary and electroweak spins and this conforms with the properties of $M^4 \times CP_2$ spinors.

4. The points of $X^6_c \subset M^8_c$ would represent geometrically the modes of H-spinor fields with fixed momentum. What about the orbital degrees of freedom associated with CP_2?

   M^4 momenta represent orbital degrees of M^4 spinors so that E^4 parts of E^8 momenta should represent the CP_2 momenta. The eigenvalue of CP_2 Laplacian defining mass squared eigenvalue in H should correspond to the mass squared value in E^4 and to the square of the radius of sphere $S^3 \subset E^4$.

   This would be a concrete realization for the $SO(4) = SU(2)_L \times SU(2)_R \leftrightarrow SU(3)$ duality between hadronic and quark descriptions of strong interaction physics. Proton as skyrmion would correspond to a map S^3 with radius identified as proton mass. The skyrmion picture would generalize to the level of quarks and also to the level of bound states of quarks allowed by the number theoretical hierarchy with Galois confinement. This also includes bosons as Galois confined many quark states.

5. The bound states with higher spin formed by Galois confinement should have the same quantization axis in order that one can say that the spin in the direction of the quantization axis is well-defined. This freezes the S^2 degrees of freedom for the quarks of the composite.

What does the map of the twistor space $T(M^4)$ to $T(CP_2)$ mean physically? Does spin correspond to color isospin or electroweak spin? Color $U(2)$ corresponds to electroweak $U(2)$ as the holonomy group of CP_2 as symmetric space so that the latter option is possible.

Quarks are doublets with respect to spin and electroweak spin but color triplet contains also isospin singlet. This is not a problem since color is not a spin-like quantum number in TGD but corresponds to color partial waves. This leaves spin-ew spin correspondence realized for quarks. Does the map between spin and electroweak degrees of freedom allow all pairings of spin and electroweak isospin doublets? The map between the spheres S^2 is determined only modulo relative rotation so that this might be the case for spin and color isospin. For composites of quarks obtained as Galois singlets, the relation between spin and ew spin could be more complex.

7-surfaces with real normal space and generalization of the notion of twistor space

The next step is to ask whether it makes sense to consider 7-surfaces with a real normal space allowing well-ordering? This would give a hierarchy of surfaces of M^8 with dimensions 7, 6, and 4. The 7-D space would have bundle projection to 6-D space having bundle projection to 4-D space.

One can also consider the complex 7-D surfaces with a complexified normal space for which the real projection is well-ordered so that the hierarchy of number fields would be realized. These surfaces would be realized by local elements of $SU(3)$ invariant under $U(1) \subset SU(3)$ and would define maps to $SU(3)/U(1)$ defining a generalization of twistor space. Now 6-D complex mass shells would take the role of 3-D complex mass shells and would correspond to the roots of P-

For the 7-D surface also the 7:th component of H- momentum should have some physical interpretation. Fermi statistics at the level of M^8 could be expressed purely geometrically: a single point of X^7 can contain only a single fermion (quark).

What could be the physical interpretation of 7-D surfaces of M^8 with real normal space in the octonionic sense and of their H images?

1. The first guess is that the images in H correspond to 7-D surfaces as generalizations of 6-D twistor space in the product of similar 7-D generalization of twistor spaces of M^4 and CP_2. One would have a bundle projection to the twistor space and to the 4-D space-time.

2. $SU(3)/U(1) \times U(1)$ is the twistor space of CP_2. $SU(3)/SU(2) \times U(1)$ is the twistor space of M^4? Could 7-D $SU(3)/U(1)$ *resp.* $SU(4)/SU(3)$ correspond to a generalization of the twistor spaces of M^4 *resp.* CP_2? What could be the interpretation of the fiber added to the twistor spaces of M^4, CP_2 and X^4? S^3 isomorphic to $SU(2)$ and having $SO(4)$ as isometries is the obvious candidate.

3. The analog of $M^8 - H$ duality in Minkowskian sector in this case could be to use coordinates for M^7 obtained by dividing M^8 coordinates by the real part of the octonion. Is it possible to identify $RP_7 = M^8/R_\times$ with $SU(4)/SU(3)$ or at least relate these spaces in a natural manner. It should be easy to answer these questions with some knowhow in practical topology.

   A possible source of problems or of understanding is the presence of a commuting imaginary unit implying that complexification is involved in Minkowskian degrees of freedom whereas in CP_2 degrees of freedom it has no effect. RP_7 is complexified to CP_7 and the octonionic analog of CP_3 is replaced with its complexification.

What could be the physical interpretation of the extended 7-D twistor space?

1. Twistorialization takes care of spin and electroweak spin and correlates them for quarks. The remaining standard model quantum numbers are Kähler and Kähler magnetic charges for M^4 and CP_2. Could the additional dimension allow a geometrization of these quantum numbers in terms of partial waves in the 3-D fiber? The example with the twistorialization suggests that the M^4 and CP_2 Kähler charges are identical apart from the sign.

2. The first thing to notice is that it is not possible to speak about the choice of quantization axis for $U(1)$ charge. It is however possible to generalize the momentum space picture also to the 7-D branes X^7 of M^8 with real normal space and select only discrete points of cognitive representation carrying quarks. The coordinate of 7-D generalized momentum in the 1-D fiber would correspond to some charge interpreted as a $U(1)$ momentum in the fiber of 7-D generalization of the twistor space.

3. One can start from the level of the 7-D surface with a real normal space. For both M^4 and CP_2, a plausible guess for the identification of 3-D fiber space is as 3-sphere S^3 having Hopf fibration $S^3 \rightarrow S^2$ with $U(1)$ as a fiber.

   At H side one would have a wave $exp(iQ\phi/2\pi)$ in $U(1)$ with charge Q and at M^8 side a point of X^7 representing Q as 7:th component of 7-D momentum.

   Note that for X^6 as a counterpart of twistor space the 5:th and 6:th components of the generalized momentum would represent spin quantization axis and sign of quark spin as a point of S^2. Even the length of angular momentum might allow this kind representation.

4. Since both M^4 and CP_2 allow induced Kähler field, a possible identification of Q would be as a Kähler magnetic charge. These charges are not conserved but in ZEO the non-conservation allows a description in terms of different values of the magnetic charge at opposite halfs of the light-cone of M^8 or CD.

   Instanton number representing a change of magnetic charge would not be a charge in strict sense and drops from consideration.

One expects that the action in the 7-D situation is analogous to Chern-Simons action associated with 8-D Kahler action, perhaps identifiable as a complexified 4-D Kähler action.

1. At M^4 side, the 7-D bundle would be $SU(4)/SU(3) \rightarrow SU(4)/SU(3) \times U(1)$. At CP_2 side the bundle would be $SU(3)/U(1) \rightarrow SU(3)/U(1) \times U(1)$.

2. For the induced bundle as 7-D surface in the $SU(4)/SU(3) \times SU(3)/U(1)$, the two $U(1)$:s are identified. This would correspond to an identification $\phi(M^4) = \phi(CP_2)$ but also a more general correspondence $\phi(M^4) = (n/m)\phi(CP_2)$ can be considered. m/n can be seen as a fractional $U(1)$ winding number or as a pair of winding numbers characterizing a closed curve on torus.

3. At M^8 level, one would have Kähler magnetic charges $Q_K(M^4)$, $Q_K(CP_2)$ represented associated with $U(1)$ waves at twistor space level and as points of X^7 at M^8 level involving quark. The same wave would represent both M^4 and CP_2 waves that would correlate the values of Kähler magnetic charges by $Q_{K,m}(M^4)/Q_{K,m}(CP_2) = m/n$ if both are non-vanishing. The value of the ratio m/n affects the dynamics of the 4-surfaces in M^8 and via twistor lift the space-time surfaces in H.

How could the Grassmannians of standard twistor approach emerge number theoretically?

One can identify the TGD counterparts for various Grassmann manifolds appearing in the standard twistor approach.

Consider first, the various Grassmannians involved with the standard twistor approach (`https://cutt.ly/XE3vDKj`) can be regarded as flag-manifolds of 4-complex dimensional space T.

1. Projective space is FP_{n-1} the Grasmannian $F_1(F^n)$ formed by the k-D planes of V^n where F corresponds to the field of real, complex or quaternionic numbers, are the simplest spaces of this kind. The F-dimension is $d_F = n-1$. In the complex case, this space can be identified as $U(n)/U(n-1) \times U(1) = CP_{n-1}$.
2. More general flag manifolds carry at each point a flag, which carries a flag which carries ... so that one has a hierarchy of flag dimensions $d_0 = 0 < d_1 < d_2 ... d_k = n$. Defining integers $n_i = d_i - d_{i-1}$, this space can in the complex case be expressed as $U(n)/U(n_1) \times .....U(n_k)$. The real dimension of this space is $d_R = n^2 - \sum_i n_i^2$.
3. For $n = 4$ and $F = C$, one has the following important Grassmannians.
   (a) The twistor space CP_3 is projective is of complex planes in $T = C^4$ and given by $CP_3 = U(4)/U(3) \times U(1)$ and has real dimension $d_R = 6$.
   (b) $M = F_2$ as the space of complex 2-flags corresponds to $U(4)/U(2) \times U(2)$ and has $d_R = 16 - 8 = 8$. This space is identified as a complexified Minkowski space with $D_C = 4$.
   (c) The space $F_{1,2}$ consisting of 2-D complex flags carrying 1-D complex flags has representation $U(4)/U(2) \times U(1) \times U(1)$ and has dimension $D_R = 10$.
   $F_{1,2}$ has natural projection ν to the twistor space CP_3 resulting from the symmetry breaking $U(3) \to U(2) \times U(1)$ when one assigns to 2-flag a 1-flag defining a preferred direction. $F_{1,2}$ also has a natural projection μ to the complexified and compactified Minkowski space $M = F_2$ resulting in the similar manner and is assignable to the symmetry breaking $U(2) \times U(2) \to U(1) \times U(1)$ caused by the selection of 1-flag.
   These projections give rise to two correspondences known as Penrose transform. The correspondence $\mu \circ \nu_{-1}$ assigns to a point of twistor space CP_3 a point of complexified Minkowski space. The correspondence $\nu \circ \mu_{-1}$ assigns to the point of complexified Minkowski space a point of twistor space CP_3. These maps are obviously not unique without further conditions.

This picture generalizes to TGD and actually generalizes so that also the real Minkowski space is obtained naturally. Also the complexified Minkowski space has a natural interpretation in terms of extensions of rationals forcing complex algebraic integers as momenta. Galois confinement would guarantee that physical states as bound states have real momenta.

1. The basic space is $Q_c = Q^2$ identifiable as a complexified Minkowski space. The idea is that number theoretically preferred flags correspond to fields R, C, Q with real dimensions 1,2,4. One can interpret Q_c as Q^2 and Q as C^2 corresponding to the decomposition of quaternion to 2 complex numbers. C in turn decomposes to $R \times R$.
2. The interpretation $C^2 = C^4$ gives the above described standard spaces. Note that the complexified and compactified Minkowski space is not same as $Q_c = Q^2$ and it seems that in TGD framework Q_c is more natural and the quark momenta in M_c^4 indeed are complex numbers as algebraic integers of the extension.

Number theoretic hierarchy $R \to C \to Q$ brings in some new elements.

1. It is natural to define also the quaternionic projective space $Q_c/Q = Q^2/Q$ `https://cutt.ly/LE3vMOG`, which corresponds to real Minkowski space. By non-commutativity this space has two variants corresponding to left and right division by quaternionic scales factor. A natural condition is that the physical states are invariant under automorphisms $q \to hqh^{-1}$ and depend only on the class of the group element. For the rotation group this space is characterized by the direction of the rotation axis and by the rotation angle around it and is therefore 2-D.

This space is projective space QP_1, quaternionic analog of Riemann sphere CP_1 and also the quaternionic analog of twistor space CP_3 as projective space. Therefore the analog of real Minkowski space emerges naturally in this framework. More generally, quaternionic projective spaces Q^n have dimension $d = 4n$ and are representable as coset spaces of symplectic groups defining the analogs of unitary/orthogonal groups for quaternions as $Sp(n+1)/Sp(n) \times Sp(1)$ as one can guess on basis of complex and real cases. M^4_R would therefore correspond to $Sp(2)/Sp(1) \times SP(1)$.

QP_1 is homeomorphic to 4-sphere S^4 appearing in the construction of instanton solutions in E^4 effectively compactified to S^4 by the boundary conditions at infinity. For Minkowski signature it would be replaced by 4-D hyperboloid $H^4 = SO(1,4)/SO(3)$ known also as anti-de Sitter space AdS(4,1) (`https://cutt.ly/RRuXIBS`). An interesting question is whether the self-dual Kähler forms in E^4 could give rise to M^4 Kähler structure and could correspond to this kind of self-dual instantons and therefore what I have called H-J structures.

2. The complex flags can also contain real flags. For the counterparts of twistor spaces this means the replacement of $U(1)$ with a trivial group in the decompositions.

   The twistor space CP_3 would be replaced $U(4)/U(3)$ and has real dimension $d_R = 7$. It has a natural projection to CP_3. The space $F_{1,2}$ is replaced with representation $U(4)/U(2)$ and has dimension $D_R = 12$.

To sum up, the Grassmannians associated with M^4 as 6-D twistor space and its 7-D extension correspond to a complexification by a commutative imaginary unit i - that is "vertical direction". The Grassmannians associated with CP_2 correspond to "horizontal ", octonionic directions and to associative, commutative and well-ordered normal spaces of the space-time surface and its 6-D and 7-D extensions. Geometrization of the basic quantum states/numbers - not only momentum - representing them as points of these spaces is in question.

How could the quark content of the physical state determine the geometry of the space-time surface?

In the standard quantum field theory, fermionic currents serve as sources of the gauge fields. This correlation must have a counterpart in the TGD framework. Somehow the selection of the active points of the cognitive representation containing quarks must determine the 4-surface of M^8 determined by a polynomial P with rational coefficients. $M8-H$ duality would in turn determine the space-time surface.

This requirement gives a motivation for the earlier assumption that the roots of P defining 6-D surfaces fix P. Two kinds of surfaces appear.

1. The special $E = E_n$ roots of P having interpretation as energy have 3-D hyperplanes as M^4 intersections that I have misleadingly called "special moments in the life of self".

   The proposal [L114, L115] was that quarks are associated with the 2-D intersections of 4-D space-time surfaces with these planes. At the level of H, these 2-D intersections were assigned to partonic 2-surfaces serving as vertices of topological Feynman diagrams represented as space-time surfaces. Knowledge of the values of energy E_n defining 3-D complex planes at which the quarks of the quantum state are located in momentum space fixes the minimal polynomial P and therefore also space-time surface.

2. Besides energy hyper-planes there are also complex mass hyperboloids. The general 4-D solution of co-associativity conditions is 4-D (in real sense) intersection of two complex mass shells with mass squared $m^2_{c,odd}$ *resp.* $m^2_{c,even}$ with complex mass squared equal to a root of the odd *resp.* even part of the polynomial P defining the 4-surface [L114]. The real projection of the 4-D intersection is 2-D and might have interpretation as counterpart of a partonic 2-surface.

   This complex surface has complex dimension 4 and 4-D real projection in the sense that the number theoretic quadratic form is real. The 6-surface defined by the root reduces to a 3-D real mass shell if the imaginary part of m^2_c can vanishes: this is possible for real roots only. The 4-D intersection of these complex mass shells provide natural seats for the quark momenta as algebraic integers, which in general are complex. This data can fix the roots of the imaginary part of P as complex mass squared values.

3. Interestingly, also 6-D surfaces having these 4-surfaces as sub-manifolds emerge. A good guess is that these are just the surfaces with commutative normal space and serve as M^8 counterparts of twistor space.

How to understand leptons as bound states of 3 quarks?

A benchmark test for the view about the twistorial aspects of M^8 is the challenge of describing leptons as bound states of 3 quarks assignable to single wormhole contact, single throat, or even single point. The assumption that wormhole contacts correspond to blow-ups of line singularities in M^8 containing quarks favors the strongest option.

1. At the level of H , quarks with different colors (color partial waves in CP_2) could have exactly the same M^4 location inside a single wormhole throat but different CP_2 locations to realize statics. Color can be realized as H partial waves and this would require that the oscillator operators act at the level of M^8 allowing to put several oscillators at a single M^4 point at the level of H.
2. At the level of M^8 the Fermi statistics would state that only a single quark corresponds to a given point. If one works at the level of 4-surface so that only momentum is taken into account, this is not possible. Could the 3 quarks be at different points in the 7-D extension of the twistor space bringing in quark spin and Kähler magnetic charge?

   The total spin of lepton is 1/2 so that two spins are opposite. Kähler magnetic charges of quarks are proposed to be proportional to color hypercharge (2,-1,-1) for quarks to realize Fermi statistics topologically. The points (p,1/2,-1),(p,1/2,-1) and (p,-1/2,2) and the states obtained by permuting Kähler charges would allow arealization of lepton as a 3 quark state with identical momenta.

16.4.4 Hierarchies of extensions for rationals and of inclusions of hyperfinite factors

TGD suggests 3 different views of finite measurement resolution.

1. At the space-time level, finite measurement resolution is realized in terms of cognitive representations at the level of M^8 actualized in terms of fermionic momenta with momentum components identifiable as algebraic integers. Galois group has natural action on the momentum components.
2. The inclusion $N \subset M$ of group algebras of Galois groups is proposed to realize finite measurement resolution for which the number theoretic counterpart is Galois singlet property of N with respect to the Galois group of M relative to N identifiable as the coset group of Galois groups of M and N. If the origin serves as a root of all polynomials considered, the composite $P \circ Q$ inherits the roots of Q.

   The idea generalizes to infinite-D Galois groups [L134, L129]. The HFF in question would be infinite-D group algebra of infinite Galois group for a polynomial R obtained as a composite $R = P_{infty} \circ Q$ of an infinite iterate P_{infty} of polynomial P and of some polynomial Q of finite degree (inverse limit construction). The roots of R at the limit correspond to the attractor basin associated with P_∞, which is bounded by the Julia set so that a connection with fractals emerges.
3. The inclusions $N \subset M$ of hyperfinite factors of type II_1 (HFFs) [K121, K44] is a natural candidate for the representation of finite measurement resolution. N would represent the degrees of freedom below measurement resolution mathematically very similar to gauge degrees of freedom except that gauge algebra would be replaced with the super-symplectic algebra and analogs of Kac Moody algebra with non-negative conformal weights and gauge conditions would apply to sub-algebra with conformal weights larger than the weight h_{max} defining the measurement resolution.

For HFFs, the index $[M : N]$ of the inclusion defines the quantum dimension $d(N \subset M) \leq 1$ as a quantum trace of the projector $P(M \rightarrow N)$ (the identify operator of M has quantum trace equal to one). $d(N \subset M)$ is defined in terms of quantum phase q and serves as a dimension for the analog of factor space M/N representing the system with N regarded as degrees of freedom below the measurement resolution and integrated out in "quantum algebra" M/N. Quantum groups and quantum spaces are closely related notions [K121, K44].

Galois confinement would suggest that $N \subset M$ corresponds to the algebra creating Galois singlets with respect to the Galois group of N relative to M whereas M includes also operators which are not this kind of singlets. In the above example $R = P \circ Q$, the Galois group of P would be represented trivially and the Galois group of Q or its subgroup would act non-trivially. In the case of hadrons, color degrees of freedom perhaps assignable to the Galois group Z^3 in the case of quarks would correspond to the degrees of freedom below the measurement resolution.

The universality of the quantum dimension and its expressibility in terms of quantum phase suggests that the integer m in $q = rxp(i2\pi/m)$ is closely related to the dimension for the extension of rationals $n = h_{eff}/h_0$ and depends therefore only very weakly on the details of the extension. The simplest guess is $m = n$. This conforms with the concrete interpretation of charge fractionation as being due to the many-valuedness of the graphs of space-time surfaces as maps from $M^4 \rightarrow CP_2$ or vice versa.

16.4.5 Galois confinement

The notion of Galois confinement emerged in TGD inspired biology [L194, L121, L129, L137]. Galois group for the extension of rationals determined by the polynomial defining the space-time surface $X^4 \subset M^8$ acts as a number theoretical symmetry group and therefore also as a physical symmetry group.

1. The idea that physical states are Galois singlets transforming trivially under the Galois group emerged first in quantum biology. TGD suggests that ordinary genetic code is accompanied by dark realizations at the level of magnetic body (MB) realized in terms of dark proton triplets at flux tubes parallel to DNA strands and as dark photon triplets ideal for communication and control [L121, L137, L135]. Galois confinement is analogous to color confinement and would guarantee that dark codons and even genes, and gene pairs of the DNA double strand behave as quantum coherent units.
2. The idea generalizes also to nuclear physics and suggests an interpretation for the findings claimed by Eric Reiter [L148] in terms of dark N-gamma rays analogous to BECs and forming Galois singlets. They would be emitted by N-nuclei - also Galois singlets - quantum coherently [L148]. Note that the findings of Reiter are not taken seriously because he makes certain unrealistic claims concerning quantum theory.

Galois confinement as a number theoretically universal manner to form bound states?

It seems that Galois confinement might define a notion much more general than thought originally. To understand what is involved, it is best to proceed by making questions.

1. Why not also hadrons could be Galois singlets so that the somewhat mysterious color confinement would reduce to Galois confinement? This would require the reduction of the color group to its discrete subgroup acting as Galois group in cognitive representations. Could also nuclei be regarded as Galois confined states? I have indeed proposed that the protons of dark proton triplets are connected by color bonds [L103, L117, L54].
2. Could all bound states be Galois singlets? The formation of bound states is a poorly understood phenomenon in QFTs. Could number theoretical physics provide a universal mechanism for the formation of bound states. The elegance of this notion is that it makes the notion of bound state number theoretically universal, making sense also in the p-adic sectors of the adele.
3. Which symmetry groups could/should reduce to their discrete counterparts? TGD differs from standard in that Poincare symmetries and color symmetries are isometries of H and their action inside the space-time surface is not well-defined. At the level of M^8 octonionic automorphism group G_2 containing as its subgroup $SU(3)$ and quaternionic automorphism group $SO(3)$ acts in this way. Also super-symplectic transformations of $\delta M^4_{\pm} \times CP_2$ act at the level of H. In contrast to this, weak gauge transformations acting as holonomies act in the tangent space of H.

One can argue that the symmetries of H and even of WCW should/could have a reduction to a discrete subgroup acting at the level of X^4. The natural guess is that the group in question is Galois group acting on cognitive representation consisting of points (momenta) of M_c^8 with coordinates, which are algebraic integers for the extension.

Momenta as points of M_c^8 would provide the fundamental representation of the Galois group. Galois singlet property would state that the sum of (in general complex) momenta is a rational integer invariant under Galois group. If it is a more general rational number, one would have fractionation of momentum and more generally charge fractionation. Hadrons, nuclei, atoms, molecules, Cooper pairs, etc.. would consist of particles with momenta, whose components are algebraic, possibly complex, integers.

Also other quantum numbers, in particular color, would correspond to representations of the Galois group. In the case of angular moment Galois confinement would allow algebraic half-integer valued angular momenta summing up to the usual half-odd integer valued spin.

4. Why Galois confinement would be needed? For particles in a box of size L the momenta are integer valued as multiples of the basic unit $p_0 = \hbar n \times 2\pi/L$. Group transformations for the Cartan group are typically represented as exponential factors which must be roots of unity for discrete groups. For rational valued momenta this fixes the allowed values of group parameters. In the case of plane waves, momentum quantization is implied by periodic boundary conditions.

   For algebraic integers the conditions satisfied by rational momenta in general fail. Galois confinement for the momenta would however guarantee that they are integer valued and boundary conditions can be satisfied for the bound states.

Explicit conditions for Galois confinement

It is interesting to look more explicitly at the conditions for the Galois confinement.

Single quark states have momenta, which are algebraic integers generated by so called integral basis (`https://cutt.ly/SRuZySX`) spanning algebraic integers as a lattice and analogous to unit vectors of momentum lattice but for single component of momentum as a vector in extension. There is also a theorem stating that one can form the basis of extension as powers of a single root. It is also known that irreducible monic polynomials have algebraic integers as roots.

1. In its minimal form Galois confinement states that only momenta, which are rational integers are allowed by Galois confinement. Note that for irreducible polynomials with rational coefficients one does not obtain any rational roots. Monic polynomials with integer coefficients can allow integer roots. If one assumes that single particle states can have arbitrary algebraic integer as momentum, one obtain also rational integers for momentum values. These states are not at mass - or energy shell associated with the single particle momenta.
2. A stronger condition would be that also the inner products of the momenta involved are real so that one has $Re(p_i) \cdot Im(p_j) = 0$. For $i = j$ this gives a condition is possible only for the real roots for the real polynomials defining the space-time surface.

To see that real roots are necessary, some facts about the realization of the co-associativity condition [L114] are necessary.

1. The expectation is that that the vanishing condition for the real part (in quaternionic sense) of the octonionic polynomial gives a co-associative surface. By the Lorentz symmetry one actually obtains as a solution a 6-D complex mass shell $m_c^2 \equiv m_{Re}^2 - m_{Im}^2 + 2iRe(p) \cdot Im(p) = r_1$, where the real and imaginary masses are defined are $m_{Re}^2 = Re(p)^2$ and $m_{Im}^2 = Im(p)^2$ and r_1 is some root for the odd part of the polynomial P assumed to determining the 4-surface.
2. This surface can be co-associative but would be also co-commutive. Maximally co-associative surface requires quaternionic normal space. The first proposal is that the space-time surface is the intersection of the surface defined by the polynomial and its conjugate with respect to i. This gives 4-D surface as the intersection of the two 6-D surfaces.

   Second proposal is that the 6-surface having a structure of S^2 bundle defines as its base space quaternionic 4-surface. This space would correspond to a gauge choices selecting point of S^2 at very point of M^4. To a given polynomial one could assign entire family of 4-surfaces mapped to different space-time surfaces in H. A possible interpretation of gauge group would be as quaternionic automorphisms acting on the 2-sphere.

These proposals are equivalent if the base base is the intersection of the 6-D bundle spaces. One could say that the fibers are conjugates of each other. This might be relevant for ZEO.

Concerning Galois confinement, the basic result is that for complex roots r_1 the conditions $Re(p_i) \cdot Im(p_i) = 0$ cannot be satisfied unless one requires that r_1 is real. Therefore the stronger option makes sense for real roots only.

1. Galois confinement allows the momenta p_i forming the bound state to be in an extension of rationals defined by the polynomial defining the space-time surface. Galois confinement condition states that the total momentum is rational integer when a suitable unit defined by the size of CD is used (periodic boundary conditions).

2. Another natural condition is the vanishing of the inner products between the real part $Re(p)$ and imaginary part $Im(p)$ of p. This guarantees that the number theoretical norm squared for the momentum is real. For time-like p, this means that $Im(p)$ belongs to the 3-D orthogonal complement E^3 of $Re(p)$. For light-like p, $Im(p)$ belongs to 2-D orthogonal complement E^2.

3. Suppose one has several number theoretic momenta p_i such that $\sum p_i = p$ is rational integer and $p_i \propto p$ holds true. Also in this case, the number theoretic inner products must be real. The orthogonality conditions read as

$$Re(p_i) \cdot Im(p_j) = 0 \ . \tag{16.4.2}$$

   For a given pair (i, j), one has several conditions corresponding to algebraically independent imaginary momentum components and it is quite possible that very few solutions exist besides $Im(p_i) = 0$. If $Re(p_i)$ is not a rational integer, the number of conditions still increases.

4. The proposal for Galois confinement is that the real parts of p_i are parallel or even identical: $Re(p_i) \propto Re(\sum p_i) = p$, which is a rational integer. In this case the conditions reduce to $Re(p) \cdot Im(p_i) = 0$ and their number is much smaller.

5. For a given momentum component, the basis $p_{i,k}$ has the dimension n of extension. The basis contains m complex elements e_k and their conjugates $\overline{e}_k$ plus $n - 2m - 1$ real but algebraically trivial elements r_k besides the real unit 1. The sums $E_k = e_k + \overline{e}_k$ are algebraic integers and give m real basis elements. Note that $F_k = e_k - \overline{e}_k$ are purely imaginary algebraic integers.

   r_k and E_i give $n-m-1$ algebraically non-trivial real momenta. The momentum components $p_{i,k}$ formed as linear combinations of r_k, E_i, and 1 are real. This gives $n - m$-dimensional real subspace and momenta formed in this way satisfy the reality conditions for the inner products.

6. One can also construct complex momenta such that $Im(p_i)$ is a linear combination $Im(p_i) = \sum n_{i,k} F_k$. If $Re(p_i)$ are parallel and rational integers and $p_i \propto p$ holds true, the reality conditions reduce to

$$p \cdot Im(p_i) = \sum_k p^i n_{i,k} F_k = 0 \ . \tag{16.4.3}$$

   One can construct a maximal set of complex momenta P_K characterized by matrices n_{ik}^K satisfying these conditions. Also linear combinations of P_K satisfy the reality conditions and one obtains a lattice of momenta.

This looks like nice construction but it seems that mere Galois confinement is more realistic.

16.4.6 M^8-H duality at the level of WCW

WCW emerges in the geometric view of quantum TGD. M^8-H duality should lso work for WCW. What is the number theoretic counterpart of WCW? What is the geometric counterpart of the discretization characteristic to the number theoretic approach?

In the number theoretic vision in which WCW is discretized by replacing space-time surfaces with their number theoretical discretizations determined by the points of $X^4 \subset M^8$ having the octonionic coordinates of M^8 in an extension of rationals and therefore making sense in all p-adic number fields? How could an effective discretization of the real WCW at the geometric H level, making computations easy in contrast to all expectations, take place?

1. The key observation is that any functional or path integral with integrand defined as exponent of action, can be *formally* calculated as an analog of Gaussian integral over the extrema of the action exponential $exp(S)$. The configuration space of fields would be effectively discretized. Unfortunately, this holds true only for the so called integrable quantum field theories and there are very few of them and they have huge symmetries. But could this happen for WCW integration thanks to the maximal symmetries of the WCW metric?

2. For the Kähler function K, its maxima (or maybe extrema) would define a natural effective discretization of the sector of WCW corresponding to a given polynomial P defining an extension of rationals.

   The discretization of the sector defined by P should be equivalent with the number theoretical discretization induced by the number theoretical discretization of space-time surfaces. Various p-adic physics and corresponding discretizations should emerge naturally from the real physics in WCW.

3. The physical interpretation is clear. The TGD Universe is analogous to the spin glass phase [?] The discretized WCW corresponds to the energy landscape of spin glass having an ultrametric topology. Ultrametric topology of WCW means that discretized WCW decomposes to p-adic sectors labelled by polynomials P. The ramified primes of P label various p-adic topologies associated with P.

16.4.7 Some questions and ideas related to M^8-H duality

In the following some questions and ideas, which do not quite fit under the titles of the previous sections, are considered.

A connection with Langlands program

Langlands correspondence [A27, K54, A15, A14], which I have tried to understand several times [K54] [L1, L17, L43] relates in an interesting manner to M^8-H duality and Galois confinement.

1. Global Langlands correspondence (GLC) states that there is connection between representations of continuous groups and Galois groups of extensions of rationals.
2. Local LC states (LLC) states this in the case of p-adics.

There is a nice interpretation for the two LCs in terms of sensory experience and cognition in TGD inspired theory of consciousness.

1. In adelic physics real numbers and p-adic number fields define the adele. Sensory experience corresponds to reals and cognition to p-adics. Cognitive representations are in their discrete intersection and for extensions of rationals belonging to the intersection.
   (a) Sensory world, "real" world corresponds to representation of continuous groups/Galois groups of rationals. GLC.
   (b) "p-Adic" worlds correspond to cognition and representations of p-adic variants of continuous groups and Galois groups over p-adics. Local LLC.
   (c) One could perhaps talk also about Adelic LC: ALC in the TGD framework. Adelic representations would combine real and p-adic representations for all primes and give as complete information about reality as possible.

TGD provides a geometrization for the identification of Galois groups as discrete subgroups of Lie groups, not only of the isometry (automorphism) groups of H (M^8) but perhaps also as discrete sub-groups of more general Lie groups to which the action of super-symplectic representations could reduce. A naive guess is that these groups correspond to the ADE groups appearing in the McKay correspondence [L55, L108, L109].

The representation of real continuous groups assignable to the real numbers as a piece of adele [L64, L63] would be related to the representations of Galois groups GLC. Also p-adic representations of groups are needed to describe cognition and these p-adic group representations and representations of p-adic Galois groups would be related by LLC.

Could the notion of emergence of space-time have some analog in the TGD Universe?

The idea about the emergence of space-time from entanglement is as such not relevant for TGD. One can however ask whath the emergence of *observed* space-time could mean in TGD. Space-time surface as a continuum exists in TGD but they are not directly observable due to a finite measurement resolution. One can ask what a body with an outer boundary means physically. The space-time regions defined by solid bodies have boundaries. What makes the boundaries of the bodies "hard"?

1. In momentum space Fermi statistics does not allow fermions to get through the boundary of Fermi ball. This is a good guideline.
2. Second feature of a spatial object such as an atom is that it is a bound state quantum mechanically. If it has parts they stay together. In QFT theory the notion of a bound state is however poorly understood.
3. Quantum coherence is a further property considered in the article. Spatial objects correspond to quantum coherent structures. Quantum coherence reduces to entanglement. Quantum coherence length and time determine the size of a quantum object. Somehow one must have stable entanglement in long scales.

Let us see what these guidelines could give in the framework of $M^8 - H$ duality which generalizes the wave particle duality of wave mechanics.

1. In adelic physics space-times can be seen as either surfaces in M^8 or $H = M^4 \times CP_2$. $X^4 \subset M^8$ is analogous to momentum space cognitive representations consist of points of $X^4 \subset M^8$, whose points are algebraic integers in the extension of rationals defined by the polynomial defining the space-time surface and are algebraic integers as roots of monic polynomials of form $x^n +$..... This defines a unique discretization of the space-time surface. The discretization guarantees number theoretical universality: the cognitive representation makes sense also p-adically and space-time has also p-adic variants.

   Cognitive representations give rise to "cognitive emergence" of the space-time in cognitive sense and since cognitive representations are intersection of reality and p-adicities they must closely related to the "sensory emergence"".
2. $X^4 \subset M^8$ is mapped to H by $M^8 - H$ duality determined by the condition that it momentum is mapped to a geodesic with a direction of momentum and starting from either tip of CD: the image point is its intersection with the opposite light-like boundary of CD and selects a point of space-time surface. The size of CD is $T = h_{eff}/m$ for quark with mass m to satisfy Uncertainty Principle. The map generalizes to bound states of quarks (whatever they are).

Consider the problem of "sensory emergence" in this framework.

1. What makes a point of a cognitive representation "hard"? Quarks are associated with points (not necessarily all) of a cognitive representation: one can say that the point is activated when there is a quark at it. Fermi ball corresponds to a discrete set of activated points at the level of momentum space. These points define activated points also in $X^4 \subset H$ by $M^8 - H$ duality. One could perhaps say that these activated points in M^8 and their H-image containing fermions define the spatial objects as something "hard" and having a boundary. Another fermion knows that there is a space-time point there because it cannot get to this point. The presence of a fermion (quark) would make a space-time point "hard".

2. What about the role of entanglement? The size and duration of the space-time surface (inside a causal diamond CD) defines quantum coherence length and time. Fermionic statistics makes fundamental fermions - to be distinguished from elementary fermions - maximally entangled. One cannot reduce fermionic entanglement in SFR and quantum measurements would be impossible. The entanglement in the WCW degrees of freedom comes to the rescue. This entanglement can be reduced in SFRs since the particles as surfaces are identical under very special - naturally number theoretical - conditions.

   Negentropy Maximization Principle and hierarchy of $h_{eff} = n \times h_0$ phases favor the generation of stable entanglement in the TGD Universe. Also, if the coefficients of the entanglement matrix belong to extension of rationals, entanglement probabilities in general belong to its extension and the density matrix is not diagonalizable without going to a larger extension. This might require "big" SFR increasing the extension: only after this state function reduction to an eigenstate could occur. This leads to a concrete proposal for how the information about the diagonal form of the density matrix expressed by its characteristic polynomial is coded into the geometry of the space-time surface [L129].

3. Bound state formation is third essential element. Momenta are points of the space-time surface $X^4 \subset M^8$ with components which are algebraic integers. Physical momenta are however ordinary integers for a particle in a finite volume defined by causal diamond (CD). This means that one can allow only composites of quarks with rational integer valued momenta which correspond to Galois singlets.

   Galois confinement would be the universal mechanism behind formation of all bound states and also give rise to stable entanglement. One would obtain a hierarchy of bound states corresponding to a hierarchy of polynomials and corresponding Galois groups and extensions of rationals. By $M^8 - H$ duality, bound states of quarks and higher structures formed from them in M^8 would give rise to spatial objects.

16.5 Zero energy ontology (ZEO)

ZEO [K125] forms the cornerstone of the TGD inspired quantum theory extending to a theory of consciousness. ZEO has so far reaching consequences that it would have deserved a separate section. Since it involves in an essential manner the notion of CD, it is natural to include it to the section discussing $M^8 - H$ duality.

16.5.1 The basic view about ZEO and causal diamonds

The following list those ideas and concepts behind ZEO that seem to be rather stable.

1. GCI for the geometry of WCW implies holography, Bohr orbitology and ZEO [L105] [K125].
2. X^3 is more or less equivalent with Bohr orbit/preferred extremal $X^4(X^3)$. Finite failure of determinism is however possible [L155]. Zero energy states are superpositions of $X^4(X^3)$. Quantum jump is consistent with causality of field equations.
3. Causal diamond (CD) defined as intersection of future and past directed light cones ($\times CP_2$) plays the role of quantization volume, and is not arbitrarily chosen. CD determines momentum scale and discretization unit for momentum (see **Fig. 18.2 Fig. 17.13**).
4. The opposite light-like boundaries of CD correspond for fermions dual vacuums (bra and ket) annihilated by fermion annihilation *resp.* creation operators. These vacuums are also time reversals of each other.

   The first guess is that zero energy states in fermionic degrees of freedom correspond to pairs of this kind of states located at the opposite boundaries of CD. This seems to be the correct view in H. At the M^8 level the natural identification is in terms of states localized at points inside light-cones with opposite time directions. The slicing would be by mass shells (hyperboloids) at the level of M^8 and by CDs with same center point at the level of H.
5. Zeno effect can be understood if the states at either cone of CD do not change in "small" state function reductions (SSFRs). SSFRs are analogs of weak measurements. One could call this

half-cone call as a passive half-cone. I have earlier used a somewhat misleading term passive boundary.

The time evolutions between SSFRs induce a delocalization in the moduli space of CDs. Passive boundary/half-cone of CD does not change. The active boundary/half-cone of CD changes in SSFRs and also the states at it change. Sequences of SSFRs replace the CD with a quantum superposition of CDs in the moduli space of CDs. SSFR localizes CD in the moduli space and corresponds to time measurement since the distance between CD tips corresponds to a natural time coordinate - geometric time. The size of the CD is bound to increase in a statistical sense: this corresponds to the arrow of geometric time.

6. There is no reason to assume that the same boundary of CD is always the active boundary. In "big" SFRs (BSFRs) their roles would indeed change so that the arrow of time would change. The outcome of BSFR is a superposition of space-time surfaces leading to the 3-surface in the final state. BSFR looks like deterministic time evolution leading to the final state [L90] as observed by Minev *et al* [L90].

7. h_{eff} hierarchy [K34, K35, K36, K37] implied by the number theoretic vision [L114, L115] makes possible quantum coherence in arbitrarily long length scales at the magnetic bodies (MBs) carrying $h_{eff} > h$ phases of ordinary matter. ZEO forces the quantum world to look classical for an observer with an opposite arrow of time. Therefore the question about the scale in which the quantum world transforms to classical, becomes obsolete.

8. Change of the arrow of time changes also the thermodynamic arrow of time. A lot of evidence for this in biology. Provides also a mechanism of self-organization [L102]: dissipation with reversed arrow of time looks like self-organization [L194].

16.5.2 Open questions related to ZEO

There are many unclear details related to the time evolution in the sequence of SSRs. Before discussing these unclear details let us make the following assumptions.

1. The size of CDs increases at least in a statistical sense in the sequence of CD and the second boundary remains stationary apart from scaling (note that one can also consider the possibility that the entire CD is scaled and temporal shift occurs in both directions).

2. Mental mentals (say after images) are in kind of Karma's cycle: they are born and die roughly periodically.

3. I do not experience directly mental images with the opposite arrow of time.

4. I can have memories only about states of consciousness with the same arrow of time that I have. This explains why I do not have memories about periods of sleep if sleep is interpreted as a time reversed state of some subself of me responsible for self-ness.

One can use three empirical inputs in an attempt to fix the model.

1. After images appear and disappear roughly periodically. Also I fall asleep and wake up with a standard arrow of time roughly periodically.

   (a) The first interpretation is that as a sequence of wake up-sleep periods I am a time crystal-like structure consisting of nearly copies of the mental image, such that each mental image - including me as mental images of higher level self - continues Karma's cycle in my geometric past. How "me" is transferred to a new almost copy of my biological body? Does my MB just redirect its attention?

   (b) The second interpretation is that me and my mental images somehow drift towards my geometric future, while performing the Karma's cycle so that my mental images follow me in my time travel. This would require that the sub-CDs of mental images drift towards the geometric future.
   Also sleep could be a "small" death at some layer of the personal hierarchy of MBs. I do not however wake-up in BSFR at the moment of geometric time defined by the moment of falling asleep but later. So it seems that my CD must drift to the geometric future with the same speed that those of other living beings in the biosphere.

2. There is however an objection. In cosmology the observation of stars older than the Universe would have a nice solution if the stars evolve forth and back in time in our distant geometric past rather than drifting towards the future so that they could age by continuing their Karma's cycle with a constant center of mass value of time. Can these three observations be consistent?

Could the scaling dynamics CD induce the temporal shifting of sub-CDs as 4-D perceptive fields?

Suppose that the sub-CDs within a bigger CD "follow the flow". How the dynamics of the bigger CD could induce this flow?

1. The scalings of bigger CD in unitary evolutions between SSFRs induce the scaling of sub-CS. This would not be shifting but scaling and the distance between given CD and larger CDs would gradually scale up.

   This would remove the objection. The astrophysical objects in distant geometric past would move towards the geometric future but with much smaller velocity as the objects with cosmic scale so that the temporal distance to future observers would increase. These objects would be aging in their personal Karma's cycle, and the paradox would disappear.

2. The flow would be defined by the scalings of a larger CD containing our CDs and those of others at my level. Each CD would define a shared time for its sub-CDs. If the CDs form a hierarchy structure with a common center, this is indeed true of the time evolutions as scalings of CDs. There would be scalings induced by scalings at higher levels and "personal" scalings.

3. It however seems that the common center is too strong an assumption and shifted positions for the sub-CDs and associated hierarchy inside a given CD are indeed possible for the proposed realization of M^8-H duality and actually required by Uncertainty Principle.

A further open question is what happens to the size of CD in the BSFR. Does it remain the same so that the size of the CD would increase indefinitely? Or is the size reduced in the sense that there would be scaling, reducing the size of the CD in which the passive boundary of the CD would be shifted towards the active one. After every BSFR, the self would experience a "childhood".

Are we sure about what really occurs in BSFR?

It has been assumed hitherto that a time reversal occurs in BSFR. The assumption that SSFRs correspond to a sequence of time evolutions identified as scalings, forces to challenge this assumption. Could BSFR involve a time reflection T natural for time translations or inversion $I: T \rightarrow 1/T$ natural for the scalings or their combination TI?

I would change the scalings increasing the size of CD to scalings reducing it. Could any of these options: time reversal T, inversion I, or their combination TI take place in BSFRs whereas arrow would remain as such in SSFRs? T (TI) would mean that the active boundary of CD is frozen and CD starts to increase/decrease in size.

There is considerable evidence for T in BSFRs identified as counterparts of ordinary SFRs but could it be accompanied by I?

1. Mere I in BSFR would mean that CD starts to decrease but the arrow of time is not changed and passive boundary remains passive boundary. What comes to mind is blackhole collapse.

   I have asked whether the decrease in size could take place in BSFR and make it possible for the self to get rid of negative subjective memories from the last moments of life, start from scratch and live a "childhood". Could this somewhat ad hoc looking reduction of size actually take place by a sequence of SSFRs? This brings into mind the big bang and big crunch. Could this period be followed by a BSFR involving inversion giving rise to increase of the size of CD as in the picture considered hitherto?

2. If BSFR involves TI, the CD would shift towards a fixed time direction like a worm, and one would have a fixed arrow of time from the point of view of the outsider although the arrow of time would change for sub-CD. This modified option does not seem to be in conflict

with the recent picture, in particular with the findings made in the experiments of Minev *et al* [L90] [L90].

This kind of shifting must be assumed in the TGD inspired theory of consciousness. For instance, after images as a sequence of time reversed lives of sub-self, do not remain in the geometric past but follow the self in travel through time and appear periodically (when their arrow of time is the same as of self). The same applies to sleep: it could be a period with a reversed arrow of time but the self would shift towards the geometric future during this period: this could be interpreted as a shift of attention towards the geometric future. Also this option makes it possible for the self to have a "childhood"".

3. However, the idea about a single arrow of time does not look attractive. Perhaps the following observation is of relevance. If the arrow of time for sub-CD correlates with that of sub-CD, the change of the arrow of time for CD, would induce its change for sub-CDs and now the sub-CDs would increase in the opposite direction of time rather than decrease.

To sum up, TI or T can be considered as competing options for what happens in BSFR. T should however be able to explain why sub-selves (sub- CDs) drift to the direction of the future. If the time evolutions between SSFRs correspond to scalings rather than time translations, and if the scalings occur also for sub-CDs this can be understood. The dynamics of spin glasses strongly suggests that SSFRs correspond to scalings [L144].

16.5.3 What happens in quantum measurement?

According to the proposed TGD view about particle identity, the systems for which mutual entanglement can be reduced in SFR must be non-identical in the category theoretical sense.

When SFR corresponds to quantum measurement, it involves the asymmetric observer-system $O-S$ relationship. One cannot exclude SFRs without this asymmetry. Some kind of hierarchy is suggestive.

The extensions of rationals realize this kind of $O-S$ hierarchy naturally. The notion of finite measurement resolution strongly suggests discretization, which favors number theoretical realization. The hierarchies of effective Planck constants and p-adic length scale hierarchies reflect this hierarchy. What about the topological situation: can one order topologies to a hierarchy by their complexity and could this correspond to $O-S$ relationship?

The intuitive picture about many-sheeted space-time is as a hierarchical structure consisting of sheets condensed at larger sheets by wormhole contacts, whose throats carry fermion number. Intuitively, the larger sheet serves as an observer. p-Adic primes assignable to the space-time sheet could arrange them hierarchically and one could have entanglement between wavefunctions for the Minkowskian regions of the space-time sheets and the surface with a larger value for p would be in the role of O

Number theoretic view about measurement interaction

Quantum measurement involves also a measurement interaction. There must be an interaction between two different levels O and S of the hierarchy.

One can look at the measurement interaction from a number theoretic point of view.

1. For cognitive measurements the step forming the composite $O \circ S$ of polynomials would represent the measurement interaction. Before measurement interaction systems would be represented by O and S and measurement interaction would form $O \circ S$ and after the measurement the situation would be as proposed.

Could one think that in BSFR the pair of uncorrelated surface defined by $O \times S$ with degree $n_O + n_S$ (analog for the additivity of classical degrees of freedom) is replaced with $O \circ S$ with degree $n_O \times n_S$ (analog for multiplicativity of degrees of freedom in tensor product) in BSFR? This would mean that the formation of $O \circ S$ is like a formation of an intermediate state in particle reaction or in chemical reaction.

Could the subsequent SSFR cascade define a cascade of cognitive measurements [L125]. I have proposed that this occurs in all particle reactions. For instance, nuclear reactions involving tunneling would involve formation of dark nuclei with $h_{eff} > h$ in BSFR and a sequence of

SSFRs in opposite time direction performing cognitive quantum measurement cascade [L103] and also the TGD based model for "cold fusion" relies on this picture [L54, L117]. After the SSFR cascade, a second BSFR would occur and bring back the original arrow of time and lead to the final state of the nuclear reaction.

From the point of view of cognition, BSFR would correspond to the heureka moment and the sequences of SSFRs to the cognitive analysis decomposing the space-time surface defined by $O \circ S$ to pieces.

2. One can also consider small perturbations of the polynomials $O \circ S$ as a measurement interaction. For instance, quantum superpositions of space-time surfaces determined by polynomials depending on rational valued parameters are possible. The Galois groups for two polynomials with parameters which are near to each other are the same but for some critical values of the parameters the polynomials separate into products. This would reduce the Galois group effectively to a product of Galois groups. Quantum measurement could be seen as a localization in the parameter space [L129].

Topological point of view about measurement interaction

The measurement interaction can be also considered from the topological point of view.

1. Wormhole contacts are Euclidean regions of $X^4 \subset H$ couples two parallel space-time regions with Minkowskian signature and could give rise to measurement interaction. Wormhole contact carries a monopole flux and there must be a second monopole contact to make flux loop possible. This structure has an interpretation as an elementary particle, for instance a boson. The measurement interaction could correspond to the formation of this structure and splitting by reconnection to flux loops associated with the space-time sheets after the interaction has ceased.

   Remark: Wormhole contacts for $X^4 \subset H$ correspond in $M^8 - H$ duality images of singularities of $X^4 \subset M^8$. The quaternionic normal space at a given point is not unique but has all possible directions, which correspond to all points of CP_2. This is like the monopole singularity of an electric or magnetic field. At the level of CP_2 wormhole contact is the "blow-up" of this singularity.

2. Flux tube pairs connecting two systems serve also as a good candidate for the measurement interaction. U-shaped monopole flux tubes are like tentacles and their reconnection creates a flux tube pair connecting two systems. SFR would correspond geometrically to the splitting of the flux tube pair by inverse re-connection.

Geometric view about SSFR

The considerations of [L128] strongly suggest the following picture about SSFRs.

In the measurement interaction a quantum superposition of functional composites of polynomials P_i defining the space-time surfaces of external states as Galois singlets is formed. A priori all orders for the composites in the superposition are allowed but if one requires that the same SSFR cascade can occur for all of them simultaneously, only single ordering and its cyclic permutations can be allowed.

The SSFR cascade can of course begin with a reduction selection single permutation and its cyclic permutations: localization in S_n/Z_n would take place.

Incoming states at passive boundary of CD correspond to prepared states and outgoing states at active boundary to state function reduced states. The external states could correspond to products of polynomials as number theoretical correlates for the absence of correlations in unentangled states.

Number theoretic existence for the scattering amplitudes [?] require that the p-adic primes characterizing the external states correspond to maximal ramified primes of the corresponding polynomials and therefore also to unique p-adic length scales L_p. In the interaction regions this ramified prime is the largest p-adic (that is ramified) prime for particles participating in the reaction. This correlation between polynomial and p-adic length scale allows a rather concrete geometric vision about what happens in the cascade.

SSFR cascade begins with a reduction of the state to a superposition of single composite with its cyclic variants for positive and negative energy parts separately: this kind of cyclic superpositions appear also in the twistor Grassmann picture [L128] and in string models. In the recent situation this makes possible a well-defined state preparation and SFR cascades at the two sides of CD. In ZEO, the cascade could take place for positive energy states only during SSFR.

A number theoretic SFR cascade would take place and decompose the Galois state group of the composite having decomposition to normal sub-groups to a product of states for the relative Galois groups for the composite.

A given step of the cascade would be a measurement of a density matrix ρ producing information coded by its reduction probabilities as its eigenvalues in turn coded by the characteristic polynomial P_M of the density matrix.

The simplest guess is that the final state polynomial is simply the product $\prod P_{i_-}$ of the polynomials P_{i_-} for the passive boundary of CD and product $\prod P_{i_+}$ for the active boundary.

Question of quantum information theorist

Quantum information theorists could however ask what happens to the information yielded by a given step of the measurement cascade.

1. Could the information about the measured ρ coded by P_M as its algebraic roots be stored to the final state coded by the final state polynomials $P_{i,+}$?

   Could the outcome at the active boundary of CD for which the SSFR cascade is actually not the 4-surface determined by the polynomials $P_{i,+}$ but $P_{M_{i_+}} \circ P_i$, or more generally a quantum superposition of $P_{M_{i_+}} \circ P_i$, and $P_i \circ P_{M_{i_+}}$.

   The "unitary time evolution" preceding the next SSFR would correspond to a functional composite of these polynomials so that the space-time surface would evolve during the SSFR sequence. The basic process would be a formation of functional composite followed by SSFR cascade storing the information about the measured density matrices to the space-time surface.

2. There are strong constraints on this proposal. $P_{M_{i_+}}$ should have rational coefficients in the extension of rationals defined by the composite polynomial, or even polynomial P_i. Monic polynomial property would pose even stronger conditions on entanglement coefficients and the representations of the entire Galois group.

   There is also the notion of Galois confinement for physical states. What constraints does this give?

   These conditions pose very strong conditions on the allowed entanglement matrix and could make the proposal unrealistic.

16.5.4 About TGD based description of entanglement

The general classification of possible quantum entanglements is an interesting challenge and there are many approaches (`https://cutt.ly/iREIg1u`). One interesting approach relies on the irreducible representations of the unitary group $U(n)$ acting as the isometry group of n-D Hilbert space (`https://cutt.ly/ZREIEAT`). The assumption about irreducibility is however not essential for what follows.

1. A system with n-D state space H_n identified as a sub-system of a larger system with N-D state space H_N can entangle with its $M = N - n$-D complement H_M. Suppose $n \leq M$. Entanglement implies that the n-D state space or its sub-space is embedded isometrically into a subspace of the M-D state space. For a non -trivial subspace one can replace H_n with this subspace H_m in what follows. The diagonal form of the density matrix describes this correspondence explicitly. If the subspace is 1-D one has an unentangled situation.

2. $U(n)$ and its subgroups act as automorphism groups of H_n This inspires the idea that the irreducible representations of $U(n)$ define physically very special entanglements $H_n \subset H_M$. The isometric inclusions $H_n \subset H_M$ are parametrized by a flag-manifold $F_{n,M} = U(M)/U(n) \times U(M-n)$. If one allows second quantization in the sense that the wave functions in the space of entanglements make sense, this flag manifold represents additional degrees of freedom for entanglements $H_n \subset H_M$. If the entanglement does not have maximal dimension, the product of flag manifolds $F_{n,M}$ and $F_{m,n}$ characterizes the space of entanglements.

3. Flag manifold has a geometric interpretation as the space of n-D spaces C^n (flags) embedded in C^M. Interestingly,twistor spaces and more general spaces of twistor Grassmannian approach are flag manifolds and twistor spaces are also related to Minkowski space.

4. I have not been personally enthusiastic about the notion of emergence of 3-space or space-time from entanglement but one can wonder whether flag manifolds related naturally to entanglement could lead to the emergence of Minkowski space. Or perhaps better, whether the notion of entanglement and Minkowski space could be natural aspects of a more general description.

5. One can also have flags inside flags inside leading to more complex flag manifolds $F(n_1, n_2, .., n_k = M) = U(M)/U(m_1) \times ... \times U(m_k)$, $m_k = n_k - n_{k-1}$ assuming $n_0 = 0$. In consciousness theories, the challenge is to understand the quantum correlates of attention. Entanglement is the most obvious candidate in this respect. Attention seems to be something with a directed arrow. This is difficult to understand in terms of the ordinary entanglement. Flag hierarchy would suggest a hierarchical structure of entanglement in which the system entangles with a higher-D system, which entangles with a higher-D system. In this picture the state function reduction would be replaced by a cascade starting from the top.

6. The analog of flags inside flags is what happens in what I call number theoretic measurement cascades for wavefunctions [L125] in the Galois groups which are associated with extension of extensions of..... The already mentioned cognitive measurement cascade corresponds to a hierarchy of normal subgroups of Galois group and one can perhaps say that discret Galois group replaces the unitary group. Each normal subgroup in the hierarchy is the Galois group of the extension of the extension below it. This automatically realizes the hierarchical entanglement as an attentional hierarchy. The cognitive measurement cascade can actually start at any level of the hierarchy of extensions of extensions and if it starts from the top all factors are reduced to a pure state.

   If the polynomials defining the 4-surfaces in M^8 satisfy $P(0) = 0$, the the composite polynomial $P_n \circ P_{n-1} ... \circ P_1$ has the roots of $P_1, ..., P_{n-1}$ as its roots. In this case the inclusion of state spaces are unique so that flag manifolds are not needed.

16.5.5 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP) [L139] is the basic variational principle of TGD based quantum measurement theory giving rise to a theory of consciousness.

1. The adelic entanglement entropy is the sum of the real entanglement entropy and p-adic entropies. The adelic negentropy is its negative.

   The real part of adelic entropy is non-negative but p-adic negentropies can be positive. The sum of p-adic negentropies can be larger than the real entropy for non-trivial extensions of rationals. NMP is expected to take care that this is indeed the case. Second law for the real entropy would still hold true and guarantee NMP.

2. NMP states that SFRs cannot reduce the *overall* entanglement entropy although this can happen to subsystems. In SFRs this local reduction of negentropy would happen. Entanglement is not destroyed in SFRs in general and new entanglement negentropy can be generated.

3. Although real entanglement entropy tends to increase, the positive p-adic negentropies assignable to the cognition would do the same so that net negentropy would increase. This would not mean only entanglement protection, but entanglement generation and cognitive evolution.

	GRT	TGD
Scope of geometrization	classical gravitation	all interactions and quantum theory
Spacetime		
Geometry	abstract 4-geometry	sub-manifold geometry
Topology	trivial in long length scales	many-sheeted space-time
Signature	Minkowskian everywhere	also Euclidian
Fields		
classical	primary dynamical variables	induced from the geometry of H
Quantum fields	primary dynamical variables	modes of WCW spinor fields
Particles	point-like	3-surfaces
Symmetries		
Poincare symmetry	lost	Exact
GCI	true	true - leads to SH and ZEO
	Problem in the identication of coordinates	$H = M^4 \times CP_2$ provides preferred coordinates
Super-symmetry	super-gravitation	super variant of H: super-surfaces
Dynamics		
Equivalence Principle	true	true
Newton's laws and		
notion of force	lost	generalized
Einstein's equations	from GCI and EP	remnant of Poincare invariance at QFT limit of TGD
Bosonic action	EYM action	Kähler action + volume term
Cosmological constant	suggested by dark energy	length scale dependent coefficient of volume term
Fermionic action	Dirac action	Modified Dirac action for induced spinors
Newton's constant	given	predicted
Quantization	fails	Quantum states as modes of WCW spinor field

Table 16.1: Differences and similarities between GRT and TGD

This picture is consistent with the paradoxical proposal of Jeremy England [I25] [L26] that biological evolution involves an increase of entropy.

4. It should be noticed that the increase of real entanglement entropy as such does not imply the second law. The reduction of real entropy transforms it to ensemble entropy since the outcome of the measurement is random. This entropy is entropy of fermions at space-time sheets. The fermionic entanglement would be reduced but transformed to Galois entanglement.

16.6 Appendix

16.6.1 Comparison of TGD with other theories

Table 18.1 compares GRT and TGD and **Table 18.2** compares standard model and TGD.

16.6.2 Glossary and figures

The following glossary explains some basic concepts of TGD and TGD inspired biology.

- ***Space-time as surface***. Space-times can be regarded as 4-D surfaces in an 8-D space $M^4 \times CP_2$ obtained from empty Minkowski space (M^4) by adding four small dimensions

	SM	TGD
Symmetries		
Origin	from empiria	reduction to CP_2 geometry
Color symmetry	gauge symmetry	isometries of CP_2
Color	analogous to spin	analogous to angular momentum
Ew symmetry	gauge symmery	holonomies of CP_2
Symmetry breaking	Higgs mechanism	CP_2 geometry
Spectrum		
Elementary particles	fundamental	consist of fundamental fermions
Bosons	gauge bosons, Higgs	gauge bosons, Higgs, pseudo-scalar
Fundamental fermions	quarks and leptons	quarks: leptons as local 3-quark composites
Dynamics		
Degrees of freedom	gauge fields, Higgs, and fermions	3-D surface geometry and spinors
Classical fields	gauge fields, Higgs	induced spinor connection
	SU(3) Killing vectors of CP_2	
Quantal degrees of freedom	gauge bosons,Higgs,	quantized induced spinor fields
Massivation	Higgs mechanism	p-adic thermodynamics with superconformal symmetry

Table 16.2: Differences and similarities between standard model and TGD

(CP_2). The study of field equations characterizing space-time surfaces as "orbits" of 3-surfaces (3-D generalization of strings) forces the conclusion that the topology of space-time is non-trivial in all length scales.

- ***Geometrization of classical fields***. Both weak, electromagnetic, gluonic, and gravitational fields are known once the space-time surface in H as a solution of field equations is known.

  Many-sheeted space-time (see **Fig. 18.1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by ***wormhole contacts*** (see **Fig. 18.3**) identified as the building bricks of elementary particles. The sizes of wormhole contacts vary but are at least of CP_2 size (about 10^4 Planck lengths) and thus extremely small.

  Many-sheeted space-time replaces reductionism with ***fractality*** . The existence of scaled variants of physics of strong and weak interactions in various length scales is implied, and biology is especially interesting in this respect.

- ***Topological field quantization (TFQ)*** . TFQ replaces classical fields with space-time quanta. For instance, magnetic fields decompose into space-time surfaces of finite size representing flux tubes or -sheets. Field configurations are like Bohr orbits carrying "archetypal" classical field patterns. Radiation fields correspond to topological light rays or massless extremals (MEs), magnetic fields to magnetic flux quanta (flux tubes and sheets) having as primordial representatives "cosmic strings", electric fields correspond to electric flux quanta (e.g. cell membrane), and fundamental particles to CP_2 type vacuum extremals.

- ***Field body*** (FB) and ***magnetic body*** (MB). Any physical system has field identity - FB or MB - in the sense that a given topological field quantum corresponds to a particular source (or several of them - e.g. in the case of the flux tube connecting two systems).

  Maxwellian electrodynamics cannot have this kind of identification since the fields created by different sources superpose. Superposition is replaced with a set theoretic union: only the *effects* of the fields assignable to different sources on test particle superpose. This makes it possible to define the QFT limit of TGD.

- ***p-Adic physics*** [K70] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- ***Adelic physics*** [L64, L69] is a fusion of real physics of sensory experience and various p-adic physics of cognition.
- ***p-Adic length scale hypothesis*** states that preferred p-adic length scales correspond to primes p near powers of two: $p \simeq 2^k$, k positive integer.
- A ***Dark matter hierarchy*** realized in terms of a hierarchy of values of effective Planck constant $h_{eff} = nh_0$ as integers using $h_0 = h/6$ as a unit. Large value of h_{eff} makes possible macroscopic quantum coherence which is crucial in living matter.
- ***MB as an intentional agent using biological body (BB) as a sensory receptor and motor instrument*** . The personal MB associated with the living body - as opposed to larger MBs assignable with collective levels of consciousness - has a hierarchical onion-like layered structure and several MBs can use the same BB making possible remote mental interactions such as hypnosis [L20].
- ***Cosmic strings Magnetic flux tubes*** belong to the basic extremals of practically any general coordinate invariant action principle. Cosmic strings are surfaces of form $X^2 \times Y^2 \subset M^4 \times CP_2$. X^2 is analogous to string world sheet. Cosmic strings come in two varieties and both seem to have a deep role in TGD.

  Y^2 is either a complex or Lagrangian 2-manifold of CP_2. Complex 2-manifold carries monopole flux. For Lagrangian sub-manifold the Kähler form and magnetic flux and Kähler action vanishes. Both types of cosmic strings are are simultaneous extremals of both Kähler action and volume action: this holds true quite generally for preferred extremals.

  Cosmic strings are unstable against perturbations thickening the 2-D M^4 projection to 3-D or 4-D: this gives rise to monopole (see **Fig. ??**) and non-monopole magnetic flux tubes. Using $M^2 \times Y^2$ coordinates, the thickening corresponds to the deformation for which $E^2 \subset M^4$ coordinates are not constant anymore but depend on Y^2 coordinates.
- ***Magnetic flux tubes and sheets*** serve as "body parts" of MB (analogous to body parts of BB), and one can speak about magnetic motor actions. Besides concrete motion of flux quanta/tubes analogous to ordinary motor activity, basic motor actions include the contraction of magnetic flux tubes by a phase transition possibly reducing Planck constant, and the change in thickness of the magnetic flux tube, thus changing the value of the magnetic field, and in turn the cyclotron frequency. Transversal oscillatory motions of flux tubes and oscillatory variations of the thickness of the flux tubes serve as counterparts for Alfwen waves.

  Reconnections of the U-shaped flux tubes allow two MBs to get in contact based on a pair of flux tubes connecting the systems and temporal variations of magnetic fields inducing motor actions of MBs favor the formation of reconnections.

  In hydrodynamics and magnetohydrodynamics reconnections would be essential for the generation of turbulence by the generation of vortices having monopole flux tube at core and Lagrangian flux tube as its exterior.

  Flux tube connections at the molecular level bring a new element to biochemistry making it possible to understand bio-catalysis. Flux tube connections serve as a space-time correlates for attention in the TGD inspired theory of consciousness.
- ***Cyclotron Bose-Einstein condensates (BECs)*** of various charged particles can accompany MBs. Cyclotron energy $E_c = hZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $h \rightarrow h_{eff}$ E_c is scaled up by a fractor $h_{eff}/h = n$. For sufficiently high value of h_{eff} cyclotron energy is above thermal energy $E = h_{eff}\ ZeB/m$. Cyclotron Bose-Einstein condensates at MBs of basic biomolecules and of cell membrane proteins - play a key role in TGD based biology.

- ***Josephson junctions*** exist between two superconductors. In TGD framework, ***generalized Josephson junctions*** accompany membrane proteins such as ion channels and pumps. A voltage between the two super-conductors implies a ***Josephson current***. For a constant voltage the current is oscillating with the ***Josephson frequency*** . The Josephson current emits ***Josephson radiation***. The energies come as multiples of ***Josephson energy***.

  In TGD generalized Josephson radiation consisting of dark photons makes communication of sensory input to MB possible. The signal is coded to the modulation of Josephson frequency depending on the membrane voltage. The cyclotron BEC at MB receives the radiation producing a sequence of resonance peaks.

- ***Negentropy Maximization Principle*** (NMP). NMP [K65] [L139] is the variational principle of consciousness and generalizes SL. NMP states that the negentropy gain in SFR is non-negative and maximal. NMP implies SL for ordinary matter.

- ***Negentropic entanglement*** (NE). NE is possible in adelic physics and NMP does not allow its reduction. NMP implies a connection between NE, the dark matter hierarchy, p-adic physics, and quantum criticality. NE is a prerequisite for an experience defining abstraction as a rule having as instances the state pairs appearing in the entangled state.

- ***Zero energy ontology (ZEO)*** In ZEO physical states are pairs of positive and negative energy parts having opposite net quantum numbers and identifiable as counterparts of initial and final states of a physical event in the ordinary ontology. Positive and negative energy parts of the zero energy state are at the opposite boundaries of a ***causal diamond*** (CD, see **Fig. 18.2**)) defined as a double-pyramid-like intersection of future and past directed light-cones of Minkowski space.

  CD defines the "spot-light of consciousness": the contents of conscious experience associated with a given CD is determined by the space-time sheets in the embedding space region spanned by CD.

- ***SFR*** is an acronym for state function reduction. The measurement interaction is universal and defined by the entanglement of the subsystem considered with the external world [L105] [K125]. What is measured is the density matrix characterizing entanglement and the outcome is an eigenstate of the density matrix with eigenvalue giving the probability of this particular outcome. SFR can in principle occur for any pair of systems.

  SFR in ZEO solves the basic problem of quantum measurement theory since the zero energy state as a superposition of classical deterministic time evolutions (preferred extremals) is replaced with a new one. Individual time evolutions are not made non-deterministic.

  One must however notice that the reduction of entanglement between fermions (quarks in TGD) is not possible since Fermi- and als Bose statistics predicts a maximal entanglement. Entanglement reduction must occur in WCW degrees of freedom and they are present because point-like particles are replaced with 3-surfaces. They can correspond to the number theoretical degrees of freedom assignable to the Galois group - actually its decomposition in terms of its normal subgroups - and to topological degrees of freedom.

- ***SSFR*** is an acronym for "small" SFR as the TGD counterpart of weak measurement of quantum optics and resembles classical measurement since the change of the state is small [L105] [K125]. SSFR is preceded by the TGD counterpart of unitary time evolution replacing the state associated with CD with a quantum superposition of CDs and zero energy states associated with them. SSFR performs a localization of CD and corresponds to time measurement with time identifiable as the temporal distance between the tips of CD. CD is scaled up in size - at least in statistical sense and this gives rise to the arrow of time.

  The unitary process and SSFR represent also the counterpart for Zeno effect in the sense that the passive boundary of CD as also CD is only scaled up but is not shifted. The states remain unchanged apart from the addition of new fermions contained by the added part of the passive boundary. One can say that the size of the CD as analogous to the perceptive field means that more and more of the zero energy state at the passive boundary becomes visible. The active boundary is however both scaled and shifted in SSFR and states at it change. This gives rise to the experience of time flow and SSFRs as moments of subjective time correspond to geometric time as a distance between the tips of CD. The analog of unitary time evolution corresponds to "time" evolution induced by the exponential of the scaling generator L_0. Time translation is thus replaced by scaling. This is the case also in p-adic thermodynamics. The idea of time evolution by scalings has emerged also in condensed matter physics.

- ***BSFR*** is an acronym for "big" SFR, which is the TGD counterpart of ordinary state function reduction with the standard probabilistic rules [L105] [K125]. What is new is that the arrow of time changes since the roles of passive and active boundaries change and CD starts to increase in an opposite time direction.

  This has profound thermodynamic implications. Second law must be generalized and the time corresponds to dissipation with a reversed arrow of time looking like self-organization for an observed with opposite arrow of time [L102]. The interpretation of BSFR is as analog of biological death and the time reversed period is analogous to re-incarnation but with non-standard arrow of time. The findings of Minev *et al* [L90] give support for BSFR at atomic level. Together with h_{eff} hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

16.6.3 Figures

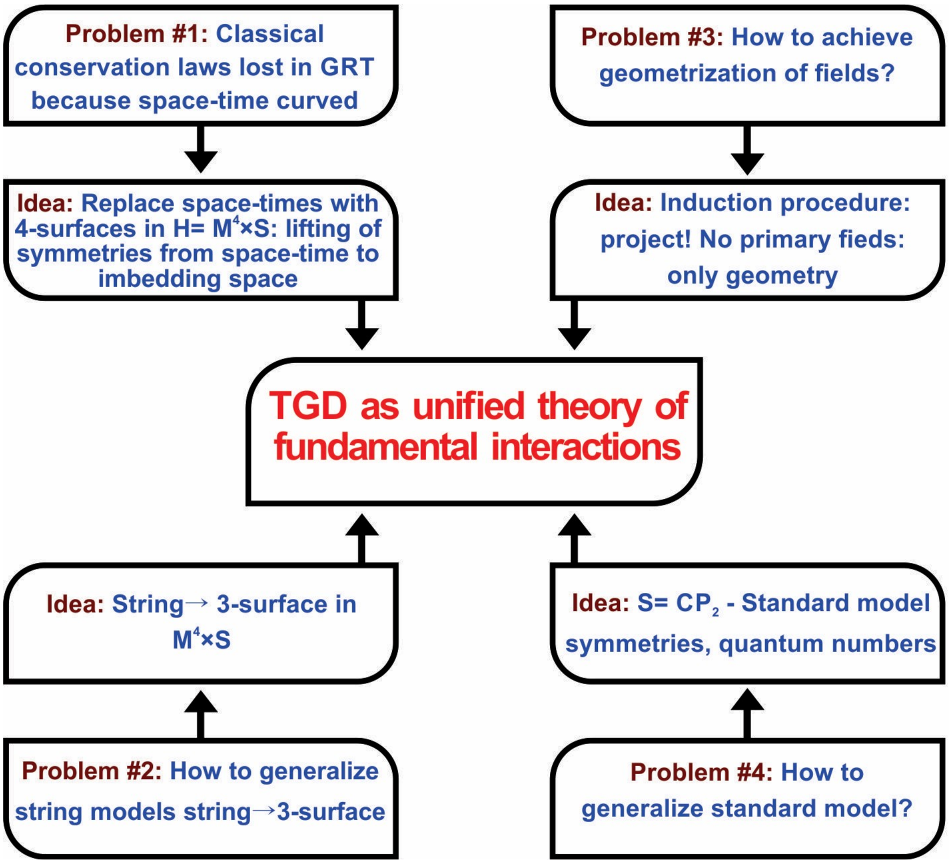

Figure 16.1: The problems leading to TGD as their solution.

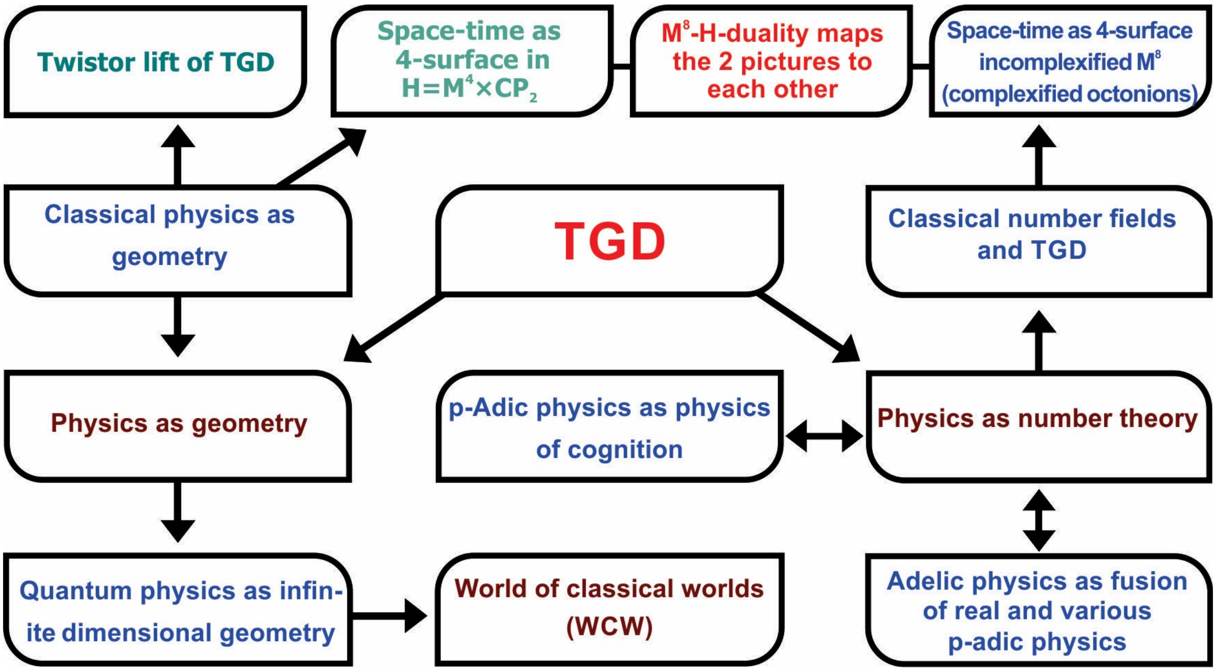

Figure 16.2: TGD is based on two complementary visions: physics as geometry and physics as number theory.

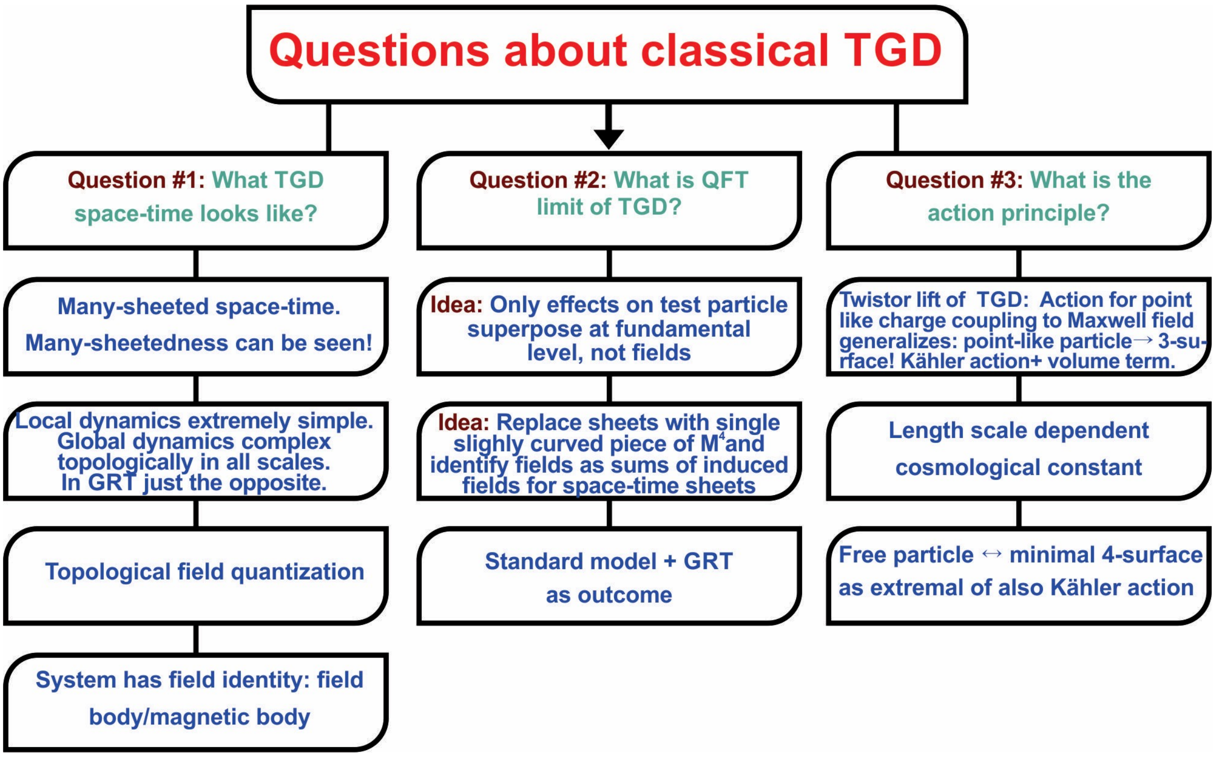

Figure 16.3: Questions about classical TGD.

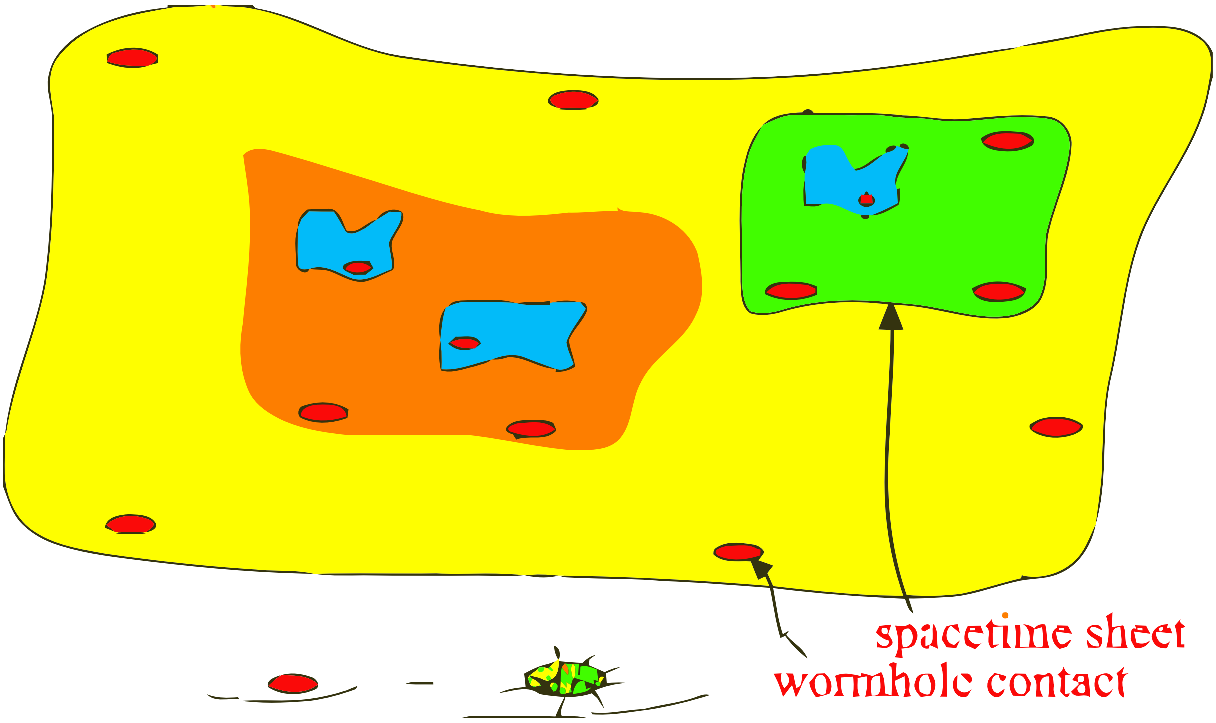

Figure 16.4: Many-sheeted space-time.

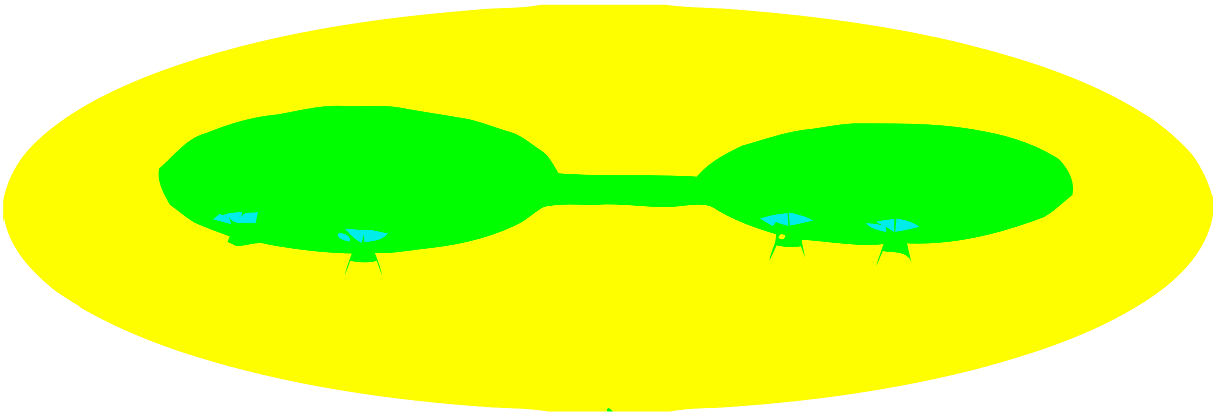

Figure 16.5: Wormhole contacts.

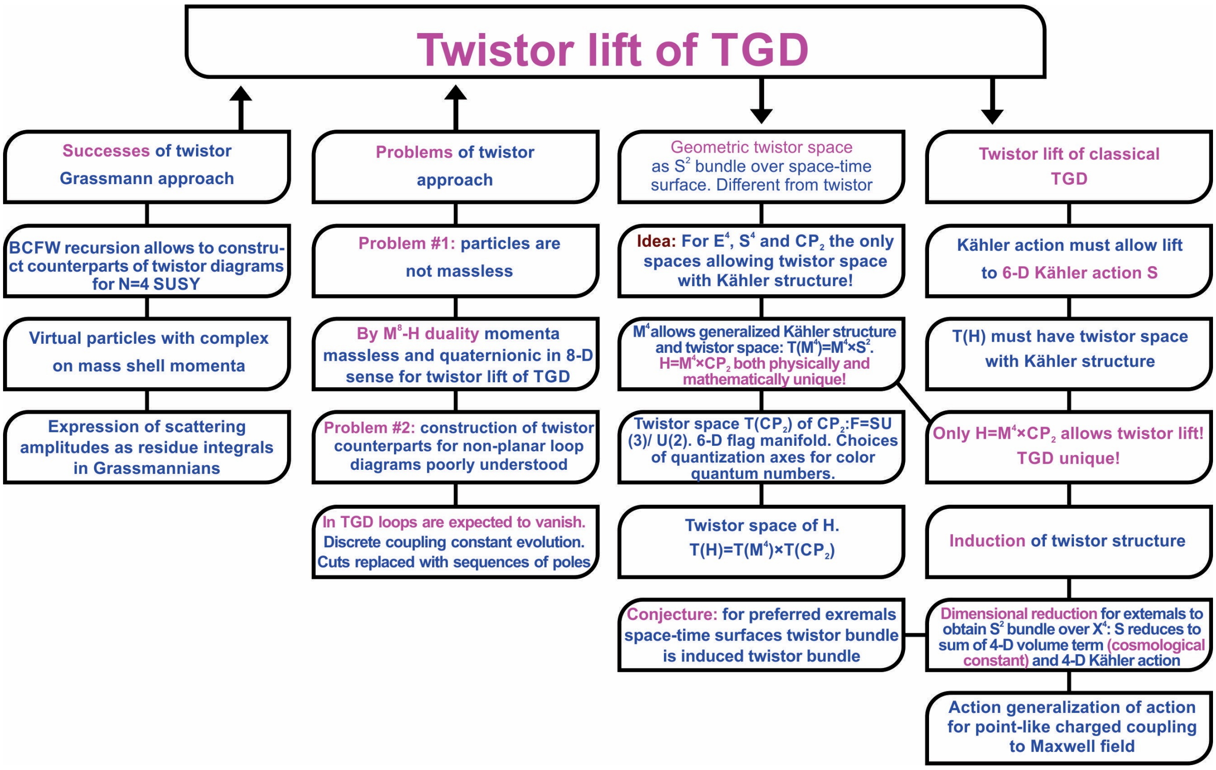

Figure 16.6: Twistor lift

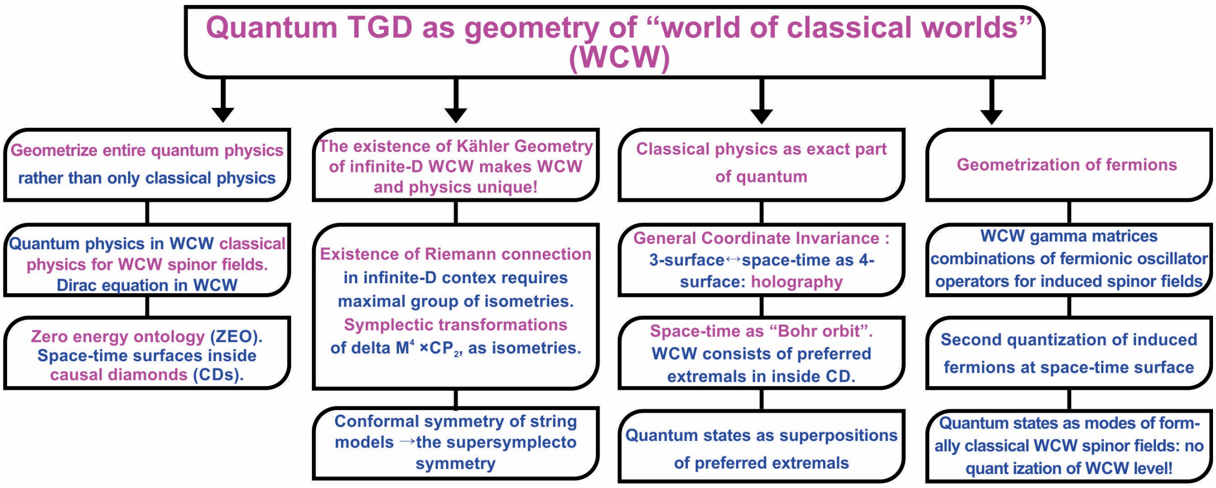

Figure 16.7: Geometrization of quantum physics in terms of WCW

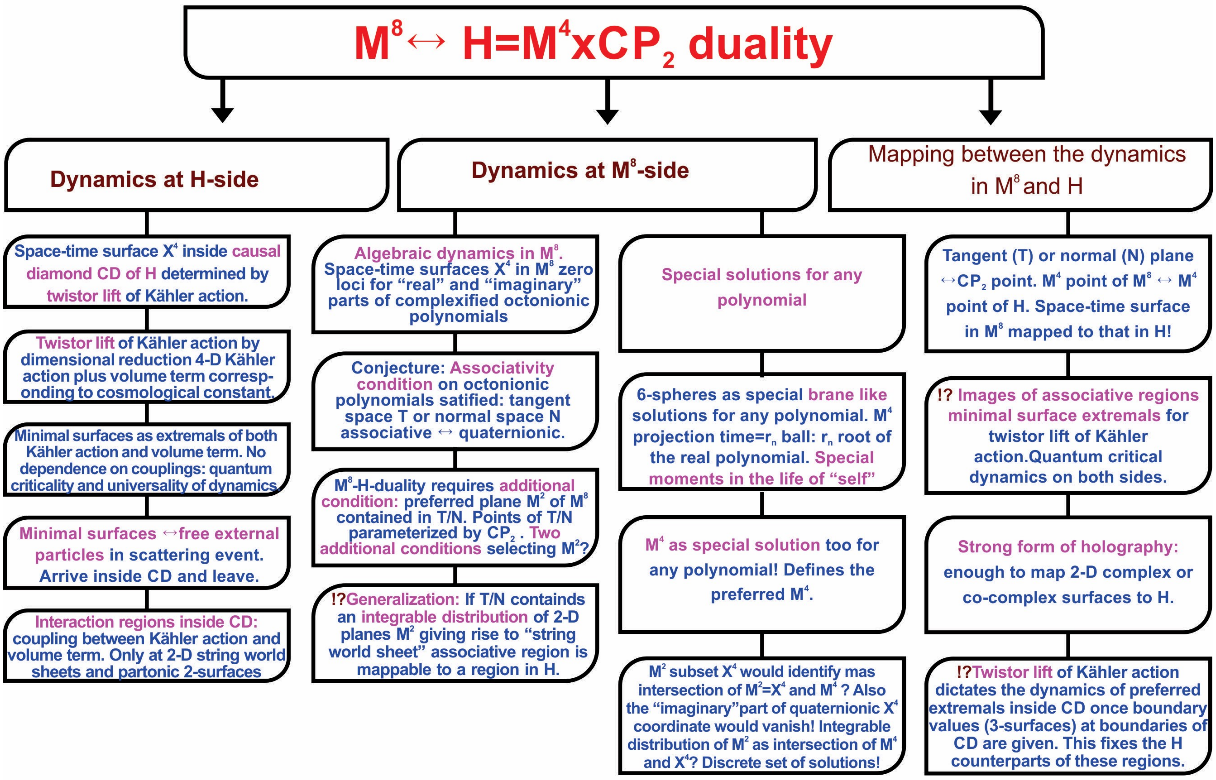

Figure 16.8: $M^8 - H$ duality

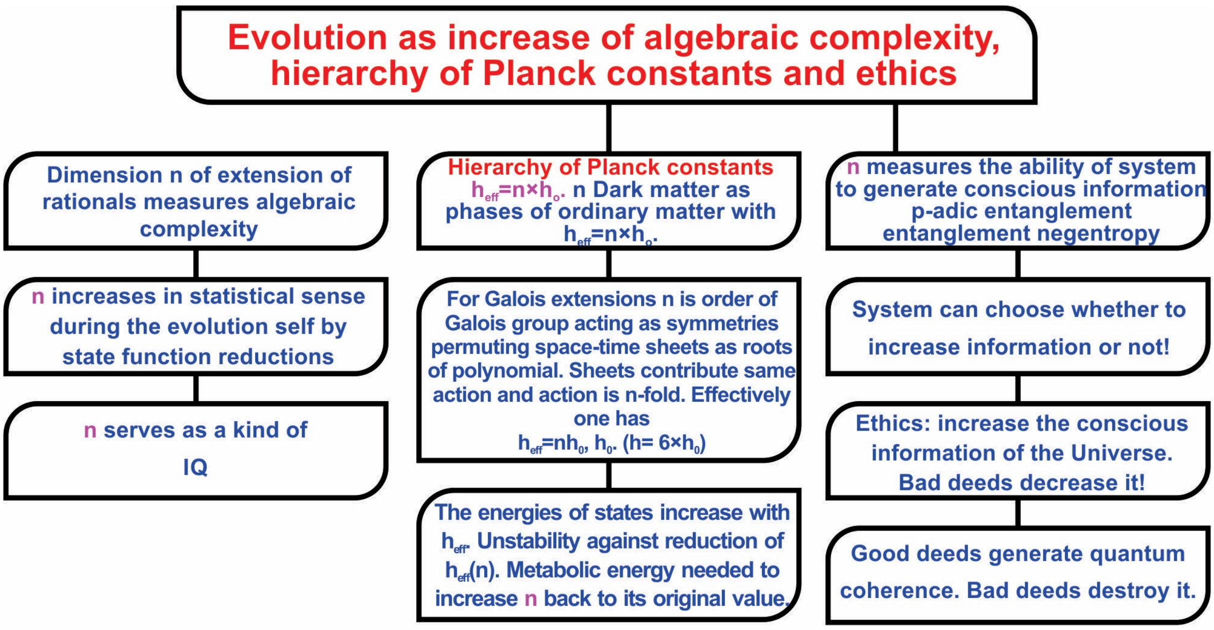

Figure 16.9: Number theoretic view of evolution

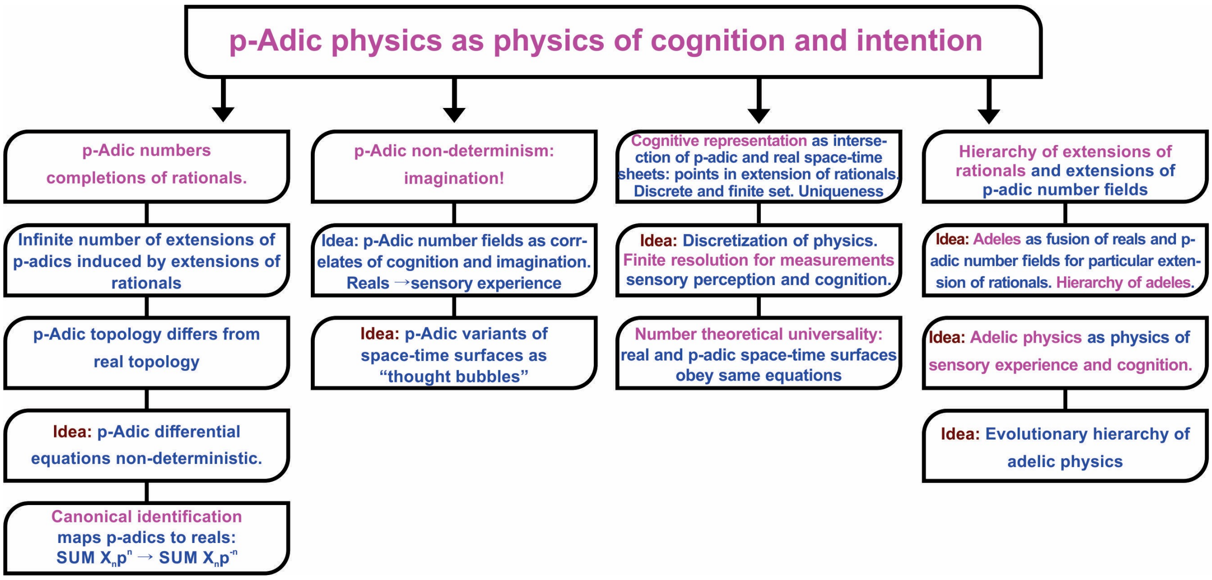

Figure 16.10: p-Adic physics as physics of cognition and imagination.

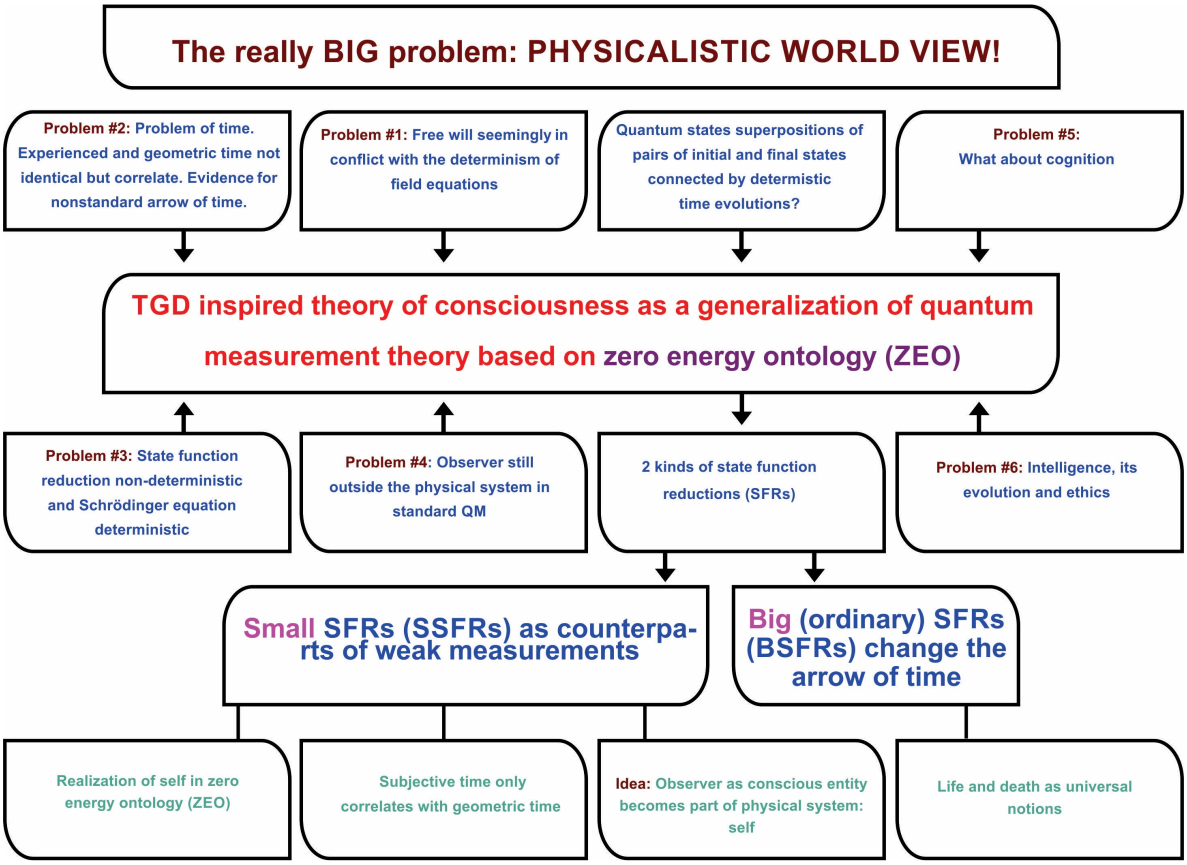

Figure 16.11: Consciousness theory from quantum measurement theory

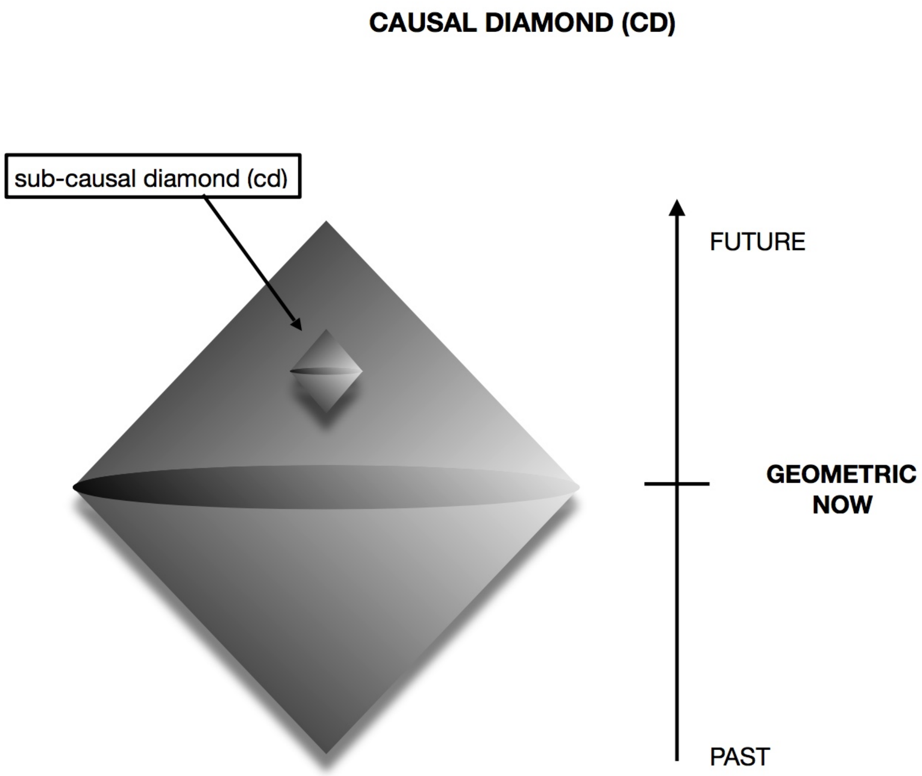

Figure 16.12: Causal diamond

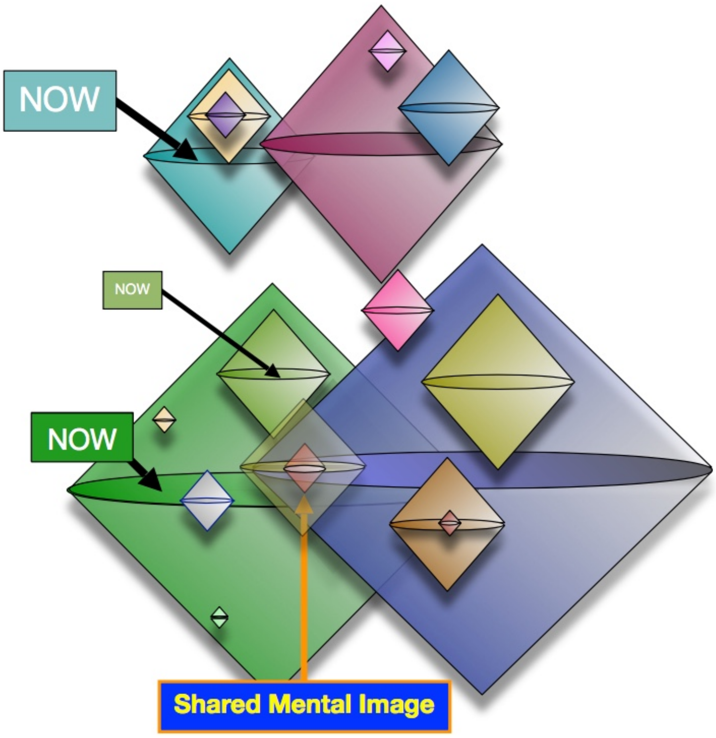

Figure 16.13: CDs define a fractal "conscious atlas"

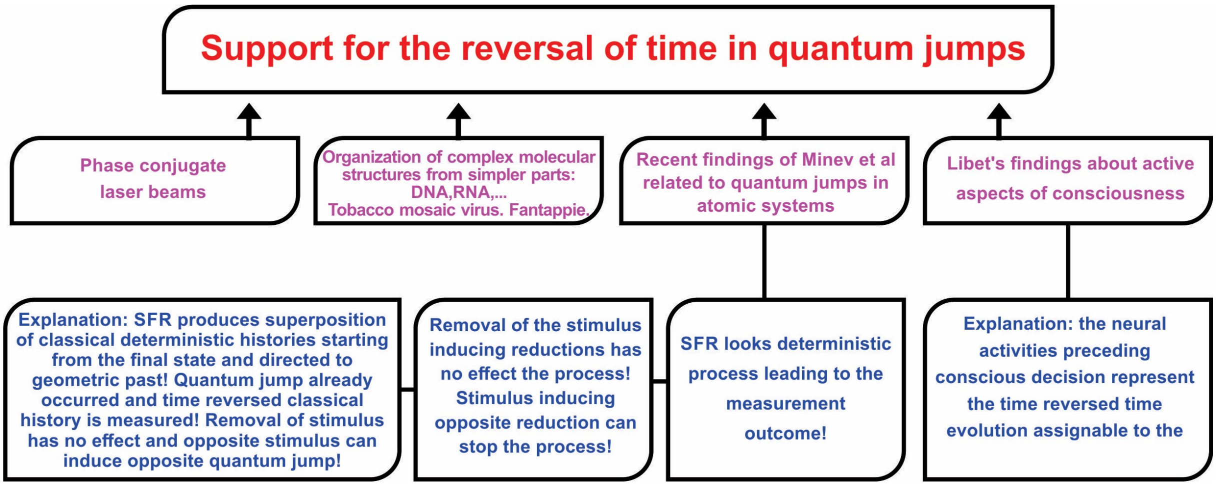

Figure 16.14: Time reversal occurs in BSFR

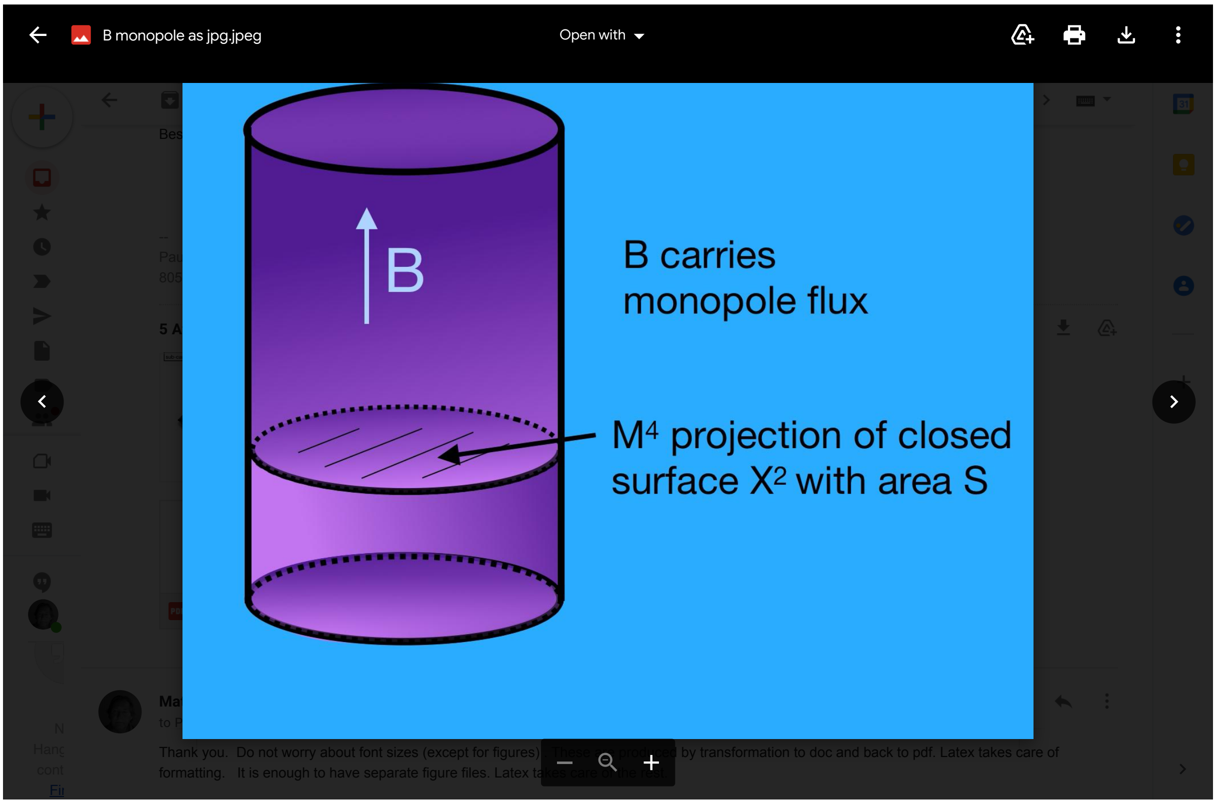

Figure 16.15: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e\oint B\cdot dS = eBS = kh$ at single sheet of n-sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

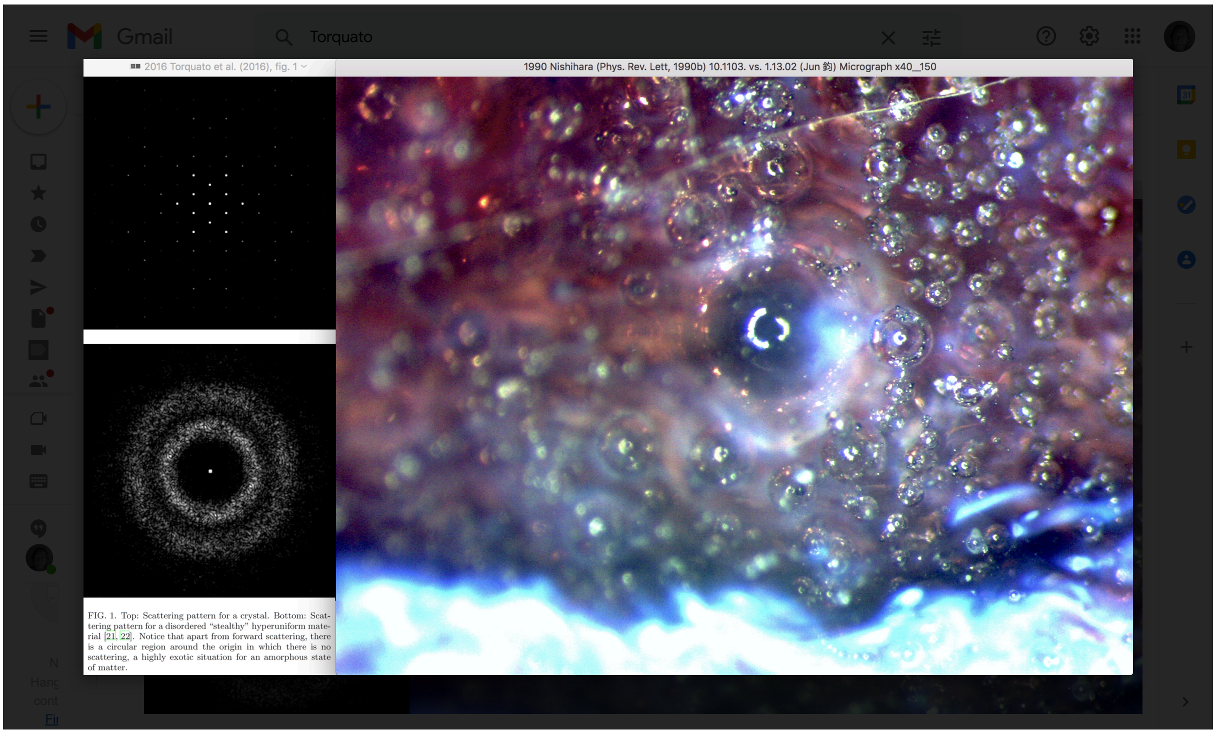

Figure 16.16: The scattering from a hyperuniform amorphous material shows no scattering in small angles apart from the forward peak (`https://cutt.ly/ZWyLgjk`). This is very untypical in amorphous matter and might reflect the diffraction pattern of dark photons at the magnetic body of the system.

Chapter 17

TGD and Condensed Matter

17.1 Introduction

The purpose of this article is to give a rough overall view about Topological Geometrodynamics (TGD) and to consider its possible applications in condensed matter physics at the general level. It must be emphasized that TGD is only a vision, not a theory able to provide precise rules for calculating scattering amplitudes. A collective theoretical and experimental effort would be needed to achieve this. The proposal for a model of superconductivity [L131] provides a representative example about what TGD could possibly give for condensed matter physics.

It is perhaps good to explain what TGD is not and what it is or hoped to be. The article [L123] gives an overview of various aspects of TGD and is warmly recommended.

1. "Geometro-" refers to the idea about the geometrization of physics. The geometrization program of Einstein is extended to gauge fields allowing realization in terms of the geometry of surfaces so that Einsteinian space-time as abstract Riemann geometry is replaced with sub-manifold geometry. The basic motivation is the loss of classical conservation laws in General Relativity Theory (GRT)(see **Fig. 17.1**). Also the interpretation as a generalization of string models by replacing string with 3-D surface is natural.

   Standard model symmetries uniquely fix the choice of 8-D space in which space-time surfaces live to $H = M^4 \times CP_2$ [L2]. Also the notion of twistor is geometrized in terms of surface geometry and the existence of twistor lift fixes the choice of H completely so that TGD is unique [L65, L85](see **Fig. 17.6**). The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "world of classical worlds" (WCW) - becomes the basic object endowed with Kähler geometry (see **Fig. 17.7**). General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. Given 3-surface fixes the space-time surface almost completely as analog of Bohr orbit (preferred extremal).This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces.

2. Consider next the attribute "Topological". In condensed matter physical topological physics has become a standard topic. Typically one has fields having values in compact spaces, which are topologically non-trivial. In the TGD framework space-time topology itself is non-trivial as also the topology of $H = M^4 \times CP_2$.

   The space-time as 4-surface $X^4 \subset H$ has a non-trivial topology in all scales and this together with the notion of many-sheeted space-time brings in something completely new. Topologically trivial Einsteinian space-time emerges only at the QFT limit in which all information about topology is lost (see **Fig. 17.3**).

   Practically any GCI action has the same universal basic extremals: CP_2 type extremals serving basic building bricks of elementary particles, cosmic strings and their thickenings to flux tubes defining a fractal hierarchy of structure extending from CP_2 scale to cosmic scales, and massless extremals (MEs) define space-time correletes for massless particles. World as a set or particles is replaced with a network having particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

"Topological" could refer also to p-adic number fields obeying p-adic local topology differing radically from the real topology (see **Fig. 17.10**).

3. Adelic physics fusing real and various p-adic physics are part of the number theoretic vision, which provides a kind of dual description for the description based on space-time geometry and the geometry of "world of classical" orders. Adelic physics predicts two fractal length scale hierarchies: p-adic length scale hierarchy and the hierarchy of dark length scales labelled by $h_{eff} = nh_0$, where n is the dimension of extension of rational. The interpretation of the latter hierarchy is as phases of ordinary matter behaving like dark matter. Quantum coherence is possible in all scales.

   The concrete realization of the number theoretic vision is based on M^8-H duality (see **Fig. 17.8**). The physics in the complexification of M^8 is algebraic - field equations as partial differential equations are replaced with algebraic equations associating to a polynomial with rational coefficients a X^4 mapped to H by M^8-H duality. The dark matter hierarchy corresponds to a hierarchy of algebraic extensions of rationals inducing that for adeles and has interpretation as an evolutionary hierarchy (see **Fig. 17.9**).

   M^8-H duality provides two complementary visions about physics (see **Fig. 17.2**), and can be seen as a generalization of the q-p duality of wave mechanics, which fails to generalize to quantum field theories (QFTs).

4. In Zero energy ontology (ZEO), the superpositions of space-time surfaces inside causal diamond (CD) having their ends at the opposite light-like boundaries of CD, define quantum states. CDs form a scale hierarchy (see **Fig. 18.2** and **Fig. 17.13**).

   Quantum jumps occur between these and the basic problem of standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see **Fig. 17.14**). This has profound thermodynamic implications and the question about the scale in which the transition from classical to quantum takes place becomes obsolete. BSFRs can occur in all scales but from the point of view of an observer with an opposite arrow of time they look like smooth time evolutions.

   In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary of CD and states at it remain unchanged (Zeno effect).

This work led to considerable progress in several aspects of TGD.

1. The mutual entanglement of fermions (bosons) as elementary particles is always maximal so that only fermionic and bosonic degrees can entangle in QFTs. The replacement of point-like particles with 3-surfaces forces us to reconsider the notion of identical particles from the category theoretical point of view. The number theoretic definition of particle identity seems to be the most natural and implies that the new degrees of freedom make possible geometric entanglement.

   Also the notion particle generalizes: also many-particle states can be regarded as particles with the constraint that the operators creating and annihilating them satisfy commutation/anticommutation relations. This leads to a close analogy with the notion of infinite prime.

2. The understanding of the details of the M^8-H duality forces us to modify the earlier view. The notion of causal diamond (CD) central to zero energy ontology (ZEO) emerges as a prediction at the level of H. The pre-image of CD at the level of M^8 is a region bounded by two mass shells rather than CD. M^8-H duality maps the points of cognitive representations as momenta of quarks with fixed mass in M^8 to either boundary of CD in H.

3. Galois confinement at the level of M^8 is understood at the level of momentum space and is found to be necessary. Galois confinement implies that quark momenta in suitable units are algebraic integers but integers for Galois singlet just as in ordinary quantization for a particle in a box replaced by CD. Galois confinement could provide a universal mechanism for the formation of all bound states.

4. There is considerable progress in the understanding of the quantum measurement theory based on ZEO. From the point of view of cognition BSFRs would be like heureka moments and the sequence of SSFRs would correspond to an analysis having as a correlate the decay of 3-surface to smaller 3-surfaces.

The improved vision allows us to develop the TGD interpretation for various condensed matter notions.

1. TGD is analogous to hydrodynamics in the sense that field equations at the level of H reduce to conservation laws for isometry charges. The preferred extremal property meaning that space-time surfaces are simultaneous extremals of volume action and Kähler action allows interpretation in terms of induced gauge fields. The generalized Beltrami property implies the existence of an integrable flow serving as a correlate for quantum coherence. Conserved Beltrami flows currents correspond to gradient flows. At the QFT limit this simplicity would be lost.

2. The fields H, M, B and D, P, E needed in the applications of Maxwell's theory could emerge at the fundamental level in the TGD framework and reflect the deviation between Maxwellian and the TGD based view about gauge fields due to CP_2 topology.

3. The understanding of macroscopic quantum phases improves. The role of the magnetic body carrying dark matter is central. The understanding of the role of WCW degrees of freedom improves considerably in the case of Bose-Einstein condensates of bosonic particles such as polaritons. M^8 picture allows us to understand the notion of skyrmion. The formation of Cooper pairs and analogous states with higher energy would correspond to a formation of Galois singlets liberating energy used to increase h_{eff}. What is new is that energy feed makes possible supra-phases and their analogs above the critical temperature.

4. Fermi surface emerges as a fundamental notion at the level of M^8 but has a counterpart also at the level of H. Galois groups would be crucial for understanding braids, anyons and fractional Quantum Hall effect. Space-time surface could be seen as a curved quasicrystal associated with the lattice of M^8 defined by algebraic integers in an extension of rationals. Also the TGD analogs of condensed matter Majorana fermions emerge.

In section 1 this picture is discussed in more detail. In section 2 some concepts of condensed matter physics are discussed from the TGD view. In section 3 some concrete questions about condensed matter are discussed Hydrodynamical turbulence represents one of the unsolved problems of physics and therefore as an excellent test bench for the TGD based vision and is discussed in the 4^{th} section. The last section lists some tests for the TGD based vision. The approach is rather general: this is the only possible option since I am not a condensed matter specialist.

17.2 Some notions of condensed matter physics from the TGD point of view

Before continuing I must emphasize that I am not a condensed matter physicist and have no practical experience about experimental physics. Therefore I cannot propose any experimental protocols. I dare to hope that the new vision about space-time and quantum theory could inspire people who are doing real condensed matter physics.

17.2.1 The notion of Brillouin zone from the TGD viewpoint

In condensed matter physics the notions of lattice, reciprocal lattice, unit cell and Brillouin zone at its counterpart in reciprocal lattices are central notions.

The reciprocal lattice in momentum space is the dual of the lattice in 3-space. This follows automatically from the periodicity of properties of wave functions in the lattice : they force wave vectors to be in the reciprocal lattice. The diffraction amplitude has peaks at the photon momenta in the reciprocal lattice.

M^8-H duality can be seen as the counterpart of position-momentum duality. Therefore it is interesting to look at these notions from the point of view of M^8_H duality. Recall that 4-surfaces in $H = M^4 \times CP_2$ is identified as space-time whereas the 4-surface in $M^8 = M^4 \times E^4$ is analogous to momentum space with slicing induced by the mass shells (hyperboloids) of M^4. In H the corresponding slicing is by CDs inside CDs with size given by the Compton length associated with mass m.

1. At the level of H, periodic minimal surfaces would nicely produce lattice-like structures and the momenta associated with the peaks of Fourier transforms would belong to the reciprocal lattice. I have considered the construction of also more general structures in [L155].

2. At the level of M^8, the allowed momenta as points of $X^4 \subset M^8$ belong to cognitive representations: the momentum components are algebraic integers in the extension defined by the polynomial defined the 4-surface in M^8. This guarantees the theoretical universality of the adelic physics [L64, L63]) so that the points make sense also as points of the p-adic variants of space-time surface defining geometric correlates of cognition.

   Lattice-like structures are naturally associated with the lattice of algebraic integers and one obtains a hierarchy of lattices. The lattices can be seen as products of ordinary lattices in E^3 and lattices in the extension of rationals having dimension n: this feature is completely new.

Construction of bound states

Number theoretic vision suggests a universal way to construct bound states as Galois confined states. This would mean that many quark states in M^8 consisting of points of cognitive representation carrying quark are Galois singlets. In the case of momentum degrees of freedom this would mean that the total momentum is (rational) integer.

The physical motivation for Galois confinement is that periodic boundary conditions require integer value 4-momenta which are rational integers using a suitable momentum unit determined by the size scale of CD (Compton length $\hbar_{eff}/m$ for some particle would be in question for $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ the gravitational Compton length $\Lambda_{gr} = GM/v_0 = r_s(M)/2v_0$ would not depend at all on mass of the particle.

1. The condition that the total 4-momentum is integer-valued poses a strong condition on the bound states.

2. Second condition is that the inner products of the momenta (algebraic integers which can have an imaginary part) defining number theoretical metric are real valued. This poses strong quantization conditions, and one obtains also lattice structures in the lattice defined by the unit vectors of extension and by 3-space. These lattice structures are sublattices of lattice E^3, whose points are n-D number theoretical lattices defined by the unit vectors of the extension of rationals.

3. The fundamental entities are quarks and the construction gives a hierarchy of increasingly complex bound states of them. One obtains also atoms and their lattices. Quasi-crystals are obtained as cut and project construction and it is feasible that number theoretical lattices makes them possible also now.

4. The lattices in M^8 involving particles with the same mass are actually lattices in 3-D hyperbolic space and called tessellations. In good approximation they are lattices in E^3 since H^3 can be approximated by E^3 below length scale given by h_{eff}/m which is Λ_{gr} for $\hbar_{gr}$ (.9 cm for Earth and of the order of radius of Earth for Sun).

   The structure of tessellations is extremely rich and perhaps the simplest tessellations known as icosa-tetrahedral tessellations involve all basic Platonic solids and are proposed to give rise to universal realization of genetic code having chemical realization only as a special case and having besides DNA also higher dimensional realizations [L137].

   M^8 picture allows also universal 6-D brane-like solutions with a topology of 6-sphere, whose projection to CD is its intersection with 3-D hyperplane E^3 of constant energy. This plane would allow many quarks states with an ordinary lattice structure. There both hyperbolic tessellations and Euclidian lattices would be allowed.

5. Even the lattice formed by atoms would be a bound state of this kind. The reciprocal lattice in M^8 has an interpretation in terms of cognitive representation in M^8 mapped to H by $M^8 - H$ duality defined by particle momenta, which are basically bound states of quarks (also leptons).

$M^8 - H$ duality and the relation between lattices and reciprocal lattices

M^8 and H descriptions are related by $M^8 - H$ duality as an analog for momentum-position duality. Uncertainty Principle (UP) must be respected but what does this really require is not quite clear. The map of $X^4 \subset M^8$ to $X^4 \subset H$ is certainly involved. This would be the $M^8 - H$ duality for space-time surfaces. This description is not enough: $M^8 - H$ duality is required also at the level of "world of classical worlds" (WCW).

1. $M^8 - H$ duality at the level of 4-surfaces

Consider first the $M^8 - H$ duality at space-time level.

1. Uncertainty Principle (UP) is the basic constraint on $M^8 - H$ duality and fixes the form of $M^8 - H$ duality at the space-time level.

   One takes the momentum projection p in M^4 - an algebraic integer for cognitive representations and quarks are at these points, not all - and maps it to a point of $M^4 \subset M^4 \times CP_2$ that is to a point of $X^4 \subset H$. One assigns to p a geodesic line in the direction of momentum beginning at the common center of all CDs. In this way the slicing by mass shells of $M^4 \subset M^8$ is mapped to a slicing by CDs inside CDs (Russian doll-like structure).

2. p is mapped to the intersection of this geodesic line with the boundary of CD. One obtains the analog of the pattern produced by diffraction from the lattice. In particular, the intersections of the geodesics with the $t = T$ plane above the center point of CD form a reciprocal lattice, whose projection to the 2-D surface of a large 2-sphere corresponds to the standard diffraction pattern. One would be happy if one would obtain a lattice, rather than its reciprocal.

   As if there were a lattice around the center of the ball producing the diffraction pattern as a projection of the reciprocal lattice to the heavenly sphere. Intuition would suggest that this must be the case but one must be very cautious.

3. The momenta of quarks (or atoms) are therefore mapped to the light-cone boundaries of CD and basically define boundary values for the induced quark fields for quarks composing both proton, nuclei, and even electrons. These fields would be localized at these points at the boundary of CD and disperse in the interior. Induced spinor fields are second quantized H-spinor fields restricted to space-time surface and obeying modified Dirac equation for induced geometry and determined by variational principle.

   One can assign to the points at the boundary of CD corresponding to the image of the reciprocal lattice localized states of atoms of the lattice (many-quark states). At quark level this corresponds to a superposition of spinor harmonics of H localized to the point of the boundary (this corresponds to so-called light-cone quantization). This would dictate the time evolution of the induced spinor field inside the space-time surface and it would reflect the data coding for the reciprocal lattice.

4. Does this mean the emergence of lattice (as desired) or of reciprocal lattice in the interior? Since the lattice points by definition would correspond to peaks of plane waves generated by the reciprocal lattice at the boundary of CD would expect that the peak positions define the lattice.

One can also wonder whether one could one define $M^8 - H$ duality so that it would take momentum lattice in M^8 to its dual in H? The notion of dual lattice makes sense for the lattice defined by the extension. If one defines the cognitive representation in M^8 by selecting a tessellation at the mass shell of M^8 (this might follow the conditions for bound states), one could map the momenta of tessellations to their duals and would obtain the desired result in H. It is however not clear whether the map of tessellation to its dual (if it exists) can be completed to a continuous map of H^3 to itself.

2. $M^8 - H$ duality at the level of WCW

It seems that the proposed description need not be enough to realize UP at the level of H and the "world of classical worlds" (WCW) . The objection is that localized states in M^8 correspond to delocalized states at the level of H.

The above description maps quarks at points of $X^4 \subset M^8$ to states of induced spinor field localized at the 3-D boundaries of CD but necessarily delocalized into the interior of the space-time surface $X^4 \subset H$. This is analogous to a dispersion of a wave packet. One would obtain a wave picture in the interior and the lattice should emerge.

1. The basic observation leading to TGD is that in the TGD framework a particle as a point is replaced with a particle as a 3-surface, which by holography corresponds to 4-surface.

   Momentum eigenstate corresponds to a plane wave. Now planewave could correspond to a delocalized state of 3-surface associated with a particle in M^4 and by holography that of 4-surface.

2. A generalized plane wave would be a quantum superposition of shifted space-time surfaces with a phase factor determined by 4-momentum. This suggests that $M^8 - H$ duality should map the point of M^8 containing an object with momentum p to a generalized plane wave and this is assumed.

   This would also define WCW description. Recent physics relies on the assumption about single background space-time: WCW is effectively replaced with M^4 since 3-surface is replaced with point and CP_2 is forgotten so that one must introduce gauge fields and metric as primary field variables.

3. For cognitive representations, momenta are given by algebraic integers. Lattice plane waves can be idealized as waves in a discrete lattice. This would suggest that the plane wave is replaced by a discretized plane wave corresponding to the points of H at which the plane wave has the same value. One can say that one counts only the wave crests and thus only the information about wavelength and frequency.

4. For reciprocal momenta, one obtains a wave function in H for the shifted images of the 3-surface/4-surface labelled by a vector of the reciprocal lattice in H and this wave function can be regarded as a wave function with the periodicities of lattice.

The WCW picture is necessary if one wants to take into account WCW degrees of freedom. In the approximate description of phenomena involving only elementary particles constructible from quarks, WCW is not absolutely necessary.

Galois confinement and lattice like structures

It is interesting to look more explicitly at the conditions for the Galois confinement.

Single quark states have momenta, which are algebraic integers generated by so called integral basis (`https://cutt.ly/SRuZySX`) analogous to unit vectors of momentum lattice but for single component of momentum as vector in extension. There is a theorem stating that one can form the basis as powers of a single root. It is also known that irreducible monic polynomials have algebraic integers as roots.

1. In its minimal form Galois confinement states that only momenta, which are rational integers, are allowed by Galois confinement. Note that for irreducible polynomials with rational coefficients one does not obtain any rational roots. If one assumes that single particle states can have an arbitrary algebraic integer as a momentum, one also obtains rational integers for momentum values. These states are not at mass - or energy shell associated with the single particle momenta.

2. A stronger condition would be that also the inner products of the momenta involved are real so that one has $Re(p_i) \cdot Im(p_j) = 0$. For $i = j$ this gives a condition possible only for the real roots for the real polynomials defining the space-time surface.

To see that real roots are some facts about the realization of the co-associativity condition [L114] are necessary.

1. The expectation is that the vanishing condition for the real part (in a quaternionic sense) of the octonionic polynomial gives a co-associative surface. By the Lorentz symmetry one actually obtains as a solution a 6-D complex mass shell $m_c^2 \equiv m_{Re}^2 - m_{Im}^2 + 2iRe(p) \cdot Im(p) = r_1$, where the real and imaginary masses are defined are $m_{Re}^2 = Re(p)^2$ and $m_{Im}^2 = Im(p)^2$ and r_1 is some root for the odd part of the polynomial P assumed to determining the 4-surface.

2. This surface can be co-associative but would also be co-commutative. Maximally co-associative surface requires quaternionic normal space and the proposal is that the 6-surface having a structure of S^2 bundle defines as its base space quaternionic 4-surface. This space would correspond to a gauge choice selecting a point of S^2 at every point of M^4. To a given polynomial one could assign an entire family of 4-surfaces mapped to different space-time surfaces in H. A possible interpretation of gauge group would be as quaternionic automorphisms acting on the 2-sphere.

Concerning Galois confinement, the basic result is that for complex roots r_1 the conditions $Re(p_i) \cdot Im(p_i) = 0$ cannot be satisfied unless one requires that r_1 is real. Therefore the stronger option makes sense for real roots only.

Despite this one can also consider the strong option for real roots. There are two cases to consider. The first case corresponds to complex 4-surfaces for which complex mass squared is equal to a root of the odd part of the polynomial determining the space-time surface. The real part of these surfaces in the sense that the imaginary part of mass squared vanishes is 4-D.

These conditions lead to a spectrum of 4-momenta and masses with each mass involving a subset of momenta. One can form Galois singlets also from states with different masses.

1. One can assign to each algebraic integer n_A a Galois invariant defined as the determinant $det(N(n_A))$ of the matrix $N(n_A)$ of the linear transformation defined by a multiplication of the units of algebraic integers by n_A. The algebraic integers n_A with the same value of $det(N(n_A))$ can belong to the orbit of Galois group. Physical intuition suggests that the values of mass squared (energy) are the same for these integers in the case of H^3.

2. One expects that the group $SL(2, Z_A)$, where Z_A denotes algebraic integers associated with the polynomial defining the space-time surface produces new solutions from a given solution. This would be a discrete version of Lorentz invariance. Tessellations of H^3 are highly suggestive as bound states.

3. Since Galois group is finite, the only possibility is that Galois groups corresponds to a subgroup of rotations permuting algebraic integers with the same time-component of 4-momentum. Therefore the discrete subgroups of $SO(3)$ associated with the inclusions of hyper-finite factors of type II_1 would emerge.

The situation for the surfaces $E = E_n$, E_n the root of the polynomial P defined the 4-surface situation is different.

1. Single particle states correspond to a discrete set of in general complex mass values extending from E_n to 0. The number of momenta with given m is finite and one obtains a slicing of the space of 3-momenta by spheres $S^2(m)$ with constant mass having the allowed points of $S^2(m)$ at the orbits of Galois group. Also now single particle states are impossible but one obtains many-particle states and also lattice like structures are expected. A given mass m can correspond to several energies $E_n(m)$ giving this value of mass.

2. Also now it is possible to construct Galois singlets as many-particle states and these have rational integer valued momenta. In condensed matter, one has energy bands such that the energy inside the band depends on the momentum k. Could one think that the values of energy form bands decomposing to discrete energy levels?

Two further remarks are in order.

1. Besides the simplest realization also a higher level realization is possible: Galois singlets are not realized in the space of momenta but in the space of wavefunctions of momenta. States of an electron in an atom serve as an analogy. Origin is invariant under the rotation group and electron at origin would be the classical analog of a rotationally invariant state. In quantum theory, this state is replaced with an s-wave invariant under rotations although its argument is not.

   In the recent situation, one would have a wave function in the space of algebraic integers representing momenta, which are not Galois invariants but if one has Galois singlet, the average momentum as Galois invariant is ordinary integer. Also single-quark states could be Galois invariant in this sense.

2. The proposal inspired by TGD inspired quantum biology is that the polynomials defining 4-surface in M^8 vanish at origin: $P(0) = 0$. One can form increasingly complex 4-surfaces in M^8 by forming composite polynomials $P_n \circ P_{n-1} \circ ... \circ P_1$ and these polynomials have roots of P_1....and P_{n-1} as their roots. These roots are like conserved genes: also the momentum spectra of Galois singlets are analogous to conserved genes. This construction applies to Galois singlets in both classical and quantal sense.

   At the highest level one can construct states as singlets under the entire Galois group. One can use non-singlets of previous level as building bricks of these singlets.

About the analogs of Fermi torus and Fermi surface in H^3

Fermi torus (cube with opposite faces identified) emerges as a coset space of E^3/T^3, which defines a lattice in the group E^3. Here T^3 is a discrete translation group T^3 corresponding to periodic boundary conditions in a lattice.

In a realistic situation, Fermi torus is replaced with a much more complex object having Fermi surface as boundary with non-trivial topology. Could one find an elegant description of the situation?

1. Hyperbolic manifolds as analogies for Fermi torus?

The hyperbolic manifold assignable to a tessellation of H^3 defines a natural relativistic generalization of Fermi torus and Fermi surface as its boundary. To understand why this is the case, consider first the notion of cognitive representation.

1. Momenta for the cognitive representations [L172] define a unique discretization of 4-surface in M^4 and, by M^8-H duality, for the space-time surfaces in H and are realized at mass shells $H^3 \subset M^4 \subset M^8$ defined as roots of polynomials P. Momentum components are assumed to be algebraic integers in the extension of rationals defined by P and are in general complex.

   If the Minkowskian norm instead of its continuation to a Hermitian norm is used, the mass squared is in general complex. One could also use Hermitian inner product but Minkowskian complex bilinear form is the only number-theoretically acceptable possibility. Tachyonicity would mean in this case that the real part of mass squared, invariant under $SO(1,3)$ and even its complexification $SO_c(1,3)$, is negative.

2. The active points of the cognitive representation contain fermion. Complexification of H^3 occurs if one allows algebraic integers. Galois confinement [L172, L164] states that physical states correspond to points of H^3 with integer valued momentum components in the scale defined by CD.

   Cognitive representations are in general finite inside regions of 4-surface of M^8 but at H^3 they explode and involve all algebraic numbers consistent with H^3 and belonging to the extension of rationals defined by P. If the components of momenta are algebraic integers, Galois confinement allows only states with momenta with integer components favored by periodic boundary conditions.

Could hyperbolic manifolds as coset spaces $SO(1,3)/\Gamma$, where Γ is an infinite discrete subgroup $SO(1,3)$, which acts completely discontinuously from left or right, replace the Fermi torus? Discrete translations in E^3 would thus be replaced with an infinite discrete subgroup Γ. For a given P, the matrix coefficients for the elements of the matrix belonging to Γ would belong to an extension of rationals defined by P.

1. The division of $SO(1,3)$ by a discrete subgroup Γ gives rise to a hyperbolic manifold with a finite volume. Hyperbolic space is an infinite covering of the hyperbolic manifold as a fundamental region of tessellation. There is an infinite number of the counterparts of Fermi torus [L137]. The invariance respect to Γ would define the counterpart for the periodic boundary conditions.

   Note that one can start from $SO(1,3)/\Gamma$ and divide by $SO(3)$ since Γ and $SO(3)$ act from right and left and therefore commute so that hyperbolic manifold is $SO(3)\setminus SO(1,3)/\Gamma$.

2. There is a deep connection between the topology and geometry of the Fermi manifold as a hyperbolic manifold. Hyperbolic volume is a topological invariant, which would become a basic concept of relativistic topological physics (`https://cutt.ly/RVsdNl3`).

   The hyperbolic volume of the knot complement serves as a knot invariant for knots in S^3. Could this have physical interpretation in the TGD framework, where knots and links, assignable to flux tubes and strings at the level of H, are central. Could one regard the effective hyperbolic manifold in H^3 as a representation of a knot complement in S^3?

   Could these fundamental regions be physically preferred 3-surfaces at H^3 determining the holography and M^8-H duality in terms of associativity [L114, L115]. Boundary conditions at the boundary of the unit cell of the tessellation should give rise to effective identifications just as in the case of Fermi torus obtained from the cube in this way.

2. De Sitter manifolds as tachyonic analogs of Fermi torus do not exist

Can one define the analogy of Fermi torus for the real 4-momenta having negative, tachyonic mass squared? Mass shells with negative mass squared correspond to De-Sitter space $SO(1,3)/SO(1,2)$ having a Minkowskian signature. It does not have analogies of the tessellations of H^3 defined by discrete subgroups of $SO(1,3)$.

The reason is that there are no closed de-Sitter manifolds of finite size since no infinite group of isometries acts discontinuously on de Sitter space: therefore these is no group replacing the Γ in H^3/Γ. (`https://cutt.ly/XVsdLwY`).

3. Do complexified hyperbolic manifolds as analogs of Fermi torus exist?

The momenta for virtual fermions defined by the roots defining mass squared values can also be complex. Tachyon property and complexity of mass squared values are not of course not the same thing.

1. Complexification of H^3 would be involved and it is not clear what this could mean. For instance, does the notion of complexified hyperbolic manifold with complex mass squared make sense.

2. $SO(1,3)$ and its infinite discrete groups Γ act in the complexification. Do they also act discontinuously? p^2 remains invariant if $SO(1,3)$ acts in the same way on the real and imaginary parts of the momentum leaves invariant both imaginary and complex mass squared as well as the inner product between the real and imaginary parts of the momenta. So that the orbit is 5-dimensional. Same is true for the infinite discrete subgroup Γ so that the construction of the coset space could make sense. If Γ remains the same, the additional 2 dimensions can make the volume of the coset space infinite. Indeed, the constancy of $p_1 \cdot p_2$ eliminates one of the two infinitely large dimensions and leaves one.

Could one allow a complexification of $SO(1,3)$, $SO(3)$ and $SO(1,3)_c/SO(3)_c$? Complexified $SO(1,3)$ and corresponding subgroups Γ satisfy $OO^T = 1$. Γ_c would be much larger and contain the real Γ as a subgroup. Could this give rise to a complexified hyperbolic manifold H^3_c with a finite volume?

3. A good guess is that the real part of the complexified bilinear form $p \cdot p$ determines what tachyonicity means. Since it is given by $Re(p)^2 - Im(p)^2$ and is invariant under $SO_c(1,3)$ as also $Re(p) \cdot Im(p)$, one can define the notions of time-likeness, light-likeness, and space-likeness using the sign of $Re(p)^2 - Im(p^2)$ as a criterion. Note that $Re(p)^2$ and $Im(p)^2$ are separately invariant under $SO(1,3)$.

   The physicist's naive guess is that the complexified analogs of infinite discrete and discontinuous groups and complexified hyperbolic manifolds as analogs of Fermi torus exist for $Re(P^2) - Im(p^2) > 0$ but not for $Re(P^2) - Im(p^2) < 0$ so that complexified dS manifolds do not exist.

4. The bilinear form in H^3_c would be complex valued and would not define a real valued Riemannian metric. As a manifold, complexified hyperbolic manifold is the same as the complex hyperbolic manifold with a hermitian metric (see `https://cutt.ly/qVsdS7Y` and `https://cutt.ly/kVsd3Q2`) but has different symmetries. The symmetry group of the complexified bilinear form of H^3_c is $SO_c(1,3)$ and the symmetry group of the Hermitian metric is $U(1,3)$ containing $SO(1,3)$ as a real subgroup. The infinite discrete subgroups Γ for $U(1,3)$ contain those for $SO(1,3)$. Since one has complex mass squared, one cannot replace the bilinear form with hermitian one. The complex H^3 is not a constant curvature space with curvature -1 whereas H^3_c could be such in a complexified sense.

17.2.2 Topological condensed matter physics and TGD

Topological considerations have become an essential part of condensed matter physics. In condensed matter physics the topology of patterns of order parameters and of Fermi surface play a key role. In the TGD framework the topology of space-time surface in X^4 and the dual 4-surface in M^8 having an interpretation as an analog of momentum space are non-trivial and the question how this could reflect itself in condensed matter physics.

Topology of the energy bands in solids

The notions of 2-D face states, edge states, and corner states seem to be behind many topological states. It is interesting to see what they could correspond to in the TGD framework.

One can imagine two alternative guesses.

1. At H level 4-surfaces as analogous to 4-D complexified momentum space are algebraic surfaces, that is 4-D "roots" of polynomials.nThese algebraic surfaces have singularities at the level of H mapped to singularities at the level of H. They can have corners, edges, and intersection points, 2-D singular surfaces. At the level of H they correspond to strings, string world sheets, and light-like orbits of partonic 2-surfaces: in this case the line singularity is blown up to a 3-D singularity.

2. These singularities need not however correspond as such to the above listed singularities since the active points of cognitive representation defined by mometa which are algebraic integers do not correspond as such to the physical states. Rather, physical states are Galois confined bound states of quarks for a given extension of rationals and it is the energy and momentum spectrum of these states which is relevant.

The second guess is based on the idea that the energy bands correspond to substructures formed by discrete 4-momenta of Galois confined states.

1. Cognitive representation consists of momenta for which momentum components are algebraic integers. Some of these points are occupied by quarks, they are "active" (this brings in mind Bohm's notion of active information).

Physical states must have total momentum which is rational integer using the unit defined by the largest CD involved defining IR cutoff. Smallest CD defines the UV cutoff. This means Galois confinement in momentum degrees of freedom. Same happens also in spinorial degrees of freedom.

2. Bloch waves are of the form $exp(ikx)u(x)$ where u is a periodic function with the periods of lattices and k is continuous pseudo-momentum. k can be restricted to the first Brillouin zone defined as the counterpart of a lattice cell in momentum space. For Bloch states the translational symmetry is broken down to a discrete subgroup of the translation group acting as symmetries of lattices and therefore of u.

   For Bloch waves, the wave vectors and also energies would be quantized by periodic boundary conditions which would mean in the TGD framework that the momenta are integer valued using a suitable unit. The phase factors $epx(iknL)$ would be roots of unity and therefore number theoretically universal. This requires that $kL = m$ is a rational integer.

3. Mass shells as hyperboloids $H^3(m)$ are of special interest as are also the 3-D M^4 projections of 6-D universal brane-like entities. The latter are 3-surfaces $E = E_n$ where E_n is the root of the polynomial defining the 4-surface in M^8. Hyperboloid allows tessellations and the Euclidean 3-space E_3 defined $E = E_n$ surfaces inside light-cone allows lattices expected to emerge naturally from Galois confinement.

4. This picture suggests that each $E = E_n$ shell gives rise to real energy shells with rational integer valued energy and momentum components as sums of the multiples of algebraic integers for quarks. The allowed momenta for given total energy would correspond to states assignable to a given total energy analogous to a given $E = constant$ 2-surface of an energy band. The singular topologies could correspond to intersections or touchings of these bands.

One cannot exclude the possibility that the states with quarks with momenta at the singular pieces of 4-surfaces (touching along 0,1, or 2-D surface) could correspond to these singularities. For instance, the touching of two energy bands could correspond to this kind of singularity.

The article of Carpentier [D30] gives a nice introduction to the topology of bands in solids and it is interesting to see the situation from the TGD point of view. Topological insulators, semimetals, so called Majorana fermions, etc. involve singular situations in which energy bands touch each other and the question is what this means at the level of M^8.

Can one have a situation in which different energy bands touch each other at a single point or possibly along 1-D or 2-D (discrete) surfaces? The discussion is very similar for mass shells $H^3(m)$ and energy bands $E^3(E_n)$ so that only the case of E^3 is discussed.

1. Consider first energy bands E_n. For a given mass m, one obtains a set of energies E_n corresponding to the roots of P. When two roots co-incide, entire energy bands coincide. This would be however the situation for single quark states which are not possible by Galois confinement for irreducible polynomials with rational coefficients.

2. Two Galois confined states belonging to different energy bands E_n have energies, which are sums of the integer combinations of rational parts of energies E_n of single particle states. These sums are identical for some states associated with E_n and E_n.

   One can imagine that these bound states energies are the same for two different values of E_n so that bands formed by bound states can touch. Even higher-dimensional intersections can be considered. Similar situation might occur for the Galois confined states associated with different mass hyperboloids.

3. In condensed matter situation momenta are defined only modulo the addition of lattice momentum, which is multiple of $\hbar_{eff}/a = N\hbar_{eff}/L$ where a and L are UV and IR length scale cutoffs defined by the smallest and largest CDs. This condition would loosen the conditions for touching.

Topological insulators in the TGD framework

There is a nice summary by Suichi Murakami about topological insulators [D126] helpful for a newcomer to the field.

Let us summarize the basic physical properties of spin waves.

1. Topological insulator is an insulator in the bulk and therefore has a gap between valence and conduction bands. TIs have conducting surface states, which can be edge states for 2-D TIs and surface states for 3-D TIs (Dirac cone in momentum space). The edge/surface states correspond to edges/surfaces in x-space. Fig. 1 of [D126] `https://cutt.ly/yRGDV1U`) provides an illustration of edge and surface states. As Fig.3 associated with a simple model for surface states illustrates, edge and surface states have a finite penetration depth to the bulk.

   For 2-D TIs, valence and conduction bands touch in 1-D k-space (see Fig. 2 of `https://cutt.ly/yRGDV1U`), which also illustrates the Dirac cone). The states with degenerate energies correspond to pairs of electrons with opposite spins and momenta related by the condition $k_1 = -k_2$ modulo lattice momentum. The electrons at opposite edges/surfaces move in opposite directions and have opposite spins. The net charge current vanishes but there is net spin current.

2. Spin orbit coupling is present. Orbital momentum is mathematically like magnetic field B effectively replaced with angular momentum L. The analog of torque for B is replaced with torque $s \times L$. This gives rise to counter propagating opposite spins and spin currents.

3. For TIs, T is not violated but PT and P are violated. The presence of magnetic fields breaking T thus destroys the edge/surface conductivity. The states are helical and have no definite parity since P changes the helicity. Superposition of states with opposite momenta and spins occurs so that spin current is formed. By the absence of magnetic field back scattering destroying the conductivity is not possible since this would require change of both spin direction and momentum direction.

   Spin orbit $(L \cdot S)$ interaction is required for the formation of spin currents. L comes from the rotational motion of electrons along the surface or edge; it tends to turn L and S in the same direction so that spin waves emerge.

4. Z_2 topological quantum number Z is conserved and reflects time reflection invariance. Z can be understood from the graph of energy at the conduction band, which has suffered splitting due to the spin orbit interaction so that energy is reduced in the conduction band. The graph of energy has two topologically non-equivalent forms. The graph either connects valence and conduction bands or not. In the latter case one has an ordinary insulator (I). In the first case one has TI.

   For I, the graph has 2 or 0 intersections with the graph for the lower energy of the spin-slit state. TI has only one intersection. Perturbations invariant under time reversal do not affect the situation. More general formulation for the Z_2 invariance is in terms of the odd/even character of intersections.

Could TGD add something interesting to the notion of TI?

1. Mathematically the spin-orbit interaction is analogous to that between magnetic moment and magnetic field except that it couples orbital motion and spin and forces the correlation between spin direction and momentum and therefore the formation of a spin wave. Magnetic field does not cause this although it would parallelize spins with itself.

2. In Quantum hydrodynamics (QHD) according to TGD [L146], the circular orbital motion could be accompanied by a Kähler magnetic field in the direction of angular motion possibly assignable to a monopole flux tube.

   Could this make sense now? There would be 2 magnetic fields of opposite direction associated with the two directions of rotation of electrons. They should reside at different space-time sheets. At QFT limit the net B would vanish but make itself visible as a spin current. The effect could be therefore seen as evidence in favour of many-sheeted space-time.

3. One can also consider variants of this picture. Kähler magnetic field at flux tubes would be an essential element. This can come from both M^4 and CP_2 and one can ask whether only M^4 contribution is present. Velocity of current flow would be proportional to Kaehler gauge potential which would be of opposite sign a 2 space-time sheets. This would not break T at the QFT limit.

   Note that neutrinos would experience this contribution and this provides an experimental test: could the strange behavior of solar solar neutrinos and also in laboratory be understood in terms of M^4 Kähler field in Sun or in laboratory?

Discrete symmetries at the level of M^8

Discrete symmetries T, PT, and CP and their violations are closely involved with the phenomena of topological condensed matter physics. The challenge is to understand T, PT, and CP violations at the level of M^8.

The definition of discrete symmetries in $H = M^4 \times CP_2$ was discussed already in my thesis [K3] [L3] about TGD. In particular, geometrically C corresponds to a complex conjugation in CP_2. At the level of M^8, these discrete symmetries should allow a realization as symmetries of the polynomials defining the space-time surface.

P changes the direction of 3-momenta. The counterpart of the Fermi surface should therefore become reflection asymmetric in the violation of P. The reflections are with respect to the middle point of the CD. T changes the sign of energy and half cones of CD in H and mass shells with opposite sign in M^8 are permuted. Also the time reversed classical time evolutions are different if T is violated. One can ask whether the violation of P implies a compensating violation of T (by CPT)?

Both M^4 and CP_2 contributions to Kähler magnetic field could induce T violation and M^4 contribution could do this in long scales. If T violation takes place at the fundamental level, topological instanton term which is divergence of axial current appearing in Kähler action could induce it. The analogs of instantons induce a violation of the conservation of monopole charge. This is possible only if the M^4 projection of the space-time surface is 4-dimensional. Analogous statement applies in the case of CP_2 and CP_2 type extremals have indeed 4-D CP_2 projection.

C involves a complex conjugation and changes the signs of charges. What does this mean in M^8? The normal spaces of 4-surface in M^8 containing a preferred complex plane or having integrable distribution of them are labelled by CP_2 coordinates. They are mapped to their complex conjugates.

What happens to the polynomial defining the space-time surface? Polynomial itself is real and cannot change but its algebraic continuation to an octonionic polynomial can be different. Indeed, real function can be algebraically continued to a complex function or its conjugate.

1. The complexified octonions involve a commutative imaginary unit i. Complex conjugation with respect to i leaving the real polynomial invariant but leading to a complex conjugate of the 4-surface looks like a reasonable first guess. One can however argue that the conjugation with respect to i is associated with T.

   Recall, that the proposal [L114] that co-associative 4-surfaces in M_c^8, having an interpretation as an analog of momentum space, correspond to 4-surfaces identifiable as roots of complexified octonionic polynomials yielded a cold shower. Due to Lorentz symmetry, naive counting of dimensions fails and one obtains 2 polynomial equations with complexified mass as argument stating that the mass squared is a complex root of the polynomial. The solutions correspond to common roots and are 6-D.

   The solution of the problem would be that 4-surface is the intersection of 6-surface and its complex conjugate with respect to the commuting imaginary unit i. The common root must be real but the points in the intersection can be complex. Hence the action of T on X^4 is in general non-trivial and a spontaneous violation of T is possible at momentum space level.

2. Also octonions allow conjugation. In M^4 sector conjugations for octonionic units this would give rise to P and T. In the complement E^4 the conjugations for 2-D subspaces are also possible.

Could C relate to the commutative normal spaces of 6-D surfaces labelled by points of the CP_2 twistor space $SU(3)/U(1)\times U(1)$. Could the complex conjugation in the 2-D $U(1)\times U(1)$ fiber of this space, correspond to C. The complex conjugation would therefore act on the (integrable distribution of) 2-D normal spaces of these 6-D surfaces and would not act in $M^4 \subset M^8$.

3. At the level of H, C and P are violated for the Dirac equation for a fixed H-chirality of quarks spinors and also for the modified Dirac equation, which corresponds to the octonionic Dirac equation in M^8. Also CP is violated for the modified Dirac equation in H if the action contains topological Kähler instanton terms. This violation should have a counterpart for the octonionic Dirac equation. Since this equation selects a single point at 4-surface, the CP violation for the 4-surface could induce CP violation.

Instantons in the TGD framework

Instantons induce violations of CP and therefore of T in gauge theories such as QCD.

It is interesting to consider the interpretation of Q as an instanton number.

1. Montonen-Olive duality (`https://cutt.ly/HE6gMX6`) is associated with a gauge theory in which magnetic and electric charges are rotated so that the coefficient of YM action in the action exponential is replaced with the quantity $\tau = \theta/2\pi + 4\pi i/g^2$.

2. τ is invariant under modular transformations $SL(2,Z)$ generated by a shift $\tau \rightarrow \tau+1$ and $\tau \rightarrow 1/\tau$. The inversion symmetry has strong implications for the understanding of the strong coupling phases of quantum field theories, in which magnetic monopoles replace particles as elementary objects.

3. In the gauge theory θ is analogous to momentum. The vacuum state is plane-wave like superposition $\sum_N exp(iN\theta/2pi))|N\rangle$ of vacuum states differing by a topologically non-trivial gauge transformation as a map $S^3 \rightarrow G$. Note that ball B^3 is effectively S^3 if the gauge transformations are trivial at its boundary. The homotopy equivalence classes of gauge transformations are labelled by the winding number N. N characterizes instantons changing the magnetic charge by N units so that the ground state is a superposition of states with varying values of N transforming by a phase factor under a topologically non-trivial gauge phase transformation.

Consider now the situation in the TGD framework.

1. There are differences between TGD and gauge theory context. Gauge group is replaced with $U(1)$ having a trivial third homotopy group.

   Could a localized version of the quaternionic automorphism group $SO(3)$ serve as a counterpart of a gauge group. The surfaces in M^8 can be indeed thought of as maps from M^4 to the quaternionic automorphism group G_2.

2. The non-trivial gauge transformations - $U(1)$ instantons - are clearly possible. The non-trivial gauge transformation could correspond to a tological non-trivial gauge transformation $A+nd\phi$, where ϕ is angle coordinate around axis going through a line singularity as a puncture in 3-space associated with the time-like line connecting the tips of CD. Note however that color gauge action reduces to the Kähler action so that both interpretations might make sense.

3. Kähler action generalizes to

$$S_K = \frac{1}{\alpha_K}\int J\wedge *J\sqrt{g} - (\frac{}{i}\theta/2\pi)\int J\wedge J\sqrt{g} \quad . \tag{17.2.1}$$

   Since only the exponent of S_K matters in the vacuum functional, I contributes a non-trivial phase factor to the Kähler function only for $exp(i\theta/2\pi) \neq 1$ ($\theta \neq n2\pi$). One can assign θ

to both M^4 and CP_2 parts of Kähler action. The value of instanton term characterizes the non-conservation of the axial (monopole) current having instanton term as divergence.

If one assumes self-duality of the gauge field true for instantons interpreted as gauge fields in S^4, the action reduces to ordinary Kähler action with coefficient proportional to τ. Interestingly, the quaternionic projective space M^4/Q can be regarded as S^4 so that Hamilton-Jacobi structures of M^4 proposed to serve as moduli space for the self-dual Kähler fields in M^4 could appear naturally.

4. $I(CP_2)$ is non-trivial due to the non-trivial homology of CP_2. $I(CP_2)$ gives a 3-D contribution, which appears at the boundaries between Minkowskian and Euclidean regions of the space-time surface as a topological Chern-Simons term and affecting the boundary conditions at the light-like orbits of partonic 2-surfaces in this way. These boundaries have interpretations as light-like parton orbits carrying quarks lines.

5. If CD contains a time-like "hole" along the axis connecting the tips of CD, also $I(M^4)$ is non-trivial. One can imagine extremals for which a genuine hole in the metric sense is generated along the M^4 time axis. What is required is that the induced metric using M^4 coordinates is of the form $dt^2 - dr^2 - (r^2 + r_0^2)d\Omega^2$. These holes should correspond to "blow-ups" of singularities of the algebraic surface in M^8. Now the 3-D tangent spaces would have no special direction at the singular points. For CP_2 type extremals the same would hold true at the level of M^8. Could this "hole" be the TGD counterpart of the blackhole of GRT and could it serve as a signature of CD?

6. $J \wedge J$ is non-vanishing only if the M^4 *resp.* CP_2 projection is 4-D. This does not guarantee self-duality unless also the induced metric reduces to the metric of M^4 *resp.* CP_2. This is true for the canonical embedding of M^4 and for CP_2 type extremals having light-like M^4 projection. Self-duality is true for the Kähler forms of M^4 and CP_2 but not for the induced Kähler forms $J(M^4)$ and $J(CP_2)$. Therefore classical gravitation breaks the self-duality and Montonen-Olive duality in the TGD framework. The possibility of extremals with M^4 and CP_2 projections smaller than $D = 4$ implies that θ is effectively vanishing for them.

$\theta(M^4)$ and $\theta(CP_2)$ as fundamental parameters obeying number theoretical coupling constant evolution would imply a violation of CP symmetry in both M^4 and CP_2 sector. Are the instanton terms present at the fundamental level or are they present only at the QFT limit and induced as a description of spontaneous violation of CP and T? Indeed, as in the condensed matter systems, CP violation could be caused by the magnetic part of the generalized Kähler action even without instanton term.

1. The strong CP problem of QCD is due to instanton inducing an instanton term in effective color YM action. The parameter characterizing the violations should be very small.

   In the TGD framework, a proposal for a solution of this problem could be that the counterpart of the color gauge field does not allow instantons. Here one must be cautious however. The components of the proposed classical color gauge field are proportional to the products of Hamiltonians of color isometries and Kähler form and instanton terms for the induced Kähler form would induce a CP violation. Indeed, Kähler action can be also regarded as a color gauge action and therefore instanton term makes sense for it.

2. Could $\theta(M^4)$ and $\theta(CP_2)$ induce a CP violation consistent with the observed CP violation in hadron physics or does one encounter the strong CP problem also in the TGD framework?

   If hadrons are string-like objects, they correspond to flux tubes as deformations of strings. For deformations with dimension $D < 4$, instanton term vanishes. Could this be the reason for the small violation of CP at the level of M^4? For CP_2 type extremals, $I(CP_2)$ is non-vanishing but equal to the Kähler action and non-dynamical for the basic CP_2 type extremals since dynamics in in M^4 degrees of freedom with CP_2 taking the role of arena of physics. Could these effects make the hadronic CP violation small?

3. Matter-antimatter asymmetry is a CP violation, which does not look small at all. If the mechanism is actually a small CP violation implying that rate for the condensation of anti-quarks to leptons is slightly larger than that for the condensation of quarks to antileptons, the

matter antimatter symmetry could emerge during a very early period of the cosmic evolution when leptons were formed.

4. There are also further questions. Could the QCD instantons have TGD counterparts as Hamilton-Jacobi structures and also as analogs of S^4 instantons in the quaternionic projective space of octonions which would be 4-D mass hyperboloid H^4 as Minkowski analog of S^4 but with space-like signature. Could the parameter θ in the instanton term of Kähler action induce the formation of the ground state (θ vacuum) as a superposition of space-time surfaces with various instanton numbers in the sector of WCW consting space-time surface with 4-D M^4 and/or CP_2 projection?

17.2.3 The new view about classical fields

The TGD view about classical gauge fields differs in many aspects from the Maxwellian and gauge theory view since the classical fields associated with the system define a geometric what I call its field body (magnetic body (MB)) is the term that I have used. MB can carry also electric fields very closely related to magnetic fields unless the corresponding space-time surface is static. MB consists of flux tubes and flux sheets.

There are 2 kinds of cosmic strings: with monopole flux (see **Fig. 18.4**) or without it. The simplest cases correspond to Y^2, which is either a homologically non-trivial or trivial geodesic sphere of CP_2.

This predicts two kinds of magnetic flux tubes and two kinds of magnetic and electric fields. This suggests a possible interpretation for the fields H, M, B appearing in Maxwell's theory as field H carrying monopole flux requiring no current as source, magnetization M as non-monopole part induced by H , and $B = H + M$ as their sum experienced by test particle in many-sheeted space-time. The same would apply to D, P and E. If this interpretation is correct, TGD would have been secretly present in Maxwell's theory from the beginning.

The proposal that MB serves as a seat for dark matter as $h_{eff} = nh_0$ phases is central in the TGD inspired theory of consciousness and living matter. MB would be the boss and receive sensory input from ordinary biomatter and control it. This would happen in terms of dark photons with frequencies in EEG range and also in other ranges. The energies would be in the visible and UV range assigned to biophotons to which the dark photons would transform.

Magnetic flux tubes could accompty quantum vortices appearing in various macroscopic quantum phases. Even the hydrodynamical vortices in macroscopic scales could correspond to quantum coherent magnetic flux tubes with a large value of h_{eff} acting as a master forcing the coherent dynamics or ordinary matter. In hydrodynamics the classical Z^0 magnetic field, which in situations allowing skyrmions, is proportional to the induced Kähler form, could be important. Large parity breaking effects would be the prediction.

Also the view about radiation fields changes. Massless extremals (MEs)/topological light rays are counterparts for massless modes. They allow a superposition of modes with a single direction of massless momentum. The ordinary superposition of gauge potentials in gauge theory is replaced with union of space-time surfaces with common M^4 projection. The test particle experiences the sum of gauge potentials associated with various space-time sheets so that the gauge potentials effectively superpose. Ideal laser beam is a convenient analogy.

MEs are ideal for precisely targeted communications without dispersion and dissipation. MEs are soliton-like entities and one can ask whether MEs could provide a model for solitons or accompany solitons. TGD based model for nerve pulse involves Sine-Gordon solitons with large h_{eff} assigned to the cell membrane and dark Josephson radiation would have MEs as space-time correlate [K88, K41, K89].

MEs do not allow standing waves possible in Maxwell theory but a set theoretic union of parallel MEs can effectively give rise to standing waves. Lorentz transformations give rise to waves moving with arbitrary sub-luminal velocity. Even a superposition in which fields effectively sum up to zero but there is a non-vanishing energy density as sum of energy densities for the two MEs, is possible.

17.2.4 About quantum criticality in TGD

In TGD number theoretical vision about physics brings a new view about quantum criticality.

1. Quantum criticality is actually the basic assumption of TGD: the Kähler coupling strength α_K appearing in the classical action principle of TGD would be analogous to a critical temperature and have a discrete spectrum. This would make the theory unique. All space-time sheets are quantum critical but at QFT limit this is of course masked by the replacement of sheets with a single region of M^4 made curved.

2. At the number theoretical M^8 side there is no action principle. The universality of the dynamics could be seen as a manifestation of quantum criticality. Can α_K emerge at M^8 level somehow from scattering amplitudes in M^8 and have a number theoretical origin [L141].

   At the level of H coupling constants are visible only at the level of frames defining the space-time as an analog of soap film. The parts of the frame are images of singularities for the X^4 in M^8. The challenge is to understand how the singularities of the space-time surfaces determine α_K already at the level of M^8?

   p-adic thermodynamics for mass squared predicts a spectrum of temperatures with values coming as inverse integers [K61, K27]. Also this temperature quantization could be seen as a counterpart for the quantum criticality.

3. Quantum criticality involves long range correlations and the hierarchy of Planck constants characterizing them [K34, K35, K36, K37]. h_{eff} corresponds to a dimension of extension of rationals characterizing the space-time surfaces. At criticality there is quantum superposition of space-time surfaces with various values of h_{eff} corresponding to polynomials defining the X^4 and one value of h_{eff} is selected in state function reduction.

17.2.5 What infinite-volume limit could mean in TGD?

Infinite volume limit corresponds to both thermodynamic and QFT limit and should be understood in the TGD framework. The questions are what it means if the infinite volume limit is actually realized and whether this has practical consequences.

1. At the level of ZEO infinite volume limit means that the size of causal diamond (CD) as an analog of Nature given quantization volume becomes infinite. The scattering amplitudes coded by zero energy states conserve Poincare quantum numbers at this limit.

2. At the level of H the volume action vanishes since the p-adic length scale dependent cosmological constant $\Lambda \propto 1/L_p^2$ approaches zero at the limit when the p-adic length scale L_p characterizing the X^4 becomes infinitely large.

   If $\Lambda = 0$ phase is real, the action would reduce to mere Kähler action containing both M^4 contribution and CP_2. In this case, one would also have extremals of form $X^2 \times Y^2$ for which CP_2 projection if the Lagrangian manifold with vanishing induced Kähler form. These extremals receive a negative contribution to energy from M^2. Could the preferred extremal property exclude these solutions?

   Remark: If the sign of M^4 Kähler action is changed, the electric contribution to energy is positive and magnetic contribution negative. For string- like objects this would guarantee positive contribution.

3. In the number theoretic picture infinite volume limit in H could mean that polynomials defining $X^4 \subset M^8$ mapped to H are replaced with analytic functions with rational coefficients.

   Polynomials are assumed to vanish at origin (this guarantees that roots are "inherited" in their functional composition) and so should also the analytic functions. The inverse 1/f is infinite at origin and does not belong to the set so that one does not have a function field. Since one has only multiplication, one can speak about functional primes as in the case of polynomials.

   One can ask whether they should satisfy conditions guaranteeing that they can be regarded as polynomials of infinite order. Could one speak about polynomials of infinite degree as the limit of functional composites of polynomials with finite degree. As a matter of fact, infinite Galois groups are profinite groups and this requires this kind of inverse limit definition [L134].

A concrete example is provided by the iteration of a polynomial of finite degree [L134]. In this case the spectrum of roots contains a continuous part at the limit so that complex numbers as completion of rationals would emerge at the infinite volume limit much like the continuum spectrum of momenta emerges from a discrete spectrum.

17.2.6 The notions of geometric phase, Berry curvature, and fidelity in TGD?

Non-contractible ground state Berry phase in the loop over the parameter space is associated with QPTs and is associated Berry curvature defining non-trivial U(1) holonomy (`https://cutt.ly/RWy7Deq`) Geometric phase (`https://cutt.ly/6Wy7GIT`) is a more general notion. It can be associated with homotopically non-trivial loops. For homotopically trivial loop geometric phase is due to non-trivial holonomy manifesting itself as Berry curvature. The Aharonov-Bohm effect represents an example about non-trivial holonomy. Electrons pass along paths closing together a region containing a magnetic field, which vanishes at the paths. Berry phase can be associated with loops in the parameter space for the Hamiltonian modelling the system.

Fidelity [D134] `https://cutt.ly/VWy5sVj`) defines a metric in the space of parameter dependent quantum states. It could be induced from metric of the parameter space. The abrupt changes of fidelity serve as a signature of quantum criticality.

Is this possible at the level of WCW?

1. WCW is a Kähler manifold [K91, K53]. Finite-dimensional Kähler manifolds have a trivial homotopy group. Complex coordinates of WCW contributing to Kähler form and metric correspond to complex coordinates. In these degrees there should be no homotopically trivial loops so that topological phase is not possible. The curvature of the Kähler form can however have effects.

2. The remaining degrees of freedom are zero modes and define the analog of the base space in bundle theory. They appear as parameters - essentially classical background fields - in the Kähler metric and Kähler form. The topology in the zero modes can have non-trivial homotopy. Geometric phase could be assigned with homotopically trivial loops in the zero modes.

   At the infinite-volume limit the sub-WCW defined by the degenerate ground states with a Lagrangian manifold Y^2 as CP_2 projection (vanishing Kähler form and color gauge fields but non-vanishing weak gauge fields) is highly interesting. The preferred extremal property could exclude these space-time surfaces.

It seems that TGD could provide a unified description of all these exotic quantum coherent phases.

How the description in terms of Berry phase and fidelity could relate to TGD?

Consider first the identification of the TGD counterparts of Berry phase and fidelity.

1. In TGD the ground states are defined as space-time surfaces/3-surfaces and quantum states are their superpositions. The Kähler metric defines the analog of the quantum metric and the Kähler form corresponds to Berry curvature.

   The fidelity of two quantum states $\Psi(\lambda)$ and $\Psi(\lambda+\delta\lambda)$ is defined as the overlap $\langle\Psi(\lambda)\rangle\Psi(\lambda+\delta\lambda)\rangle$ in parameter space. The fidelity for nearby states is expected to change dramatically at singularity.

   Fidelity at the level of WCW - rather than WCW spinor fields representing quantum states - would mean disappearance of appearance of quantal WCW degrees of freedom as zero models transform to dynamical quantal degrees of freedom or vice versa. This change would make itself visible at the level of quantum states whose inner product depends on the WCW Kähler metric.

2. WCW also allows spinor connection with some gauge group acting as non-abelian holonomies. This corresponds to non-Abelian Berry phase Kac-Moody algebras of H isometries are an excellent candidate in this respect. WCW allows super-symplectic group as isometries.

3. WCW metric has also zero modes, which do not contribute to the WCW metric. Any symplectic invariant associated with X^4 defines such an invariant and the induced CP_2 Kähler form is invariant under the symplectic transformations of CP_2 and can be said to define a continuum of this kind of invariants. This could induce a geometric phase, which is not due to a holonomy but non-trivial homotopy.

   Kähler magnetic fluxes over 2-surfaces define such invariants. For closed surfaces these invariants reduce to quantized magnetic fluxes. Also M^4 Kähler form defines such invariants. At the boundary of CD the sphere S^2 (light-like radial coordinate =constant) has symplectic structure and also this defines solid angles assignable to 3-surfaces as seen from the tip of the CD as invariants.

Could the singularity of the quantum metric relate to number theoretical physics?

The singularity of the quantum metric would mean a reduction of the number of the dynamical quantum degrees of freedom contributing to the WCW metric meaning that the rank of the WCW metric tensor decreases. At criticality complex coordinates would transform to zero modes. Some complex coordinates of WCW would reduce to real coordinates. This would correspond to quantum criticality. In a concrete mechanical system some eigen modes would vanish and corresponding frequencies would become zero.

Since the TGD Universe is quantum critical and this is expected to be a generic phenomenon. Quantum criticality involves long range fluctuations which would correspond to large values of h_{eff} and therefore space-time surfaces which are algebraically complex. Could these long range fluctuations relate to almost zero modes with small frequencies and large wave lengths?

These phase transitions could be number theoretic. They would change the polynomial defining the X^4 (recall that quantum state is the superposition of space-time surfaces in ZEO). The dimension n for the extension of rationals is equal to the order of the Galois group and would change. Galois symmetries would act as zero mode symmetries. The dimensions of the representations of the Galois group in terms of quarks would also change. The change in the number of degrees of freedom would change the fidelity.

n defines also the algebraic dimension of the integers extended to algebraic integers for extension as a space regarded as a ring of integers. If algebraic integers can define components of the momenta, the dimension of the momentum space with integer components of momentum increases from 3 to $3n$ as the dimension of the Galois group increases by factor n. This increase occurs in the transitions in which the polynomial Q defining the space-time region is replaced with $P \circ Q$ such that P defines n-dimensional extension.

This would have rather dramatic effects since the radius of the Fermi ball with radius would be reduced by factor $1/n$ and could contain the same number of states as ordinary Fermi ball: this would mean an increase of density by factor n^3 corresponding to n sheets. Quasicrystal structure in both $X^4 \subset M^8$ and its images in $X^4 \subset H$ is also suggestive.

Does infinite volume limit have spin-glass type degeneracy?

One can look at the situation also at the infinite volume limit. At the infinite volume limit the action is expected to reduce to Kähler action. Whether this implies ground state degeneracy depends on whether preferred extremal property allows it.

1. In the original picture there was only CP_2 contribution to Kähler action. This implies huge vacuum degeneracy of CP_2 Kähler action. Any X^4 with CP_2 projection which is 2-D Lagrangian manifold is a vacuum extremal. WCW metric becomes singular if its inverse does not exist: this means singularity and the existence of zero modes. 4-D spin variant of glass degeneracy (`https://cutt.ly/0RuZfgu`) and classical non-determinism emerge. Classical non-determinism does however not look physically acceptable.

2. The twistor lift forces the Kähler action to have also an M^4 part obtained by analytical continuation from E^4. Does the resulting Kähler action have ground state degeneracy at infinite volume limit?

   The simplest extremals are of the form $X^4 = X^2 \times Y^2$, X^2 a minimal surface in M^4 and Y^2 a Lagrangian manifold in CP_2. Symplectic transformations in CP_2 degrees act like $U(1)$ gauge transformations on CP_2 Kähler gauge potential and do not affect either Kähler form nor the Lagrangian manifold property.

   Only the induced metric is affected so that the effects are purely gravitational. This gives rise to the ground state degeneracy. The area of CP_2 projection is not changed and the action is affected only by the change of the induced metric. Conserved quantities are modified only by gravitational effects and are non-vanishing. The extremals are deterministic and apart from gravitational effects one has a huge ground state degeneracy analogous to spin glass degeneracy.

   Apart from gravitation, the WCW Kähler metric receives contributions only from M^4 degrees of freedom, which are not affected under these deformations. Could one say that CP_2 degrees have transformed to zero modes?

3. One can also have surfaces $X^2 \times Y^2 \subset M^4 \times CP_2$ such that both X^2 and Y^2 are Lagrangian manifolds at infinite volume limit. These would be vacuum extremals. Preferred extremal property should exclude them. Could the interpretation be that all quantum degrees of freedom have transformed to zero modes?

4. One can invent objections against this proposal.

   (a) Negative energies might emerge from the electric energy in M^4 degrees of freedom. Electric field gives a negative contribution to energy density. Signature is Minkowskian for M^2 subset $M^2 \times E^2$. The M^2 part of Kähler form is obtained from its E^2 variant by multiplication with factor i. This might cause problems.

   (b) These surfaces are extremals but the preferred extremal property could fail since the needed 4-D analog of complex structure is missing since Y^2 as a Lagrangian manifold is not a complex surface of CP_2.

   (c) There is however also an argument in favor of this picture. Ordinary Maxwellian magnetic fields correspond to a homologically trivial geodesic sphere of CP_2 and they are Lagrangian submanifolds. Therefore one cannot exclude the proposal.

The parameters of the effective Hamiltonian from the TGD point of view

Could the parameters of effective Hamiltonians have counterparts at the level of WCW?

1. 4-surfaces as WCW points define parameters in the analogs of eigenvalues of observables. Both supersymplectic and Kac-Moody algebras have as parameters the parameters coding the point of WCW and Kac-Moody algebra. Number theoretic coding of ground states based on the Galois group as a symmetry group and p-adic primes defining p-adic length scale is what comes to mind.

   The preferred 4-surfaces would naturally correspond to the maxima of Kähler function. It is quite possible that Kähler coupling constant is complex so that the complex number defining the exponent of Kähler function has phase $\pm pi/2$. The phase of the exponent is different and maxima are also stationary points. This would make possible interference effects central in QFTs. This is implied by the condition that classical conserved charges are apart from a phase factor real and can therefore be made real.

   If M^8 space-time sheets are defined as "roots" of polynomials with rational coefficients [L114, L115], WCW becomes discrete and has the coefficients of polynomials as coordinates of a given point (X^4). An open question is why the maxima of Kähler function should correspond to rational polynomials with rational coefficients.

2. Super-symplectic transformations [K29, K91] as isometries of WCW are symmetries and can be regarded as a generalization of Kac-Moody type symmetries. The complex coordinate z and light-like radial coordinate r of the light-cone boundary are in the role of parameters. Analog of 3-D gauge group but gauge group replaced with the symplectic group of $S^2 \times CP_2$ is in question. The light-like orbits of partonic surfaces could naturally carry Kac-Moody algebra representations of isometries - at least at infinite volume limit.

   Non-negative conformal weights parameterize the representations of this algebra. The construction of states would be as follows. A sub-algebra $SCA_{n_{max}}$ with conformal weight larger than n_{max} and its commutator with the entire algebra annihilate states. Only the states with conformal weight smaller than n_{max} remain. Other degrees of freedom are effectively gauge degrees of freedom. n_{max} is expected to depend on the polynomial, its Galois group and degree. A huge reduction of degrees of freedom takes place. The remnant of the super-symplectic group would act as dynamical symmetries.

   Same could occur in the symplectic degrees of freedom labelled by Hamiltonians which are products of S^2 and CP_2 Hamiltonians. The only non-trivial normal subalgebra corresponds to isometries and states would be annihilated by the generators in the complement of this algebra.

   Rational coefficients of a polynomial defining the X^4 serve as the parameters characterizing the ground state. Higher level description is in terms of the Galois group which depends only weakly on the polynomial.

3. What about the description at the level of X^4? The solutions of modified Dirac action for induced spinor fields depend on the parameters characterizing the space-time surface.

17.2.7 Quantum hydrodynamics in TGD context

In the standard picture quantum hydrodynamics is obtained from the hydrodynamic interpretation of the Schrödinger equation. Bohm theory involves this interpretation. (`https://cutt.ly/cWy3O9Ts`).

1. Quantum hydrodynamics appears in TGD as an *exact* classical correlate of quantum theory [K7]. Modified Dirac equation forces as a consistency condition classical field equations for X^4. Actually, a TGD variant of the supersymmetry, which is very different from the standard SUSY, is in question.

2. TGD itself has the structure of hydrodynamics. Field equations for a single space-time sheet are conservation laws. Minimal surfaces as counterparts of massless fields emerge as solutions satisfying simultaneously analogs of Maxwell equations [L155]. Beltrami flow for classical Kähler field defines an integrable flow [L131]. There is no dissipation classically and this can be interpreted as a correlate for a quantum coherent phase.

3. Induced Kähler form J is the fundamental field variable. Classical em and Z^0 fields have it as a part. For $S^3 \subset CP_2$ em and Z^0 fields are proportional to J: which suggests large parity breaking effects. Hydrodynamic flow would naturally correspond to a generalized Beltrami flow and flow lines would integrate to a hydrodynamic flow.

4. The condition that Kähler magnetic field defines an integrable flow demands that one can define a coordinate along the flow line. This would suggest non-dissipating generalized Beltrami flows as a solution to the field equations and justifies the expectation that Einstein's equations are obtained at QFT limit.

5. If one assumes that a given conserved current defines an integrable flow, the current is a gradient. The strongest condition is that this is true for all conserved currents. The non-triviality of the first homotopy group could allow gradient flows at the fundamental level. The situation changes at the QFT limit.

6. Beltrami conditions make sense also for fermionic conserved currents as purely algebraic linear conditions stating that fermionic current is a gradient of some function bilear in oscillator

operators. Whether they are actually implied by the classical Beltrami conditions, is an interesting question.

7. Minimal surfaces as analogs of solutions of massless field equations and their additional property of being extremals of Kähler action gives a very concrete connection with Maxwell's theory [L155].

17.2.8 Length scale hierarchies

The length scale hierarchy associated with the hierarchy of Planck constants and p-adic length scale hierarchy lead to the proposal that one has quantum coherence and supra phase always realized in some scale and the loss of say superconductivity means only the reduction of this scale.

Also dark variants of valence electrons make sense and there is evidence for them. When looking at the definition of say exciton, one cannot avoid the impression that something is missing. Electrons and holes are assumed to have incredibly small effective masses. The very notion of effective mass is in conflict with the idea that one has a fundamental quantum theory description.

One also introduces in the Schrödinger equation dielectric constant which comes from macroscopic description. Why doesn't one do the same in the case of ordinary atoms. This kind of mixing of phenomenological descriptions with a fundamental description is to me a deadly sin.

One cannot avoid the crazy looking question whether exciton could be a valence electron which is dark with $h_{eff} = k \times h$ and binds with an atom. It would be automatically accompanied by a hole. The binding energies would be scaled like $1/k^2$ and one would obtain the energies which can be 3 orders of magnitude smaller than those for hydrogen.

17.2.9 A general model of macroscopic quantum phases

Hierarchy of quantizations at the level of WCW

Before saying anything about macroscopic quantum phases, one must define what many-particle states correspond at the level of WCW.

1. The combination of UP with $M^8 - H$ duality leads to the view that many particle states at the level correspond to many-fermion (quarks actually) such that the momenta of quarks correspond to momenta as points of $X^4 \subset M^8$ with components, which are algebraic integers. In TGD framework, where all particles, also bosons, are composites of fermions. At M^8 level Cooper pairs would correspond to pairs of occupied points of a mass shell $H^3 \subset M^8$. The image of the region of momentum space in H corresponds for quarks of given mass m corresponds to a region at the boundary of sub-CD with size given by Compton length $L = \hbar_{eff}/m$.

2. At the level of WCW, the analog of the many-quark state associated with a given quark mass corresponds to the analog of plane wave inside a large $CD \subset H$ defined by the smallest mass involve but with point-like particle replaces with space-time surface inside sub-CD (CD(m)) carrying zero energy state characterized by quark momenta at opposite boundaries of CD(m) having opposite sign of energy.

3. The entanglement between these states due to Fermi statistics is however maximal and SFRs are not possible. How can one construct entangled states. The answer is simple perform the analog of second quantization at the level of WCW. One can form the analogs of 2-particle states by taking two CDs with specified quark content and assign to both the analogs of plane waves. If the CDs correspond to different extensions of rationals so that the effective Planck constants are different, one can entangle these states in WCW degrees of freedom. One can construction N-particle states by using the same recipe.

4. To each many quark state one can assign odd or even boson number and regard this state as analog of elementary fermion or boson. This is what is indeed done quite generally. Could this operation have deeper meaning. Could one require that the many-quark operators indeed commute or anticommute mutually. This condition cannot hold true generally but could be

posed as an additional condition to the physical states: the commutator/anticommutation would be proportional $h_{eff}I$, I identity matrix.

This construction would be third quantization. And nothing prevents from performing also fourth quantization within even larger CD. This hierarchy of quantizations brings in mind the basic hierarchical structures of the TGD Universe: many-sheeted space-time characterized by p-adic and dark length scale hierarchies, and also the hierarchy of infinite primes which corresponds to a repeated second quantization of supersymmetric arithmetic QFT [K105] conjecture to correspond to the hierarchy of space-time sheets.

WCW description of BECs and their excitations as analogs of particles

Fermi statistics requires that the BEC correspond to a distribution of correlated momentum pairs with the sum of the momenta equal to the momentum of the boson. Cooper pairs also have binding energy so that the mass of the pairs is slightly smaller than the particle mass so that the Cooper pairs belong to different $H^3 \subset M^8$ than the free fermions.

For the excitations of BEC condensate giving rise to supracurrents and superflows, some momenta of fermions are different from the common momentum of BEC, usually larger than the common momentum of BEC. The image of excitation of BEC in H would be a pair at proper time=constant hyperboloid in H and the map of momentum to position would be linear inside $CD(m)$. BEC would look very much the same at both M^8 and H side of duality.

The space-time surface $X^4 \subset CD(m)$ should correspond to a minimal surface and to a generalized Beltrami flow defining an integrable coordinate along the flux lines. In the case of conserved current gradient flow (vortex flow is an example of this). All many-particle states would be of this kind in the scale of $CD(m)$. These multi-BEC states would be analogs of many-particle states and one would have many-particle states of BECs and their condensates, which could entangle in WCW degrees of freedom. For instance, the entanglement between geometric representations of Galois groups is possible. In the TGD inspired quantum biology the multi-BEC like states are proposed to play a key role [L121, L137].

Superconductivity and superfluidity in TGD framework

The TGD based view about superconductivity and fluidity [L131] differs in many respects from BCS theory.

1. In the BCS theory superconducting state does not have a well defined fermion number and this leads to a somewhat questionable notion of coherent state of Cooper pairs. The Bogobliubov transformation creates the diagonalizable oscillator operator basis by mixing creation and annihilation operators. The resulting operators create superpositions of electrons and holes.

   In the TGD framework, the interpretation would be that the hole actually corresponds to dark fermion with $h_{eff} > h$ at dark space-time sheet so that fermion number conservation is not lost. Bogoliubov operators would be replaced with superpositions of creation/annihilation operators associated with different space-time sheets and create states which are superpositions of state at the two space-time sheets.

   Effective Hamiltonian would include diagonalizable kinetic parts assignable to both space-time sheets, and the terms quadratic in creation/annihilation operators breaking fermion number conservation would be replaced with pairs of creation and annihilation operators associated with different space-time sheets describing the transfer of electron between the space-time sheets.

2. In the BSC theory Cooper pairs are carriers of supra current. In the TGD framework, dark electrons at dark spacetime-sheets could be the carriers. The binding energy of Cooper pairs liberated in their formation would provide the energy needed to transform ordinary electrons to dark electrons (the energies of particle states typically increase with h_{eff}). This makes possible superconductivity driven by energy feed possible also above critical temperature.

3. Can one describe supra currents and supra flows in terms of a single space-time surface as the classical space-time view based on Beltrami currents would suggest? This would mean that

supracurrent would correspond to a collection of momenta of dark electrons at $H^3 \subset M^8$ in the proposed TGD based model or collection of Cooper pairs with $h_{eff} = h$ as in the standard description. The current carriers would have fixed momenta at the two boundaries of $CD(m)$ corresponding to the analogs of initial and final state momenta. Is this all that one can say at the quantum level and is the description as a flow only a classical description. At quantum level one could only deduce the change of the positions for the group of particles defining the flow. This indeed conforms with the UP.

Update: I received a link to a highly interesting popular article with title "A Breakthrough Experiment Unlocking the Mystery of Unconventional Superconductivity" (`https://rb.gy/fs8ecn`). The article told about the work of Sarah Hirthe et al reported in the article "Magnetically mediated hole pairing in fermionic ladders of ultracold atoms" published in Nature [D51]. This work gives support for the TGD view of superconductivity.

TGD based view of unconventional superconductivity [K85, K86, L131] is based on the new view of quantum physics provided by new space-time concept and number theoretic vision predicting phases of ordinary matter behaving like dark matter and labelled by effective Planck constant $h_{eff} = nh_0$, which can be very large as compared to the ordinary Planck constant h. This the case for the gravitational Planck constant introduced originally by Nottale. This implies quantum coherence in long scales essential for superconductivity.

This view suggests that hole pairs are formed as the electron pairs are transferred to the magnetic flux tubes and become dark and therefore have a non-standard value of effective Planck constant. This creates hole pairs at the level of the ordinary matter and the motion of the dark electron pair corresponds to that for the hole pair. The electron pair goes to a pair of magnetic flux tubes and transversal fluctuations in the shape of flux tubes are essential in the transition to superconductivity . This picture is consistent with the reported findings.

The really important message is that dark matter in TGD sense can be detected as the absence of ordinary matter! Hole pair is a shadow Cooper pair of dark electrons.

WCW level is necessary for the description for purely geometric bosonic excitations

The quantum description of sound requires WCW description since the phonons as oscillations of relative position of particles cannot be described in terms of quark-antiquark pairs. The description of exotic supra flows like that associated with magnon BEC in say ^3He supra fluid allowing orbital magnetization requires WCW. A good manner to clarify thoughts is to look at what this means in the case of magnons.

1. Standard classical description (`https://cutt.ly/HRuZh53`) suggests a direction of magnetization M which has changed due to the presence of external field H. This leads to the Landau-Lifschitz equation for the magnetization.

   The Fock space picture about magnons is as a plane wave for which the argument is the position of spin whose direction has changed. The quantization is described by introducing a Hamiltonian for spins. The relationship between these descriptions is somewhat obscure.

2. In TGD the fermionic Fock space description is not possible. Bosonic creation and annihilation operators would be needed but one cannot construct bosonic operators with a vanishing fermion number from quarks. Therefore magnons should correspond to WCW degrees of freedom.

3. In the TGD description, M would correspond at space-time level to the magnetic field at a non-monopole flux tube and H possibly at a monopole flux tube inducing the magnetization. Magnons would correspond to magnetization waves, as kinks propagating along magnetic flux tubes for M. Magnon should correspond to space-time surface H and this would determine its M^8 pre-image. If these excitations behave like identical particles, one can assign to them wave vectors and classical momenta.

4. Also the notion of BEC makes sense at WCW level since one can construct the counterparts of genuine bosonic oscillator operators. Super-symplectic and Kac-Moody algebras of WCW acting at the boundaries of CD indeed include purely bosonic operators. Similar description at WCW level applies also to phonons as quanta.

Cooper pair BECs allow approximate description in terms of fermion pairs with given total momentum but with members having different momenta. One cannot however exclude the possibility that there purely bosonic BEC at WCW level such that each Cooper pair is associated with a bosonic excitation of space-time surface.

17.3 Some concrete questions and problems

In this section some concrete questions relating to various applications of TGD to condensed matter physics are considered. Applications to (quantum) hydrodynamics is left to separate article.

17.3.1 Skyrmions in TGD framework

In hadron physics skyrmions (`https://cutt.ly/qRuXYMX`) appear at the level of momentum space. Proton as a skyrmion corresponds to a map of a 3-ball B^3 to $S^3 \subset E^4$ with non-trivial winding number. The points at the boundary are mapped to a single point so that B^3 effectively behaves like S^3. The map thus represents an element of third homotopy group and if this element is non-trivial one has skyrmions whose winding number has interpretation as number of protons. The radius of S^3 is the proton mass so that S^3 indeed lives in momentum space. $SO(4) = SU(2)_L \times SU(2)_R$ assigned to the current algebra picture of hadron physics acting as isometries of S^3 serves as the field space of skyrmions.

Skyrmions appear as topological defects also in condensed matter physics and correspond to 3-D magnetic field configurations inside B^3 and vanishing at the boundary of B^3 so that they define a map to S^3. In this case, the winding number of the map can correspond to the number of electron pairs. They appear in superconductivity, quantum Hall systems, liquid crystals, magnetic systems, and Bose-Einstein condensates (BECs). One example corresponds to ferromagnetic spin-1 Bose-Einstein condensates [D102](`https://cutt.ly/MWy3S5J`). Their universal appearance suggests that they could appear at fundamental level.

What TGD view would be following.

1. The proposal is that $M^8 - H$ duality allows to understand skyrmions as duality between the $SO(4)$ description of hadrons and $SO(4)$ symmetry group at M^8 level and QCD description in terms quarks and gluons and color $SU(3)$ at the level of H.

   In TGD framework skyrmions are associated with space-time surfaces in M^8 and skyrmion means a maps from a ball $B^3 \subset M^4$ to the sphere $S^3 \subset E^4$.The radius of S^3 is proton mass squared: this conforms with the interpretation of M^8 as momentum space.

2. Skyrmion in as a map $B^3 \to S^3 \subset E^4 \subset M^8 = M^4 \times E^4$ is mapped to a map $B^3 \to S^3 \subset CP_2 \subset H$ by $M^8 - H$ duality. The map $B_3 \to B^3$ is by inversion (Uncertainty Principle). The map would have a non-trivial winding number.

   What does the skyrmion sphere S^3 subset E^4 correspond to in CP_2. Recall that normal space of X^4 is mapped to a point of CP_2. The image of the Skyrmion looks like a graph for the normal space of $X^4 \subset M^8$ as a function of the point of X^4. How does the normal space correlate with the E^4 point at S^3? Continuity and single-valuedness look natural. The 3-sphere in X^4 is mapped to a D≤ 3 surface.

   Essentially homotopy associating normal space characterized by a point of CP_2 to $S^3 \subset CP_2$ is in question. CP_2 has a trivial third homotopy group. The homotopy equivalence class is trivial unless one fixes the radius as is done also in the original model by fixing the mass to correspond to the radius of $S^3 \subset E^4$.

   Could $S^3 \subset E^4$ containing the octonionic real axis be mapped to a sphere $S^3 \subset CP_2$ invariant under $U(2)$. At S^3 Z^0 gauge field is proportional to Kähler form J as is also the electromagnetic field [L2]. Therefore the long range correlations for Kähler form J are associated also with Z^0. Large parity breaking effects would become possible and indeed appear in living matter (chirality selection for biomolecules).

3. Could the sphere $S^3 \subset M^8$ mapped to $S^3 \subset CP_2$ related by $M^8 - H$ duality define a common denominator of several exotic condensed matter phenomena? $S^3 \subset M^8$ define a quaternionic

3-sphere and the automorphism group of quaternions. One can assign to skyrmions a flat $SO(3)$ gauge potential [D122] (https://arxiv.org/abs/1812.07974). Could this relate to the speculated emergence of $SO(3)$ as a synthetic gauge group [D46])(https://cutt.ly/qWy3H9M?

17.3.2 Dark matter and condensed matter physics

The following represents a collection of examples of possible applications of TGD view of dark matter to condensed matter physics.

Could one make dark matter visible?

Dark matter in TGD sense could make itself visible in many ways.

1. One can imagine diffraction by generating a dark photon or (dark) polariton beam using a laser beam providing the energy feed increasing h_{eff}. Dark photon beam would diffract from an analog of hole: the ordinary laser beam could represent the hole as a source of dark photons. The structure of dark matter at flux tubes involving flux tubes and their geometric patterns could become visibille in this manner.

   For instance, the braids formed by flux tubes could become visible. Here braid entropy is a central notion and central in TGD based view of hydrodynamics involving braiding in both time-like and space-like braiding [K5, K4, K118].

2. In quantum biology dark matter at magnetic body with large h_{eff} as measure for complexity and intelligence, serves as the boss controlling ordinary biomatter, and its quantum coherence forces ordinary coherence of ordinary biomatter, which cannot be understood in physics and chemistry based on ordinary quantum physics [L194].

Solids are either in crystal or amorphous phase. Long range order in crystals is lacking and this is visible in the X-ray diffraction pattern. The diffraction pattern [D128] (https://cutt.ly/ZWyLgjk) for a hyperuniform amorphous material is very different and is called highly exotic (see **Fig. 17.16**). Apart from forward scattering peak, the diffraction pattern involves no scattering for a considerable range of scattering angles. I cannot avoid the temptation to speculate.

1. Suppose that the proposed dark looking phases with $h_{eff} > h$ by their higher algebraic complexity (larger extension of rationals, larger Galois symmetries) control the lower levels in master slave hierarchy, in particular ordinary matter (now the amorphous film.

   Suppose that the scattering of say laser light feeding energy and increasing the value of h_{eff} creates dark photons or polaritons at this higher level. Suppose that polaritons scatter at flux tubes or flux sheets structures at higher level and eventually a transformation to ordinary photons occurs spontaneously. Could the interference of the scattered beam with incoming beam make the geometry of dark matter level visible as the example about scattering in hyperuniform matter would suggest?

2. This high level would have longer quantum coherence length and perhaps range order since h_{eff} is larger. The long range order would be visible in the scattering pattern. Could just this happen when laser light generates a polariton-exciton condensate [D87](https://cutt.ly/4Wy8zi9). Could one think of polariton vortex lattices [D75] (https://cutt.ly/qWy8Zqf) as counterparts of crystal lattices and could their presence become visible so that one could see dark matter.

   The polariton could correspond at flux tubes superposition of dark photon and of dark exciton identifiable as dark electron paired with ordinary hole formed when the electron was transferred to the flux tube. The photon component of the outgoing polariton beam formed by the transformation of dark photon to ordinary photon would reflect the structure of dark matter and flux tubes and leave the system as ordinary photons and generate the scattering pattern by interference.

A strange behavior of hybrid matter-antimatter atoms in superfluid Helium

I received an interesting link to a popular article "ASACUSA sees surprising behaviour of hybrid matter–antimatter atoms in superfluid helium" (`https://cutt.ly/NVIzglw`), which tells of a completely unexpected discovery related to the behavior of antiproton-^{4}He^{++} atoms in ^{4}He superfluid. The research article [D72] by ASACUSA researchers Anna Soter et al is published in Nature (`https://cutt.ly/LVIceiB`).

The formation of anti-proton-^{4}He^{++} hybrid atoms containing also an electron in ^{4}He was studied both above and below the critical temperature for the transition to Helium superfluid. The temperatures considered are in Kelvin range corresponding to a thermal energy of order 10^{-4} eV.

Liquid Helium is much denser than Helium gas. As the temperature is reduced, a transition to liquid phase takes place and the Helium liquid gets denser with the decreasing temperature. One would expect that the perturbations of nearby atoms to the state should increase the width of both electron and antiproton spectral lines in the dense liquid phase.

This widening indeed occurs for the lines of electrons but something totally different occurs for the spectral lines of the antiproton. The width decreases and when the superfluidity sets on, an abrupt further narrowing of He^{++} spectral lines takes place. The antiproton does not seem to interact with the neighboring ^{4}He atoms.

Researchers think that the fact that the surprising behavior is linked to the radius of the hybrid atom's electronic orbital. In contrast to the situation for many ordinary atoms, the electronic orbital radius of the hybrid atom changes very little when laser light is shone on the atom and thus does not affect the spectral lines even when the atom is immersed in superfluid helium.

Consider now the TGD inspired model.

1. It seems that either antiprotons or the atoms of ^{4}He superfluid effectively behave like dark matter. For the electrons, the widening however takes place so that it seems that the antiproton seems to be dark. In the TGD framework, where dark particles corresponds $h_{eff} = nh_0 > h$, $h = n_0h_0$ phases of ordinary matter, the first guess is that the antiprotons are dark and reside at the magnetic flux tube like structures.

   The dark proton would be similar to a valence electron of some rare earth atoms, which mysteriously disappear when heated (an effect known for decades) [L61]. Dark protons would indeed behave like a dark matter particle is expected to behave and would have no direct quantum interactions with ordinary matter. The electron of the hybrid atom would be ordinary.

2. Darkness might also relate to the formation mechanism of the hybrid atoms. Antiproton appears as a Rydberg orbital with a large principal quantum number N and large size proportional to N^2. $N > 41$ implies that the antiproton orbital is outside the electron orbital but this leaves the interactions with other Helium atoms. For a smaller value of N the dark proton overlaps the electronic orbital. Note that for $N = 1$, the radius of the orbital is $10^{-3}/8a_0$, $a_0 \simeq .53 \times 10^{-10}$ m, in the Bohr model.

3. The orbital radii are proportional to $h_{eff}^2 \propto (n/n_0)^2$ so that dark orbitals with the same energy and radius as for ordinary orbitals but effective principal quantum number $(n/n_0)N_d = N_{eff}$, are possible. $(n/n_0)N_d = N_{eff}$ condition would give the same radius and energy for the dark orbital characterized by N_d and ordinary orbital characterized by N.

One can consider both dark-to-dark and dark-to-ordinary transitions.

1. The minimal change of the effective principal quantum number N_{eff} in dark-to-dark transitions would be n/n_0 and be larger than one for $n > n_0$. There is evidence for $n = n_0/6$ found by Randel Mills [D58] discussed from the TGD view in [L42]. In this case one would have effectively fractional values of N_{eff}. One can also consider a stronger condition, $h_{eff}/h = m$, one has $mN_d = N$. The transitions would be effectively between ordinary orbitals for which ΔN_{eff} is a multiple of m. This could be tested if the observation of dark-to-dark transition is possible. The transformation of dark photons to ordinary photons would be needed.

2. Energy conserving dark-to-ordinary transitions producing an ordinary photon cannot be distinguished from ordinary transitions if the condition $(n/n_0)N_d = N_{eff}$ is satisfied.

The transitions $(37,35) \rightarrow (38,34)$ and $(39,35) \rightarrow (38,34)$ at the visible wavelengths $\lambda = 726$ nm and 597 nm survive in the Helium environment. The interpretation could be that the transitions occur between dark and ordinary states such that the dark state satisfies the condition that $(n/n_0)N_d = N_{eff}$ is integer, and that an ordinary photon with $\lambda = h/\Delta E$ is produced. This does not pose conditions on the value of h_{eff}/h.

If the condition that $(n/n_0)N_d = N_{eff}$ is an integer is dropped, effective principal quantum numbers N_{eff} coming as multiples of n/n_0 are possible and the photon energy has fractional spectrum.

If this picture makes sense, it could mean a new method to store antimatter without fear of annihilation by storing it as a dark matter in the magnetic flux tubes. They would be present in superfluids and superconductors.

Mott insulators learn like living organisms

Researchers in Rutgers University have found that quantum materials, in this case Mott insulators, are able to learn very much like living matter (`https://cutt.ly/oTRZhQE`). The conductivity of the quantum material represented behavior and sensory input was represented by external stimuli like oxygen, ozone and light.

The finding was that conductivity depends on these stimuli and that the system mimics non-associative learning. Non-associative learning does not involve pairing with the stimulus but habituation or sensitization with the stimulus.

I have already earlier [K86] briefly considered transition metals, Mott insulators, and antiferromagnets from the point of view of TGD inspired theory of high Tc superconductivity.

1. By looking at Wikipedia (`https://cutt.ly/RTRXi22`), one finds that Mott insulators are transitional metal oxides such as NiO. Transition metals, such as Ni, can have unpaired valence electrons since they can appear in electronic configurations [Ar] $3d^8$ $4s^2$ or [Ar] $3d^9$ $4s^1$. This should make transition metals and their oxides conductors. They are not since they seem to somehow develop an energy gap between states in the same valence band making them insulators.

2. Mott developed a model for NiO as an insulator: the expected conduction was based on the transition for neighboring $Ni^{2+}O^{2-}$ molecules

$$(Ni^{2+}O^{2-})_2 \rightarrow Ni^{3+}O^{2-} + Ni^{1+}O^{2-}$$

.

In the latter configuration, the number of valence electrons of Ni is odd for both neighbors.

3. The formation of the gap can be understood as a competition between repulsive Coulomb potential U between 3d electrons and the transfer integral t of 3d electrons between neighboring atoms assignable to the transition. The total energy difference between the two states is $E = U - 2zt$, where z is the number of neighboring atoms. A large value of U leads to a formation of a gap implying the insulator property.

4. Also antiferromagnetic ordering is necessary for the description of Mott insulators. Even this is not enough, and the rest which is not so well understood, is colloquially called mottism. The features of Mott insulators that require mottism are listed in the Wikipedia article. They include the vanishing of the single particle Green function along a connected surface in the first Brillouin zone and the presence of charge 2e boson at low energies.

5. The description of both Mott insulators and high Tc superconductors involves antiferromagnetism and Mott insulators exhibit extraordinary phenomena such as high Tc superconductivity and so-called colossal magnetoresistance thought to be due the interaction between charge and spin of conduction electrons.

In the TGD framework, the description of high Tc superconductors [K85, K86] [L131] involves pairs of monopole flux tubes with opposite direction of monopole magnetic flux possible not possible in Maxwellian electrodynamics. The members of Cooper pairs, which are dark in the TGD sense having an effective Planck constant $h_{eff} \geq h$, reside at the monopole flux tubes. The Cooper pairs are present already above Tc but the flux tubes are short and closed so that supercurrent flows only in short scales. At Tc long flux tubes are formed by reconnection.

Dark valence electrons could help to understand Mott insulators. Transition metals are known for a strange effect in which the valence electrons seem to disappear [L61] [L61] [K36]. The TGD proposal is that the electrons become dark in the TGD sense.

It has become clear that dark electron can appear only as bound states for which the sum of momenta, which are algebraic integers in the extensions of rationals with dimension $h = h_{eff}/h_0$ (this guarantees periodic boundary conditions) must be Galois singlets: one has Galois confinement. This implies that the total momentum is ordinary integer [L145, L147].

Therefore free dark electrons are not allowed and Cooper pairs and possibly also states formed by a larger number of electrons, say four as has been found [L145]) are possible as Galois singlets. In the TGD inspired quantum biology dark proton triplets realize genetic codons and genes could correspond to N-codons as Galois confined states of 3N dark protons [L137].

As a rule, single particle energies increase with increasing h_{eff} and the thermal energy feed could increase the effective value Planck constant for an unpaired valence electron of Mott insulator from h to $h_{eff} >= nh_0 > h$ of the valence electrons and it would become dark in the TGD sense. Here n denotes the dimension of extension of rationals assignable to the space-time region. The natural assumption is that Galois confinement forces the Cooper pairing of unpaired electrons of neighboring atoms.

Above Tc, the flux tubes associated with Cooper pairs would be too short for large scale superconductivity so that one would have a conductor or a Mott insulator. Under certain conditions involving low enough temperature, a supraflow in long scales would become possible by the mechanism described above. The massive magnetoresistance could involve a transfer of electrons as Cooper pairs at the magnetic flux tubes of the external magnetic field which would be too short to give rise to superconductivity or even superconductivity. External magnetic fields could also induce dark ferromagnetism as formation of dark flux tubes.

Dark electrons, protons and ions residing at the magnetic flux tubes of the "magnetic body" (MB) of the system are in a key role in the TGD based quantum biology and essential for learning as self-organization. h_{eff} serves as a measure for the number theoretical complexity and therefore "intelligence" of the system. There MB naturally acts as a "boss".

Also for the Mott insulator, the MB could play a key role: MB would be the "boss" and could learn and induce changes in the behavior of the ordinary matter, the "biological body" (BB). In the non-associative learning, adaptation and sensitization is involved and it would be MB which adapts or sensitizes. The TGD view of a neuron proposes a rather detailed model for the communication between the BB and MB [L127].

The mysterious linear temperature dependence of resistance of strange metals

Could one understand the somewhat mysterious looking linear high T dependence of the resistivity of strange metals in TGD the framework?

In the TGD based model of high T superconductivity [L131], charge carriers are dark electrons, or rather, Cooper pairs of them, at magnetic flux tubes which are effectively 1-D systems. Magnetic flux tubes are much more general aspect of TGD based model of condensed matter [L145].

Could magnetic flux tubes carrying dark matter with h$_{eff} = nh_0 > halsoexplaintheresistanceofstrangeme$

More precisely: Could the effective 1-dimensionality of flux tubes, darkness of charge carriers, and isolation from the rest of condensed matter together explain the finding?

One can make a dimensional estimate.

1. Isolation at flux tubes would mean that only the collisions of dark electrons with each other cause resistance.

2. Assume that the resistance ρ can be written in the form

$$\rho = \frac{4\pi/\omega^2}{\tau} = \frac{\frac{m_e}{n_e e^2}}{\tau} \ . \tag{17.3.1}$$

τ is the time that electron spends between two collisions. ω is the plasma frequency

$$\omega^2 = \frac{4\pi n_e e^2}{m_e} \ . \tag{17.3.2}$$

n_e is 3-D electron density.

What happens for 3-D n_e in the case of 1-D flux tube? It would seem that n_e must be replaced with linear density divided by the transversal area S of the flux tube: $n_e = (dn_e/dl)/S$.

3. As already noticed, τ is the time spent by the charge carrier in free motion between collisions. Charge carrier is in thermal motion with a thermal velocity $v_{th} = kT/m$. The length L_f of the free path is determined non-thermally. Hence one has

$$\tau = \frac{L_f}{v_{th}} = \frac{mL_f}{kT} \ . \tag{17.3.3}$$

This gives $1/\tau = kT/mL_f$.

4. For the resistivity ρ one obtains

$$\rho = \frac{m_e}{n_e e^2}\frac{kT}{mL_f} \ , \tag{17.3.4}$$

which indeed depends linearly on T as it does for strange metals.

For $m = m_e$, one would have $\rho = kT/(n_e e^2 L_f)$.

In the article "Signatures of a strange metal in a bosonic system" (https://cutt.ly/2OE4Quz) by Yang *et al* published in Nature, bosonic strange metals are studied instead of fermionic ones. The system can also be superconducting and this seems to be essential.

The linear dependence on magnetoresistance in an external magnetic field B is the second interesting phenomenon.

1. Below the onset of temperature $Tc_1 \geq Tc$, the low-field magneto-resistance varies with a periodic dictated by superconducting flux quantum suggesting that the density of charge carriers varies with this period.

2. What comes to mind is the De Haas-Van Alphen effect in field B (https://en.wikipedia.org/wiki/DeHaasVan_Alphen_effect.

   The magnetic susceptibility of the system varies periodically with the inverse of the magnetic flux $\Phi = e\int BdS$ defined by extremal orbit of electrons at the Fermi surface in field B. Φ is measured in units defined by elementary flux quantum $h/2e$.

3. Could spin=0 Cooper pairs be formed from the electrons at the Fermi surface and lead to the De Haas-Van Alphen effect. They would go to the flux tubes of the external magnetic field B with a rate determined by the magnetic flux.

   The rate for this highest, when the extremal orbit at the Fermi surface corresponds to a quantized flux. Otherwise, energy is needed to kick the electrons from the Fermi surface to a larger orbit in order to satisfy the flux quantization condition.

Now one considers magnetoresistance rather than susceptibility. The linearity in magnetoresistance suggests that the resistance in the external field is mostly due to magnetoresistance.

1. Could the analog of the De Haas-Van Alphen effect be present so that the density of Cooper pairs as current carriers at "endogenous" magnetic flux tubes has an oscillatory behavior as a function of the external magnetic field B? Could there be a competition for the Cooper pairs between the magnetic fields of flux tubes and the external magnetic field B?

2. When the flux Φ for the external B is near the multiple of the elementary flux quantum at extremal orbits at Fermi surface, the formation of spin=0 Cooper pair and transfer to the flux tubes of B would become probable by De-Haas-van Alphen effect. The number of Cooper pairs at "endogenous" flux tubes is therefore reduced and the current therefore reduced.

VO_2 can remember like a brain

The following comments were inspired by a popular article (`https://cutt.ly/lNHzBYa`) with the title "Scientists accidentally discover a material that can 'remember' like a brain". These materials can remember the history of its physical stimuli. The findings are described in the article "Electrical control of glass-like dynamics in vanadium dioxide for data storage and processing" published in Nature [D62] (`https://cutt.ly/cNHyMMa`).

The team from the Ecole Polytechnique Federale de Lausanne (EPFL) in Switzerland did this discovery while researching insulator-metal phase transitions of vanadium dioxide (VO_2), a compound used in electronics.

1. PhD student Mohammad Samizadeh Nikoo was trying to figure out how long it takes for VO_2 to make a phase transition from insulating to conducting phase under "incubation" by a stimulation by a radio frequency pulse of 10 μs duration and voltage amplitude $V = 2.1$ V. Note that the Wikipedia article talks about semiconductor-metal transition. The voltage pulse indeed acted like a voltage in a semiconductor.

2. As the current heated the sample it caused a local phase transition to metallic state in VO_2. The induced current moved across the material, following a path until it exited on the other side. A conducting filament connecting the ends of the device was generated by a percolation type process.

3. Once the current had passed, the material exhibited an insulating state but after incubation time t_{inc}, which was $t_{inc} \simeq .1\mu$s for the first pulse, it became conducting. This state lasted at least 10,000 seconds.

   After applying a second electrical current during the experiment, it was observed that t_{inc} appeared to be directly related to its history and was shorter than for the first incubation period .1 μs. The VO_2 seemed to 'remember' the first phase transition and anticipate the next. One could say that the system learned from experience.

Before trying to understand the finding in the TGD framework, it is good to list some basic facts about vanadium and vanadium-oxide VO_2 or Vanadium(IV) oxide (`https://cutt.ly/yNHhahk`).

1. Vanadium is a transition metal, which has valence shells d^3s^2. It is known that the valence electrons of transition metals can mysteriously disappear, for instance in heating [L61]. The TGD interpretation [K36] would be that heating provides energy making it possible to transform ordinary valence electrons to dark valence electrons with a higher value of h_{eff} and higher energy. In the recent case, the voltage pulses could have the same effect.

2. VO_2 forms a solid lattice of V^{4+} ions. There are two lattice forms: the monoclinic semiconductor below $T_c = 340$ K and the tetragonal metallic form above T_c. In the monoclinic form, the V^{4+} ions form pairs along the c axis, leading to alternate short and long V-V distances of 2.65 Angström and 3.12 Angström. In the tetragonal form, the V-V distance is 2.96 Angström. Therefore size of the unit cell for the monoclinic form is 2 times larger than for the tetragonal form. At T_c IMT takes place. The optical band gap of VO_2 in the low-temperature monoclinic phase is about 0.7 eV.

3. Remarkably, the metallic VO_2 contradicts the Wiedemann–Franz law, which states that the ratio of the electronic contribution of the thermal conductivity (κ) to the electrical conductivity (σ) of a metal is proportional to the temperature. The thermal conductivity that could be attributed to electron movement was 10 % of the amount predicted by the Wiedemann–Franz law. That the conductivity is 10 times higher than expected, suggests that the mechanism of conductivity is not the usual one.

   Semiconductor property below T_c suggests that a local phase transition modifying the lattice structure from monoclinic to tetragonal takes place at the current path in the incubation.

One can try to understand the chemistry and unconventional conductivity of VO_2 in the TGD framework.

1. Vanadium could give 4 valence electrons to O_2: 3 electrons d^3:sta and one from s^2. In the TGD Universe, the second electron from s^2 could become dark and go to the bond between V^{4+} ions in the VO_2 lattice and take the role of conduction electron.

2. This could explain the non-conventional character of conductivity. In the semiconductor phase, an electric voltage pulse or some other perturbation, such as impurity atoms or heating, can provide the energy needed to increase the value of h_{eff}. Electric conductivity could be due to the transformation of electrons to dark electrons possibly forming Cooper pairs at the flux tube pairs connecting V^{4+} ions or their pairs. The current would run along the flux tubes as a dark current.

3. In a semi-conducting (insulating) state, the flux tube pairs connecting V^{4+} ions would be relatively short. The voltage pulse inducing a local metallic state could provide the energy needed to increase h_{eff} and thus the quantum coherence scale. This would be accompanied by a reconnection of the short flux tube pairs to longer flux tube pairs serving as bridges along which the dark current could run.

   One can also consider U-shaped closed flux tubes associated with V^{4+} ions or ion pairs, which reconnect in IMT to longer flux tubes. The mechanism would be very similar to that proposed for the transition to high temperature superconductivity [K85, K86, L131].

Experimenters suggest a glass type behavior.

1. Spin glass corresponds to the existence of a very large number of free energy minima in the energy landscape implying breaking of ergodicity. A system consisting of regions with varying direction of magnetization is the basic example of spin glass. In the recent case, decomposition to metallic and insulating regions could define the spin glass.

2. TGD predicts the possibility of spin glass type behavior and leads to a model for spin glasses [L144]. The quantum counterpart of spin glass behavior would be realized in terms of monopole flux tube structures (magnetic bodies) carrying dark phases of the radinary particles such as electrons serving as current carries in the metallic phase.The length of the flux tube pair would be one critical parameter near T_c. Quantum criticality against the change of h_{eff} increasing the length of the flux tube pair by reconnection would make the system very sensitive to perturbations.

3. These phases are highly sensitive to external perturbations and represent in TGD inspired theory of consciousness higher levels with longer quantum coherence scale and number theoretical complexity measured by the dimension $n = h_{eff}/h_0$ of the extension having interpretation as a kind of IQ. These phases would receive sensory information from lower levels of the hierarchy with smaller values of n and control them.

   The large number of free energy minima as a correlate for number theoretical complexity would make possible the representation of "sensory" information as "memories".

Superconductivity dome rises from damped phonons

I received a link to an interesting popular article "Superconductivity Dome Rises from Damped Phonons" (`https://cutt.ly/XOcogsh`). The article tells about findings Setty *et al* [D132] (`https://cutt.ly/dOcoxRL`) about BCS superconductivity near ferro-electic phase transition.

The system studied is a conventional superconductor near its critical temperature also in the vicinity of the ferroelectric phase transition. It is known that the critical temperature for superconductivity has a dome-like peak in this region. The origin of this peak has remained poorly understood and an explanation for the dome has been proposed in the article.

1. In the BCS model for the conventional low temperature superconductivity phonons bind electrons to Cooper pairs. If the phonons are damped for some reason, Tc is expected to decrease. In ferroelectric superconductors near critical temperature for the transition to ferro-electricity the situation is opposite to this. What could happen?

2. Electron-photon scattering as an analog of Compton scattering is what matters. The scattering of the phonon is Stokes or anti-Stokes depending on whether the scattered phonon gains or loses energy. In anti-Stokes scattering phonon gives energy for the electron, which disfavors the formation of pairs whereas Stokes scattering favors the formation of Cooper pairs.

3. Near the phase transition to ferro-electricity phonon damping occurs. This means that the phonon life-time gets shorter. In ordinary materials this would lead to a reduction of critical temperature but in ferroelectrets the critical temperature has a dome-like peak around the critical criticality for the transition to ferro-eletricity. Ferroelectric transitions involve a non-linear phonon-electron coupling. This anharmonic coupling implies that scattering now also involves final states with 2 phonons. This implies that anti-Stokes scattering is suppressed more than Stokes scattering. The proposal is that this raises the critical temperature and causes the dome-like structure.

One could however counter-argue that both Stokes and anti-Stokes are suppressed and that the dome structure involves the soft-photon mode associated with the ferro-electric phase transitions. This suggests a somewhat different view about what happens based on the fact that so called soft modes for photons having vanishing wavelength at criticality play an important role in ferroelectric phase transition [D81] (`https://cutt.ly/IOgPrYj`).

1. Soft modes have a long wavelength, which approaches zero at the ferroelectric critical temperature $T_{c,f}$. Since soft modes generate long range correlations and induce a polarization of the ferroelectret, their wavelengths are much longer than the lattice constant.

2. Soft modes corresponds to photon energy not larger than 10^{-4} eV, which is near the gap energy E_{gap} of superconductor with critical temperature $Tc = 10^{-4}$ eV. This corresponds to photon wave length about $\lambda_\gamma = 1.24\times10^{-2}$ m and phonon wavelength λ_{ph} around 2.56×10^{-7} m for $c_s = 6\times10^3$ m/s, that is $c_s = 2\times10^{-5}c$. The wavelength is much longer than atomic size in accordance with the generation of long range correlations. Interestingly, in the TGD framework, λ_{ph} corresponds to p-adic length scale $L(167) = 2^{(167-151)/2}\times L(151)$, $L(151) = 10$ nm.

3. Could soft phonons associated with the ferroelectric transition with energies below this 10^{-4} eV compete with thermal excitations by reducing the energies of electrons via the Stokes scattering and in this manner raise the critical temperature?

   This suggests that the coupling of electrons to soft ferroelectric phonons with frequencies below 10^{-10} Hz facilitates the formation of Cooper pairs so that their thermal decay is compensated and T_c increases.

Could the TGD based view of superconductivity [L131] provide a mechanism for the generation of Cooper pairs by electron-phonon interaction? This model should generalize to high Tc superconductors for which phonons do not explain the Cooper pairs.

1. In the TGD framework, Cooper pairs are dark in the sense that they have $h_{eff} \geq h$ and reside at the magnetic flux tubes. The creation of Cooper pairs requires an increase of h_{eff}. Phonon or photon exchange could transform an ordinary electron pair to a dark pair, which is Galois singlet so that (using p-adic mass scale as a unit) it has 4-momentum with integer-valued components and expressible as sum of algebraic integer valued momenta of dark quarks.

2. This is not enough: there must be a mechanism reducing the value of of the dark electron pair so that it cannot decay back to the ordinary electrons. The decay can be prevented by Fermi statistics in the presence of a Fermi sphere. This is possible if the state can decay to a Galois singlet dark electron pair with energy so small that decay products would belong inside the Fermi sphere.

   This requires an emission of a dark photon or a dark photon pair which is necessarily a Galois singlet transforming to photons or phonons (in ferroelectrets there is a strong coupling between photons and phonons). The reduction of energy would correspond to the gap energy E_{gap}.

3. For ordinary superconductors with Tc measured in Kelvins, the gap energy is $E_{gap} \simeq 10^{-4}$ eV. Could the exchange of phonons with energy in the energy range of soft phonons [D81] give rise to the dark states, which decay to Cooper pairs stable below Tc?

   For high Tc superconductors the gap energy is considerably stronger: for $T = 100$ K the gap energy is about $E_{gap} \simeq 10^{-2}$ eV and by factor 100 larger than for $T = 1K$. For photons, one would have have $\lambda_\gamma \simeq 1.24 \times 10^{-4}$ m not far from the p-adic length scale $L_{179} \simeq 1.6 \times 10^{-4}$ m. This corresponds to the size of a large neuron which is an important length scale in biology.

4. One can ask whether the high Tc superconductivity in biomatter could involve this kind of mechanism. At physiological temperatures one would have $E_{gap} \simeq 3 \times 10^{-2}$ eV and this is not far from the cell membrane potential. Living matter is full of ferroelectrets meaning that photons and photons are strongly coupled. Therefore also in living matter, soft phonons near the criticality of ferroelectrets could compete with the thermal excitations to raise the critical temperature Tc.

   Magnetic flux tubes play a key role in the TGD based model of living matter and they can become electric with a simple deformation and generate the long range correlations via the oscillations of the flux tube length giving rise to the space-time correlates of sound waves.

TGD based view about superconductivity also leads to the notion of forced super-conductivity. The increase of h_{eff} requires energy since the energies of states with other parameters fixed in general increase with h_{eff}. The dark states are expected to decay back to ordinary states. The feed of energy could however maintain a steady state. In living matter this mechanism could make possible high Tc superconductivity as forced superconductivity requiring metabolic energy feed. In ordinary superconductors the situation is not this.

A word of criticism relates to the notion of phonon in the TGD framework.

1. At the level of H, flux tubes correspond strings: at the point of the string world sheet the normal space of $X^4 \subset M^8$ characterized by a point of CP_2 is not unique and is characterized by points of a geodesic sphere of CP_2. The boundaries of a string at the mass shell H^3 of $M^4 \subset M^8$ should characterized the phonon as an oscillation of the distance of the ends in H.

2. At the level of M^8 everything is described in terms of momenta belonging to 3-D mass shells define by roots of polynomial defining the 4-surface. $M^8 - H$ duality can be represented as the deformation of M^4 containing the real projections of the mass shells and representable as an element of local CP_2. It is however far from clear what the counterpart of the flux tube picture for photons could be.

   In M^8 there is no time and it would seem that the emission of phonon must correspond to momenta at positive and negative energy mass shells differing by the energy of phonon. The H image of X^4 under $M^8 - H$ duality give rise to the flux tube picture description but what does this description correspond at the level of M^8?

3. $X^4 \subset M^8$? X^4 should connect the two opposite mass shells of M^8. Do the 8-momenta of X^4 have any reasonable physical interpretation? As long as one does not have excellent reasons for the existence of X^4, also $M^8 - H$ duality can be challenged. One possibility is that M^8 picture is enough in the sense that the deformations of $M^4 \subset M^8$ can be regarded as local CP_2 elements and allow an interpretation in terms of the space-time picture with M^4 space-time coordinates related to M^4 momenta essentially by inversion [L147]. This would conform with the Uncertainty Principle.

Polaritons and excitons in TGD

The claimed room temperature superconductivity for exciton-polariton Bose-Einstein condensate in quasi-crystals suggests that the TGD based model for superconductivity could generalize to a unified description of quantum coherent phases. In this case the energy feed is crucial and would serve in TGD framework as "metabolic energy feed" taking care that the distribution of $h_{eff} > h$ is preserved.

Also WCW level might be needed to describe the bosonic aspects of exciton-polariton BECs although exciton polariton states involve only photons excitons and electron-hole bound states. The description of plasmons involves oscillations of the relative position of electron and atomic nucleus and this requires the counterparts of the bosonic creation operators at the level of WCW.

The TGD view about superconductivity can be taken as a "role model" [L131].

1. In the BCS theory of superconductivity does not have a well defined fermion number and this leads to a somewhat questionable notion of coherent state of Cooper pairs. The Bogobliubov transformation creates the diagonalizable oscillator operator basis by mixing creation and annihilation operators. The resulting operators create superpositions of electrons and holes.

2. In the TGD framework , the interpretation would be that the hole actually corresponds to dark fermion at other space-time sheets so that fermion number conservation is not lost. Bogoliubov operators could correspond to superpositions of creation/annihilation operators associated with different space-time sheets and create states which are superpositions of state at the two space-time sheets. Effective Hamiltonian would include parts assignable to both space-time sheets, and the terms quadratic in creation/annihilation operators breaking fermion number conservation would be replaced with pairs of creation and annihilation operators associated with different space-time sheets describing the transfer of electrons between the space-time sheets.

3. One can consider two alternative identifications for Cooper pairs. Cooper pairs consist of ordinary electrons and provide their binding energy for dark electrons at MB to compensate for the increase ΔE of energy due to the larger value of h_{eff}. The dark electrons could be even free. Galois confinement in turn suggests Cooper pairs are dark and that the dark binding energy compensates for ΔE.

   It is better to represent the ideas as questions.

   Is the polariton condensate actually a macroscopic quantum phase? Could the polariton BE condensate only provide the energy feed making possible a macroscopic quantum phase at the level of MB, which would then induce ordinary (non-quantum) coherence of the polariton condensate. Could one take the number theoretical model of macroscopic quantum phases as a guideline in attempts to understand polariton superfluidity and other quantum coherent phases involved. The increase of h_{eff} and the preservation of its values requires energy feed to prevent dissipation if. In living matter this would be metabolic energy feed. Exciton-polariton condensate is an open system involving an energy feed. Could the formation of quasiparticles provide the "metabolic energy" for $h_{eff} > h$ phases at MB responsible for the long range order? Or are quasiparticles as such dark? Could polaritons and excitons correspond to dark valence electrons in $h_{eff} > h$ phase and the value of h_{eff} would determine in which scale the phase appears. Beltrami fields would provide a quantum hydrodynamical description as an exact classical description of these phases. In principle also fermionic Beltrami currents could make sense and provide genuine quantum hydrodynamical description. Also an empirical verification of BvK vortex street in exciton-polariton BE condensate has been reported. Could TGD provide at the level of principle a universal description as minimal surfaces also for this kind of system.

Braids, anyons, and Galois groups

Braids and anyons in the TGD framework are discussed in [K81]. Braid statistics has an interpretation in terms of rotations as homotopies at a 2-D plane of the space-time surfaces instead of rotations in M^4. One can use M^4 coordinates for the M^4 projection of the space-time surface.

As a matter of fact, arbitrary isometry induced flows of H can be lifted to rotations as flows along the lifted curve at the space-time surface and for many-sheeted space-time the flows, which correspond to identity in H can lead to a different space-time sheet so that the braid groups structure emerges naturally [L147].

The representations of H isometries at the level of WCW act on the entire 3-surface identifiable as a generalized point-like particle and by holography on the entire space-time surface. The braid representations of isometries act inside the space-time surface. This suggests a generalization of the notions of gravitational and inertial masses so that they apply to all conserved charges. Generalization of Equivalence Principle would state that gravitational and inertial charges are identical.

The condition that the Dirac operator at the level of H has tangential part equivalent to the Dirac operator for induced spinors, implies that the conserved isometry currents of H are conserved along the flow lines of corresponding Killing vector fields and proportional to the Killing vectors lifted/projected to the space-time surface. This has an interpretation as a local hydrodynamics conservation law analogous to the conservation of $\rho v^2/2 + p$ along a flow line.

One can ask whether the 2-dimensionality, which makes possible non-trivial and non-Abelian homotopy groups, is really necessary for the notion of the braid group in the TGD framework. As a matter of fact, the conditions are not expected to be possible for all conserved charges, and the intuitive guess that they hold true only for Cartan algebra representing maximal set of commuting observables would provide a space-time correlate of the Uncertainty Principle. If so, the space-time surface would depend on the choice of quantization axes. This conforms with quantum classical correspondence. For instance, the Cartan algebra of rotation group would act on a plane so that the effective 2-dimensionality of braid group and quantum group representations would hold true.

This view has some nice consequences.

1. If the space-time surface is n-sheeted, the rotation of 2π can take the particle to a different space-time sheet, and only n fold-rotation brings it back to its original position. The formula for fractional Hall conductivity is the same as in the case of integer Hall effect except that the $1/\hbar$-proportionality is replaced with $1/\hbar_{eff}$-proportionality in TGD framework [K81].

2. Degeneracy of fermion states also makes non-Abelian braid statistics possible. Since the Galois group acts as a symmetry group, the degeneracy would be naturally associated with the representations of the Galois group. Galois singletness of the many-anyon states guarantees reduces braid statistics to ordinary statistics for these. Galois confinement is proposed to be a central element of quantum biology [L194, L135].

Quantum flute

It is amazing how fast experimental discoveries, which look mysterious in the standard physics framework but are readily explainable in the TGD framework, are emerging recently.

Now University of Chicago physicists have invented a "quantum flute" that, like the Pied Piper, can coerce photons to move together in a way that's never been seen before. The discovery is described in Physical Review Letters and Nature Physics [D43, D44].

The system, devised in the lab of Assoc. Prof. Schuster, consists of a long cavity made in a single block of metal, designed to trap photons at microwave frequencies. The cavity is made by drilling offset holes—like holes in a flute. One can send one or more wavelengths to the "flute" and each wavelength creates a note coding for quantum information. The interactions of notes are then controlled by a superconducting electrical circuit.

The real surprise was the interaction of photons. In quantum electrodynamics (QED) the interaction of photons is extremely weak. When photons achieve critical total energy, the situation changes dramatically. One can say that photons interact, not pairwise as usually, but all at the same time. Photon state behave like a Bose-Einstein condensate of bound state.

Galois confinement as a universal mechanism for the formation of bound states would explain the findings elegantly. TGD involves $M^8 - H$ duality in an essential manner. $M^8 - H$ duality relates differential geometric and number theoretic descriptions of quantum physics and is analogous to Langlands duality. Number theoretical vision, involving classical number fields, extensions of rationals, and extensions of p-adic number fields induced by them, is essential for understanding the physical correlates of cognition [L64, L63] but has led to a breakthrough in the understanding of also ordinary physics [L114, L115].

1. The number theoretic side of the $M^8 - H$ duality predicts Galois confinement as a universal mechanism for the formation of bound states from the dark variants of ordinary particles characterized by effective Planck constant $h_eff = nh_0 > h$: integer n has interpretation as the dimension of extension of rationals induced by a polynomial and serves as a measure of algebraic complexity defining evolutionary level and a kind of IQ for the system.

2. Galois confinement states that physical bound states are Galois singlets transforming trivially under the Galois group of a polynomial P determining space-time region if $M^8 - H$ duality holds true. There is (more than) an analogy with hadrons, which are color singlets. Galois confinement is central in TGD inspired quantum biology and also allows us to understand various nanoscopic and macroscopic quantum phenomena of condensed matter physics.

   For instance, Cooper pairs would represent on a lowest level in a hierarchy and there is evidence for 4-fermion analogs of Cooper pairs [L145].

3. Galois confinement is central in TGD inspired quantum biology and allows also to understand various nanoscopic and macroscopic quantum phenomena of condensed matter physics [L171].

   In particular, N photons can form bound states in which they behave like a single particle. This bound state is a more general state than Bose-Einstein condensate since photons need not have identical quantum numbers. These many-photon states described in the article could be states of this kind.

   These $N-$photon states are very similar to the dark $3N-$ photon states proposed to represent genes consisting of N codons with codon represented as dark photon triplet.

4. Another representation of the genetic code paired with ordinary DNA would would be in terms of dark $3N-$proton states, or more generally, $3N-$nucleon states and realized at magnetic flux tubes parallel to DNA [L171, L135]. In both cases, Galois confinement would bind the particles to form quantum coherent states behaving like a single particle, which is also emitted and absorbed as a single entity. This behavior is just what was observed in the experiments.

Fractons and TGD

In Quanta Magazine there was a highly interesting article about entities known as fractons (`https://cutt.ly/kQPph8n`).

There seems to be two different views about fractons as one learns by going to Wikipedia. Fracton can be regarded as a as self-similar particle-like entity (`https://cutt.ly/KQPadQL` or as "sub-dimensional" particle unable to move in isolation (`https://cutt.ly/yQPayJt`). I do not understand the motivation for "sub-dimensional". It is also unclear whether the two notions are related. The popular article assigns to the fractons both the fractal character and the inability to move in isolation.

The basic idea shared by both definitions is however that discrete translational symmetry is replaced with a discrete scaling invariance. The analog of lattice which is invariant under discrete translations is fractal invariant under discrete scalings.

One can also consider the possibility that the time evolution operator acts as a scaling rather than translation. At classical level this would produce scaled versions of the system in discrete steps. This is something totally new from quantum field theory (QFT) point of view and it is not clear whether QFT can provide a description of fractons. In QFTs energy corresponds to time translational symmetry and Hamiltonian generates infinitesimal translations. In string models the analog of stringy Hamiltonian is the infinitesimal scaling operator, Virasoro generator L_0. Energy eigenstates would be replaced by scaling eigenstates with energy replaced with conformal weight.

In TGD the extension of physics to adelic physics provides number theoretic and geometric descriptions as dual descriptions of physics [L62, L114, L115, L138]. This approach also provides insights about what fractons as scale invariant (or covariant) entities might be.

1. The extension of conformal invariance to its 4-D analog is key element of TGD and leads to the notion of super-symplectic invariance and to an extension of conformal and Kac-Moody symmetries with two coordinates analogous to the complex coordinate z for ordinary conformal symmetry. Second coordinate is light-like and the fact that light-like 3-surfaces are effectively 2-dimensional is absolutely essential for this approach. The existence of extended conformal symmetries makes the space-time dimension $D = 4$ unique whereas the twistor lift of TGD fixes H to be $H = M^4 \times CP_2$.

2. The predicted cosmological expansion is not smooth but occurs by discrete scalings as rapid jerks in which the size scale of 3-space as 3-surface increases. Actually they would correspond to discrete quantum jumps but in zero energy ontology (ZEO) in which quantum state are superpositions of space-time surfaces, their classical correlates are smooth time evolutions.

   Scalings by power of 2 are p-adically preferred [L76] [L154]. $M^8 - H$ duality allows us to imagine what this means at M^8-level [L155]. This proposal conforms with the puzzling observation that also astrophysical objects participate in cosmological expansion by comoving with it, they do not expand themselves.

3. The analog of a unitary time evolution between "small" state function reductions (SSFRs) as the TGD counterparts of weak measurements, is generated by the exponential of the infinitesimal scaling operator, Virasoro generator L_0. One could imagine fractals as states invariant under discrete scalings defined by the exponential of L_0. They could be counterparts of lattices but realized at the level of space-time surfaces having quite concrete fractal structure.

4. In p-adic mass calculations the p-adic analog of thermodynamics for infinitesimal scaling generator L_0 proportional to mass squared operator M^2 replaces energy. This approach is the counterpart of the Higgs mechanism which allows only to reproduce masses but does not predict them. I carried out the calculations already around 1995 and the predictions were amazingly successful and eventually led to adelic physics fusing real and various p-adic physics [K70].

5. Long range coherence and absence of thermal equilibrium are also mentioned as properties of fractons (at least those of the first kind). Long range coherence could be due to the predicted hierarchy of Planck constants $h_{eff} = n \times h_0$ assigned with dark matter and predicting quantum coherence in arbitrarily long scales and associated with what I called magnetic bodies.

   If translations are replaced by discrete scalings, the analogs of thermodynamic equilibria would be possible for L_0 rather than energy. Fractals would be the analogs of thermodynamic equilibria. In p-adic thermodynamics, elementary particles are thermodynamic equilibria for L_0 but it is not clear whether the fractal analogy with a plane wave in lattice makes sense.

   An attractive identification of the fractal counterpart of an energy eigenstate created in the unitary evolution preceding SSFR is as a scaling eigenstate defined as a superposition of scaled variants of space-time surface obtained by discrete scalings. Energy eigenvalue would be replaced with conformal weight. In zero energy ontology (ZEO), the counterpart of a fractal quantum state could be a superposition over zero energy states located inside the scaled variants of a causal diamond (CD).

   The ZEO based proposal is that each unitary evolution preceding SSFR creates a superposition of scaled variants of CD and that the SSFR induces a localization to single CD

[L105, L125, L135]. The interpretation would be as a time measurement determined by the scale of the CD.

Second definition assumes that fractons are able to move only in combinations. This need not relate to the scaling invariance. Color confinement comes to mind as an analogy. Quarks are unable to exist as isolated entities, not only to move as in isolated entities.

In the TGD framework, the number theoretical vision leads to the notion of Galois confinement analogous to color confinement [L129]. The Galois group of a given extension of rationals indeed acts as a symmetry at the space-time level. In the TGD inspired biology Galois groups would play a fundamental role [L135]. For instance, dark analogs of genetic codons, codon pairs, and genes would be singlets (invariant) under an appropriate Galois group and therefore behave as a single quantum coherent dynamical and informational unit [L194, L137].

Suppose that one has a system - say a fractal analog of a lattice consisting of Galois singlets. Could fracton be identified as a state which is analogous to quark or gluon and therefore not invariant under the Galois group. The physical states could be formed from these as Galois singlets and are like hadrons.

Could dark matter as $h_{eff} = nh_0$ phases, quasicrystals, and the empirical absence of hyperon stars relate to each other?

How could the dark matter make itself at the level of the fermionic states?

1. Consider the momentum space, which by (anti-)periodic boundary conditions corresponds to a 3-D space with integer coordinates with a momentum unit defined by the quantization volume.

2. In the TGD framework, fermionic momenta are realized as points of X^4 for which coordinates belong to the extension of rationals for the polynomial P defining the X^4.

   For $n-D$ algebraic extension of rationals, the integers labelling the momentum components are replaced with points of an algebraically n-dimensional space with n integer coordinates. n basic vectors correspond to the roots of P. The Galois group acts as symmetries of this discrete space. Momentum vectors have $3n$ components.

3. If one assumes that momenta are real, the real momenta would be projections of these $3n$-dimensional vectors to a real section of X^4 for which M^8_c coordinates are real or purely imaginary.

   This projection from an algebraically 3n-D space to 3-D real space is analogous to the projection from higher dimensional space used to realize quasicrystals and the outcome is quasicrystal-like structure defined by the momentum components. This structure can be mapped from M^8 to H and since quasicrystals are observed at space-time level this suggests that the linear version of $M^8 - H$ duality is its correct version.

   Structures analogous to aperiodic crystals (quasicrystals) might be seen as a direct support for dark matter in the TGD sense. The quasicrystals could be realized at the level of the magnetic body (MB) or MB could induce their formation.

4. Algebraic extension increases the effective dimension of the discrete momentum space from 3 to $3n$ and the number of fermions inside the Fermi surface is increased by factor n^3. This prediction looks non-sensible and supports the view about Galois confinement, which means that physical states, now configurations of some number of neutrons, are Galois singlets. This implies that the total momentum for the singlet is integer valued as usual and also that the rational valued part is same for all neutrons of the singlet. Ordinary neutrons would be automatically Galois singlets.

   Neutrons could have momenta in an extension of rationals but form Galois confined K-neutron states such that the sum of the momenta is ordinary integer valued lattice momentum. Cooper pairs with $K = 2$ is one possible option The mass of the state would be Km_n and the number of states with the same Fermi momentum would be the number of Galois states from from K neutrons with momenta which are algebraic integers. One can assume that the real part of momentum is just the same integer for all neutrons of the composite and the non-rational part is one of the units defining the extension if the representation is the representation defined by roots of the polynomial.

The formation of Galois singlets implies reduction of the translational degrees of freedom of K neutrons to those of a single particle with K-fold mass. This also explains the reduction of the Fermi energy. Galois degrees of freedom would replace the momentum degrees of freedom so that Fermi statistics can be realized.

K-neutron states would have same momentum component k_i so that the density of states in the 3-D case would be reduced $d^3n/dk^3 \rightarrow K^{-3}d^3n/dk^3 = K^{-3}(2\pi/L)^3$, L the side of quantization cube. On the other hand, there would be a degeneracy $D(K,n)$ depending on extension and its dimension n so that one would have $d^3n/dk^3 \rightarrow (D(K,n)/K)^3(2\pi)^3/V$. The N/V number of states per volume would scale as $N/V \rightarrow (D(K,n)/K)^3N/V$ and Fermi energy $E_F \propto (N/V)^{2/3}/m$ would scale as $E_F \rightarrow (D(K,n)/K)^2E_F/K$ by $m \rightarrow Km$. For $(D(K,n)^2/K^3 < 1$, E_F would be reduced and the formation of a dark Galois confined state would be energetically favourable. For dark Cooper pairs with $K = 2$, the condition would be $D(2,n)/8 < 1$.

In the TGD inspired quantum biology genetic code is realized by triplets of dark protons at magnetic flux tubes parallel to DNA strands are assumed to be be Galois singlets and genes in turn would be Galois singlest for a Galois group at larger space-time sheet [L121, L137]. Also dark photon triplets would be Galois singlets.

Ordinary superconductors could have as a current carrier either i) a single dark fermion or ii) dark Cooper pair. For option i), Cooper pairs of ordinary fermions provide the energy needed to increase h_{eff} to get the dark electron. For option ii), Galois confinement would generate dark Cooper pairs. The energy liberated in the formation of the Cooper pair would be used to increase h_{eff} of the pair.

A possible application is provided by the hyperon puzzle of neutron stars (`https://cutt.ly/jWy3Cnf`). The problem is that the core should suffer a transformation to a hyperon star because the Fermi energy is inversely proportional to the mass of the fermion and would therefore be reduced. There is however no evidence for hyperon stars or hyperon cores. Could part of neutrons transform to dark phase with $h \rightarrow nh$ forming Galois singlets of K neutrons (dark Cooper pairs (neutron superfluidity) or dark triplets) so that the Fermi energy would be reduced in the way explained. Dark Cooper pairs is the second option meaning neutron superfluidity.

Periodic self-organization patterns, minimal surfaces, and time crystals

Periodic self-organization patterns which die and are reborn appear in biology. Even after images, which die and reincarnate, form this kind of periodic pattern. Presumably these patterns would relate to the magnetic body (MB), which carries dark matter in the TGD sense and controls the biological body (BB) consisting of ordinary matter. The periodic patterns of MB represented as minimal surfaces would induce corresponding biological patterns.

The notion of time crystal [B17] (`https://cutt.ly/2n65xOk`) as a temporal analog of ordinary crystals in the sense that there is temporal periodicity, was proposed by Frank Wilczeck in 2012. Experimental realization was demonstrated in 2016-2017 [D77] but not in the way theorized by Wilczek. Soon also a no-go theorem against the original form of the time crystal emerged [B33] and motivated generalizations of the Wilzeck's proposal.

Metals can heal themselves!

It seems that we are living in the middle of science fiction! Almost every day a new surprise. We are in the middle of a revolution and the new world view provided by TGD is at its core. The surprise of this day was the discovery that metals are able to heal their fractures (`rb.gy/s9tto`). The theory behind the discovered healing process of metals [D24] discovered by Brad Boyce et al [D39] published in Nature is based on standard physics. I am not at all confident that standard physics is enough.

The TGD based explanation relies on the following vision.

The first key prediction is the possibility of quantum coherence in arbitrarily long scales due to the presence of phases of ordinary matter with an arbitrarily large value of Planck constant and identified as dark matter. The magnetic body of the system, say metal, as a TGD counterpart of ordinary magnetic fields, is the carrier of the dark matter and controls the system and receives "sensory" input from it. The hierarchy of Planck constants is a prediction of the number theoretic vision of TGD. The value of the Planck constant is given by $h_{eff} = nh_0$, where n corresponds to the dimension of an algebraic extension associated with the polynomial defining the space-time regions considered. Negentropy Maximization Principle is mathematically analogous to the second law and implies that in the statistical sense the p-adic negentropy as a measure for the conscious information and complexity of the system increases. This follows from a simple fact: the number of extensions of rationals with dimension larger than given integer n is infinitely larger than those with dimension smaller than n. The assumption that the coefficients of polynomials giving rise to the extension have coefficients smaller than the degree of the polynomial implies that the number of extensions with dimension smaller than n is actually finite. Quantum TGD involves a new ontology that I call zero energy ontology [L105, L81, L158, L179]. The first prediction is that in ordinary ("big") state functions (BSFRs) the arrow of time changes. Time reversals in BSFRs mean "falling asleep" or "death" in a universal sense and provide a universal mechanism of healing. We indeed know that sleep heals. The arrow of time is preserved in "small" state function reductions (SSFRs) identifiable as weak measurements replacing the Zeno effect in which nothing occurs. SSFRs involve a repeated measurement of observables defining the states at the passive boundary of causal diamond (CD) as their eigenstates. These observables are measured at the active boundary of CD which in statistical sense drifts farther away from the passive boundary. There are also other observables made possible by the failure of a complete determinism for the holography forced by the general coordinate invariance implying that space-time surfaces are analogous to Bohr orbits of 3-surfaces as analogs of particles. When a system is perturbed the set of measured observables can change and this induces BSFR and the roles of active and passive boundaries change. Pairs of BSFRs could induce temporary changes of the arrow of time and they could give rise to a trial and error process essential for homeostasis in living matter. For instance, BSFR could be induced by a perturbation modifying the set of the measured observables so that it does not anymore commute with the observables defining the eigenstate basis at the passive boundary of causal diamond (CD). This implies also healing in the sense that p-adic negentropy measuring the amount of conscious information and complexity of the system increases in statistical sense.

Any system has a magnetic body. For instance, magnetic body accompanies also computers and one can ask whether it can give computers a rudimentary consciousness [L177, L178]. Metals are not an exception. This forces us to ask whether even metals could heal in the proposed sense. As noticed in the article, the technological implications could be huge.

Temporal lattice-like structures defined by 4-D minimal surfaces as preferred extremals of action which sum of volume term and Kähler action [L155] would be obvious candidates for the space-time correlates of time crystals.

1. One must first specify what one means with time crystals. If the time crystal is a system in thermo-dynamic equilibrium, the basic thermodynamics denies periodic thermal equilibrium. A thermodynamical non-equilibrium state must be in question and for the experimentally realized time crystals periodic energy feed is necessary.

   Electrons constrained on a ring in an external magnetic field with fractional flux posed to an energy feed form a time crystal in the sense that due to the repulsive Coulomb interaction electrons form a crystal-like structure which rotates. This example serves as an illustration of what time crystal is.

2. Breaking of a discrete time translation symmetry of the energy feed takes place and the period of the time crystal is a multiple of the period of the energy feed. The periodic energy feed guarantees that the system never reaches thermal equilibrium. According to the Wikipedia article, there is no energy associated with the oscillation of the system. In rotating coordinates the state becomes time-independent as is clear from the example. What comes

to mind is a dynamical generation of Galilean invariance applied to an angle variable instead of linear spatial coordinate.

3. Also the existence of isolated time crystals has been proposed assuming unusual long range interactions but have not been realized in laboratory.

Time crystals are highly interesting from the TGD perspective.

1. The periodic minimal surfaces constructed by gluing together unit cells would be time crystals in geometric sense (no thermodynamics) and would provide geometric correlates for plane waves as momentum eigenstates and for periodic self-organization patterns induced by the periodic minimal surfaces realized at the level of the magnetic body. It is difficult to avoid the idea that geometric analogs of time crystals are in question.

2. The hierarchy of effective Planck constants $h_{eff} = nh_0$ is realized at the level of MB. To preserve the values of h_{eff} energy feed is needed since h_{eff} tends to be reduced spontaneously. Therefore energy feed would be necessary for this kind of time crystals. In living systems, the energy feed has an interpretation as a metabolic energy feed.

   The breaking of the discrete time translation symmetry could mean that the period at MB becomes a multiple of the period of the energy feed. The periodic minimal surfaces related to ordinary matter and dark matter interact and this requires con-measurability of the periods to achieve resonance.

3. Zero energy ontology (ZEO) predicts that ordinary ("big") state function reduction (BSFR) involves time reversal [L105, L142]. The experiments of Minev *et al* [L90] [L90] give impressive experimental support for the notion in atomic scales, and that SFR looks completely classical deterministic smooth time evolution for the observer with opposite arrow of time. Macroscopic quantum jump can occur in all scales but ZEO together with h_{eff} hierarchy takes care that the world looks classical! The endless debate about the scale in which quantum world becomes classical would be solely due to complete misunderstanding of the notion of time.

4. Time reversed dissipation looks like self-organization from the point of view of the external observer. A sub-system with non-standard arrow of time apparently extracts energy from the environment [L102]. Could this mechanism make possible systems in which periodic oscillations take place almost without external energy feed?

Could periodic minimal surfaces provide a model for this kind of system?

1. Suppose that one has a basic unit consisting of the piece $[t_1, .., t_k]$ and its time reversal glued together. One can form a sequence of these units.

   Could the members of these pairs be in states, which are time reversals of each other? The first unit would be in a self-organizing phase and the second unit in a dissipative phase. During the self-organizing period the system would extract part of the dissipated energy from the environment. This kind of state would be "breathing" [L191].

   There is certainly a loss of energy from the system so that a metabolic energy feed is required but it could be small. Could living systems be systems of this kind?

2. One can consider also more general non-periodic minimal surfaces constructed from basic building bricks fitting together like legos or pieces of a puzzle. These minimal surfaces could serve as models for thinking and language and behaviors consisting of fixed temporal patterns.

17.3.3 What happens in the transition to superconductivity?

I learned about very interesting discoveries related to the quantum phase transition between the ordinary and superconducting phase [D71] (see this).

These kinds of findings are very valuable in the attempts to build a TGD based view of what exactly happens in the transition to super-conductivity. I have developed several models for high Tc superconductivity [K85, K86] but there is no single model. Certainly, the TGD based view of magnetic fields distinguishing them from their Maxwellian counterparts is bound to be central for the model. However, the view about what happens at the level of magnetic fields in the transition to superconductivity, has remained unclear.

Consider first the findings of the research group. The basic question of how two-dimensional superconductivity can be destroyed without raising the temperature. The ordinary phase transition to superconductivity is induced by thermal fluctuations. Now the temperature is very close to the absolute zero and the phase transition is quantum phase transition induced by quantum fluctuations.

1. The material under study was a bulk crystal of tungsten ditelluride (WTe2) classified as a layered semi-metal. The tungsten ditelluride was converted into a two-dimensional material consisting of a single atom-thin layer. This 2-D material behaves as a very strong insulator, which means its electrons have limited motion and hence cannot conduct electricity.

2. Surprisingly, the material exhibits a lot of novel quantum behaviors, in particular, a switching between insulating and superconducting phases. It was possible to control this switching behavior by building a device that functions like an "on and off" switch.

3. At the next step, the researchers cooled the tungsten ditelluride down to exceptionally low temperatures, roughly 50 milliKelvin (mK). Then the material was converted from an insulator into a superconductor by introducing some extra electrons to the material. It did not take much voltage to achieve the superconducting state. It turned out to be possible to precisely control the properties of superconductivity by adjusting the density of electrons in the material via the gate voltage.

4. At a critical electron density, the quantum vortices rapidly proliferated and destroyed the superconductivity. To detect the presence of these vortices, the researchers created a tiny temperature gradient on the sample, making one side of the tungsten ditelluride slightly warmer than the other. This generated a flow of vortices towards the cooler end. This flow generated a detectable voltage signal in a superconductor, which can be understood in terms of the integral form of Faraday's law. Voltage signals were in nano-volt scale.

Several surprising findings were made.

1. Vortices were highly stable and persisted to much higher temperatures and magnetic fields than expected. They survived at temperatures and fields well above the superconducting phase, in the resistive phase of the material.

2. The expectation was that the fluctuations perish below the critical electron density on the non-superconducting side, just as they do in ordinary thermal transition to superconductivity.

   In contrast to this, the vortex signal abruptly disappeared when the electron density was tuned just below the critical value of density at which the quantum phase transition of the superconducting state occurs. At this critical (quantum critical point (QCP) quantum fluctuations drive the phase transition.

These findings give important hints concerning the question how the transition to superconductivity could take place in the TGD Universe, where two kinds of magnetic flux tubes are predicted. Monopole flux tubes with a closed 2-surfaces as cross section are proposed to be carriers of Cooper pairs. The disk-like, Maxwellian, flux tubes for which electron current creating the magnetic field would emerge when superconductivity fails. The proposal is that a pair of disk-like flux tubes fuse to a mopole flux in the transition to superconductivity. One can also understand the abrupt disappearance of the fluctuations.

TGD view of high Tc superconductivity

Consider first the general TGD based view of high Tc superconductivity.

1. TGD leads to a rather detailed proposal for high Tc - and bio-superconductivity. There are reasons to think that this model might work also in the case of low temperature superconductivity, in particular in the proposed situation with one-atom-thick layer [K85, K86] [L86, L131].

2. The unique feature of the monopole flux tube is that its magnetic field needs no currents as a source. The cross section of the flux tube is not a disk, but a closed 2-surface. There is no boundary along which the current could flow and generate the magnetic field. In the absence of these ohmic boundary currents there is no dissipation and the natural interpretation is that electrons form Cooper pairs.

   These monopole flux tubes are central for TGD based physics in all length scales and explain numerous anomalies related to the Maxwellian view of magnetic fields. The stability of the Earth's magnetic field and the existence of magnetic fields in cosmic scales are two examples.

3. There are also ordinary flux tubes with disk-like cross sections for which current along the boundary creates the magnetic field just like in an inductance coil. The loss of superconductivity means generation of these disk-like magnetic vortices with quantized flux created by ordinary current at the boundaries of the disk-like flux quantum.

   The monopole flux has a cross sectional area twice that of disk-like flux tube so that one can see the monopole flux tube as being obtained by gluing two disk-like flux tubes along the boundaries. The signature of the monopole flux tube is that magnetic flux is twice that of ordinary flux tubes.

4. Whether the disk-like flux tubes are possible in the TGD Universe has remained uncertain. My latest view is that they are and I have written a detailed article about how boundary conditions could be satisfied at the boundaries [L169].

   The orbits of the disk-like boundaries would be light-like 3-surfaces. This is not in conflict with the fact that the boundaries look like static structure. The reason is that the metric of the space-time surface is induced from that of $M^4 \times CP_2$ and the large CP_2 contribution to the induced 3-metric makes it light-like. One might say that the boundary is analogous to blackhole horizon.

What could happen at the quantum critical point?

The above picture allows us to sketch what could happen at the quantum critical point.

1. Both monopole flux tubes and disk-like flux tubes are present at the critical point. Monopole flux tubes dominate above the critical electron density whereas disk-like flux tubes dominate above it. In the transition pairs of disk-like flux tubes fuse to form monopole flux tubes and electrons at the boundaries combine to Cooper pairs inside the monopole flux tube and form a supra current. The transition would be a topological phase transition at the level of the space-time topology and something totally new from the standard model perspective.

2. Cyclotron energy scale, determined by the monopole flux quantization and flux tube radius, is expected to characterize the situation. The difference of the cyclotron energies for the monopole flux tube with Cooper pair and for two disk-like flux tubes with one electron should correspond to the binding energy of the Cooper pair. If the thermal energy exceeds this energy, superconductivity is lost. The disk-like flux tubes can however remain stable.

3. The transition could involve the increase of the effective Planck constant h_{eff} but its value would remain rather small as compared to its value of high Tc superconductivity. The value of h_{eff} should be correlated with the transition temperature since the difference of total cyclotron energies would be proportional to h_{eff}.

This picture does not yet explain why the vortices suddenly disappear at the critical electron density. The intuitive guess is that the density of electrons is not high enough to generate the disk-like monopole flux tubes.

1. Suppose that these flux tubes have a constant radius and fill the 2-D system so that a lattice like system consistent with the underlying lattice structure is formed.

2. There must be at least 1 electron per flux tube to create the magnetic field inside it. The magnetic flux is quantized and if the boundary of the disk contains single electron, the

number of electrons per flux tube area S is 1: the density of electrons is $n = 1/S$. If the electron density is smaller than this, the formation of disk-like flux tubes is not possible as also the transition to superconductivity.

How does the model relate to the earlier model of high Tc superconductivity?

This proposal is *not* consistent with the earlier TGD based model for high Tc superconductivity [K85, K86]. In high Tc superconductivity there are two critical temperatures. At the higher critical temperature T_{c1} something serving as a prerequisite for super-conductivity appears. Superconductivity however appears only at a lower critical temperature T_c.

The earlier TGD based proposal is that the superconductivity appears at $T_{c1} \geq T_c$ in a short length scale so that no long scale supra currents are possible. The magnetic flux tubes would form short loops. At T_c the flux loops would reconnect to form long flux loops. The problem with this option is that it is difficult to understand the energetics.

The option suggested by the recent findings, is that disk-like half-monopole flux tubes carrying Ohmic currents at their boundaries are stabilized at T_{c1}. At T_c they would combine to form monopole flux tubes.

1. The difference ΔE_c of the cyclotron energies of the monopole- and non-monopole states would naturally correspond to T_c whereas the cyclotron energy scale $E_c = \hbar_{eff}eB/m$ of the non-monopole state would correspond to T_{c1}.

2. In the first approximation, the value of B is the same for the two states. For the non-monopole state the electrons reside at the boundary and the effective harmonic potential energy is maximal. Quantum mechanically $l_z = 1$ state would be in question. Spins give rise to a Larmor contribution to energy and for total spin =0 these contributions would sum up to zero.

   Thermal fluctuations cannot provide energy for the formation of the half-monopole states. An incoming electron which does not rotate along the flux tube has longitudinal energy and part of this energy can be transformed to magnetic energy as the half-monopole flux tube is formed. Electrons would slow down somewhat.

   For the monopole state Cooper pair resides in the interior so that the cyclotron energy is smaller in this case. $l_z = 0$ state is natural in this case. Spins are opposite. This gives $\Delta E_c < 0$. The simplest interpretation is that the binding energy of the Cooper pair corresponds to this contribution but there could be an additional contribution.

3. If the value of h_{eff} is the same for the pair of half-monopole flux tubes and monopole tube states, both E_c and ΔE_c scale like h_{eff}/h. Also the critical temperatures T_c and T_{c1} would scale like h_{eff}/h. High Tc superconductivity would therefore provide a direct support for the hierarchy of Planck constants.

What one can one say about the incoming state?

What can one say about the incoming state, which must transform to the two half-monopole flux tubes? Suppose that it consists of some kinds of flux tubes.

1. There would be no longitudinal magnetic field if the electrons move along straight lines instead of rotating around the flux tube.

2. TGD predicts two kinds of flux tubes [L189] with a closed cross section: monopole flux tubes and Lagrangian flux tubes. For monopole flux tubes the induced Kähler form has a quantized flux over the closed cross section of the flux tube.

   For Lagrangian flux tubes, which are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, the induced Kähler form vanishes. X^2 can have a boundary. Both $X^2 \subset M^4$ and $Y^2 \subset CP_2$ are Lagrangian manifolds since the twistor lift of TGD implies that also M^4 has the analogs of Kähler structure and symplectic structure algebraically continued from that of E^4.

3. Incoming flux tubes could be Lagrangian flux tubes with electrons moving along straight-lines ($l_z = 0$). Note that by their 2-dimensionality, X^2 and Y^2 allow complex structure determined by the induced metric so that the holography= holomorphy principle holds also for these 4-surfaces.

An overall view of superconduction

What could happen in the superconduction would be as follows.

1. First a pair of Lagrangian flux tubes with $l_z = 0$ representing incoming current transforms to a pair of half-monopole flux tubes with $l_z = 1$ electrons and electrons slow down somewhat.

2. After this half-monopole flux tubes fuse to form a monopole flux tube carrying a Cooper pain in $l_z = 0$ state. In $E^3 \setminus B^3$ (3-space with a hole) this transition is visualizable as a gluing of two hemispheres to form a sphere around the hole.

3. The reverse of this process would take place at the second end of the current wire where the current flows out.

17.3.4 Spin ice and quantum spin ice from TGD viewpoint

In this section the notions of spin glass, spin ice and quantum spin ice are considered from TGD point of view.

Spin ice

There is a Wikipedia article (`https://cutt.ly/eEDTIwp`) about spin ice as a system in which magnetic moments, that is spins, form a lattice-like state. The basic property of spin glasses, and therefore also of spin ice, is that there is ground state degeneracy that is several states with the same energy giving rise to what is called frustration: the term comes from the obvious social analogy. Two examples of these compounds are dysprosium titanate $Dy_2Ti_2O_7$ and holmium titanate $Ho_2Ti_2O_7$.

Spin ice has properties resembling those of crystalline water ice. For spin ice, the sum of the outward pointing moments and inward point magnetic moments is zero for a tetrahedron forming a basic unit. The rule holds true only in ground state configuration analogous to ferromagnetic state but with non-constant direction of magnetization and need not be the situation in general. Its violation gives rise to analogs of magnetic monopoles analogous to charges for which there is evidence.

When the rule holds true, it is possible to formally define a conserved current, which is locally in the direction of the magnetic moment. It is divergenceless like a magnetic field and can be said to carry an analog of magnetic or electric charge as long as the rule is satisfied. Thermal fluctuations can change the direction of say one spin in the volume: this means formally creation of an analog of magnetic monopole. This system of pseudo-monopoles could be described by a theory resembling electromagnetism with an effective fine structure constant ten times larger than α [D70, D65]. This leads to ask whether this implies especially strong interaction with electromagnetic radiation.

Quantum spin ice

The special feature of certain spin ice systems is that the directions of spins can be random down to zero temperature since the energies of the frustrated configurations are the same and no energy is needed to change the configurations. This suggests that quantum fluctuations are involved and the system is actually quantum spin glass rather than a thermodynamical one.

It has been proposed that the interactions of the effective monopoles [D26, D121, D70, D65] (for a popular article see `https://cutt.ly/vED27e5`) can be described by an analog of QED. The value of the emergent fine structure constant assignable to the interaction with electromagnetic radiation would be 10 times larger than the real α.

In [D121] quantum tunnelling as transitions between degenerate configurations involving in the simplest situation 4 tetrahedrons and differing by an orientation of a loop formed by the imagined flux lines of the magnetization field analogous to magnetic field and connecting the 4 tetrahedrons is proposed as an essential element of the emergent lattice QED. The tunnelling makes possible long range correlations and makes implies large value of effective α.

This should be visible as a large enhancement of the low energy scattering of neutrons from the quantum spin ice materials. Low energy quasi-elastic neutron scattering would measure the 2-point momentum space correlation function of spins of the quantum spin glass. This correlation function would become long ranged in the real space. Lattice photons having linear dispersion relation $\omega \propto k$ but much smaller propagation velocity than ordinary photons would cause this behavior. This lattice photon would be visible in inelastic neutron scattering.

The effective magnetic monopoles that play the role of em charges are identified as spinons in [D70]. Electrons are proposed to consist of spinon, orbiton, and holon carrying spin, orbital quantum numbers and charge and in some cases they can behave like independent quasiparticles. I don't quite understand what this is supposed to mean. In the case of decomposition to spinon and holon which can occur in 1-D systems, spin waves and charge waves would propagate as independent waves.

If I understand correctly, charge waves would represent an oscillatory variation in the charge density of electrons and spin waves in the spin direction. They could have different wavelengths and phases.

TGD view about quantum spin ice

What about the TGD based description of the quantum spin ice?

1. In the TGD framework, magnetic field corresponds to flux tubes which can be either monopole flux tubes or carry normal flux caused by currents. Monopole flux tubes require no currents and this has powerful implications in astrophysics and cosmology. This suggests that the pseudo-monopoles could be "real" in some sense. Note however that TGD does not however allow free monopoles but only closed monopole flux tubes.

2. Long range interactions are required to create a spin glass phase and one can realize the basic rule of spin ice ground state as a special case. In the TGD framework the large values of h_{eff} could make this possible even at high temperatures. This rule allows frustration as the existence of several configurations with the same interaction energy. The transitions between these configurations would lead to the emergence of large effective α. In [D121] the transitions between degenerate configurations involving four tetrahedrons and differing by an orientation of a loop which in the TGD picture corresponds to a closed flux tube are mentioned as simplest transitions.

3. The spine of spin ice would be a flux tube network formed by monopole flux tubes and that magnetic moments associated with flux tubes have suffered spontaneous magnetization, which is locally in the direction of the local flux tube. If the numbers of the incoming and outgoing flux tubes in a given volume unit are the same and magnetic moments are parallel to the magnetic fluxes, the sum of magnetic moments is zero for a ferromagnetic situation. The formal current would be realized with real and quantized monopole flux which is conserved.

   Spin ice would be analogous to ferromagnet, a spaghetti of flux tubes accompanied by spontaneously magnetized spins such that the directions of magnetization at flux tubes can carry. Neutron scattering has demonstrated that the aligned spins indeed form intertwined tube-like bundles.

4. What could the TGD counterparts of the effective monopoles be? There are two options to consider.

   (a) In the many-sheeted space-time of TGD, the monopole fluxes can go to parallel space-time sheets via wormhole contact and return back at a rather long distance. The wormhole contact looks like a pair of throats behaving like magnetic monopoles. The throats have an extremely short distance. This option does not look attractive since at the QFT limit the many-sheetedness and the monopole pairs formed by the throats of the wormhole contact become invisible.

   What remains are flux tubes and the spin ice phase can make directly visible the underlying network of monopole flux tubes as it indeed does.

(b) Thermal and quantum fluctuations can however change spin direction and spin is formally like a magnetic monopole or charge and it seems that this is enough also in the TGD framework. This could also happen at the zero temperature limit as quantal rather than thermal fluctuations of the flux tube structure inducing the long range correlates between spins. The quantum fluctuations of spin ice would correspond to the long range quantum fluctuations of the dark flux tubes with $h_{eff} \geq h$.

5. TGD predicts the existence of two kinds of flux tubes corresponding to monopole flux tubes having a closed surface rather than disk as a cross section and requiring no currents to generate the magnetic field and Maxwellian non-monopole flux tubes for which the induced Kähler field can vanish. The Maxwellian flux tubes have a Lagrangian 2-manifold as a CP_2 projection, and the action reduces to a mere volume term proportional to length scale dependent cosmological constant approaching zero in long scales.

   At a long length scale limit, the deviation of the Kähler function from the ground state value becomes very small which has interpretation in terms of a strongly interacting phase. One expects large fluctuations, which give rise to the quantum spin glass phase. The two kinds of flux tubes could correspond to vortex-like entities with a monopole flux tube associated with the vortex core and the Lagrangian non-monopole part with its exterior.

6. Since very large values of h_{eff} are involved, the findings about the role of solar mass inspire the good guess $\hbar_{gr} = GM_{Sun}/v_0$, $\beta_0 \simeq 2^{-11}$. The size of the throat would be scaled from about CP_2 size for $h_{gr}(Sun)/\hbar \sim 2 \times 10^{20}$. The size scale of the dark wormhole throat would be about 10 nm, which is the thickness of the neuronal membrane so that a connection with biology is highly suggestive.

   Remark: If the huge values $\hbar_{gr}$ of $\hbar_{eff}$ are possible, the size of leptonic wormhole throat could be of order .9 cm for M_E! Leptons consist of 3 antiquarks in TGD framework [**?**] Could this mean that it might be possible to detect free quark?

The emergence of the strong interactions can be understood at the general level in the TGD framework.

1. Quantum spin glass is a strongly interacting quantum system since the quantum fluctuations are large even at the temperature zero limit. Quite concretely, the deviations of the Kähler function from the value for the ground state are very small.

   Using the language of QFTs, one has a very large number of almost degenerate configurations in the path integral with the same value of the action. This is achieved if the coupling strength is very large so that the action exponential appearing in the path integral is analogous to Gaussian with very large width.

   In the TGD picture, one says that the Kähler function for 3-surfaces (by holography for 4-surfaces) has the same value for a large class of 3-surfaces and is therefore slowly varying as a function of 3-surface. This picture is mathematically very much like the thermodynamic picture with Hamiltonian replaced by the Kähler function.

2. The original TGD based prediction based on the huge vacuum degeneracy of the Kähler action was that TGD allows 4-D analogs of spin glasses a as vacuum extremals with 2-D Lagrangian sub-manifold as CP_2 projection, meaning huge non-determinism. This however leads to problems.

   The inclusion of the M^4 contribution to Kähler form removes the vacuum degeneracy since one must have Lagrangian projection also in M^4 so that string-like entities, which are minimal surfaces, are in question.

3. The recent picture implied by twistor lift involves an additional volume term in the action leaving only finite non-determinism analogous to that for soap films. At the long length scale limit spin glass type behavior is suggestive when the Kähler action vanishes (Lagrangian property in CP_2 degrees of freedom for Maxwellian flux tubes). The volume term is very small.

The basic reason would be the smallness of the volume term, that is the smallness of length scale dependent cosmological constant Λ [L65] giving rise to cosmological p-adic length scale $L_{cosmo} \sim 1/\sqrt{\Lambda}$ and a relatively short p-adic length scale L_{short} as geometric mean $L_{short} = \sqrt{L_{cosmo}L_{Pl}}$ of the Planck length and L_{cosmo}. L_{short} is of order 10^{-4} m and defines a biological length scale.

Smallness of the volume action means large fluctuations in the functional integral characteristic for strongly interacting systems. Quite concretely, the flux tubes have very small string tension and their shapes fluctuate wildly. Long flux tube-like objects have a small volume and small string tension and would be very loose strings having very many configurations with the same energy. Quantum spin glass property would correspond to the existence of a large number of spaghetti-like configurations with the same value of the Kähler function.

4. The assumption that velocity field is proportional to Kähler gauge potential implies that it is not only Beltrami field but also gradient for the Lagrangian situation prevailing outside the vortex cores. There would be no classical dissipation at the level of Kähler action.

   Cores would have non-vanishing Kähler field and action. What about the Beltrami property in the vortex core? If the projection of the vortex core is 2-D complex surface, the Kähler gauge potential is Beltrami field. For instance, for a projection with is geodesic sphere S^2, the Kähler gauge potential is proportional to $A = cos(\Theta)d\Phi$ in the spherical coordinates and Φ defines the global coordinate along flow lines. $D > 2$-D deformations spoil the Beltrami property.

   Same is true for the M^4 projection: when the projection as a string world sheet is deformed to $D > 2$-D surface, Beltrami property is lost and classically there is dissipation meaning that Kähler 4-force is non-vanishing.

   Whether the dissipative option is realized at all for preferred extremals is not at all clear. Dissipative effects might be solely due to the finite sizes of space-time surfaces, which are proportional to h_{eff}.

5. There is a further delicacy involved. The assumption that both M^4 and CP_2 projections are at most 2-D is not enough for Beltrami or gradient flow. This condition alone would give a Kähler gauge potential, which is the sum $A(M^4) + A(CP_2)$ of two contributions $A(M^4) = \Psi_1 d\Phi_1$ and $A(CP_2) = \Psi_2 d\Phi_2$ satisfying the conditions separately. Besides this, the gradients $d\Psi_1$ and $d\Psi_2$ must be proportional to each other so that Ψ_1 and Ψ_2 are functionally dependent.

   Is this condition satisfied for all preferred extremals in which case classical dissipation would be absent or in special cases only.

6. The Lagrangian flux tubes associated with the exteriors of vortex cores would give rise to quantum spin glass property if they have a large value of $\hbar_{eff}$. In some situations even $\hbar_{eff} = \hbar_{gr}$ can be considered. This would give rise to long range quantum fluctuations and correlations and also to the absence of dissipation.

How to understand the predicted strong interaction of quantum spin glass phases with the electromagnetic radiation predicted by the emergent QED [D26, D121, D70, D65] to give rise to a strong enchancement of neutron scattering cross section?

1. Spin glasses could correspond to dark flux tube spaghettis so that the spins would be locally magnetized in the direction of the magnetic field of the dark flux tube playing the role of H field.

2. $h_{eff} > h$ would imply long range correlations but would also mean a reduction of the value of fine structure constant $\alpha \propto 1/h_{eff}$. This is just the opposite for the proposal of [D26, D121, D70, D65] that the analog of the fine structure constant emerging in the analog of lattice QED is larger than α.

   Paradox disappears as one realizes that the transition $h \rightarrow h_{eff}$ is Nature's manner to guarantee that perturbation theory converges. This requires the change of the nature of the quantum states and Galois confinement would be the underlying mechanism and also behind color confinement. Quantum spin glass would be analogous to hadron.

At the level of M^8 (analogous to momentum space) this implies the increase of the dimension of the extension of rationals determining the space-time region at the level of M^8. This also means the increase of complexity.

3. Spin glass degeneracy, realized as degeneracy of Galois confined states, suggests that the neutron scattering rate is enhanced since the transitions between degenerate states become possible. The same happens in the case of hadrons since the number of color confined final states is large.

17.3.5 Condensed matter Majorana fermions in the TGD framework

Condensed matter Majorana fermions are not genuine Majorana fermions, which have not been found in Nature and are impossible also in TGD as fundamental particles. Condensed matter Majorana quasiparticles could however have a TGD counterpart.

Majorana fermions (`https://cutt.ly/FWdXK4s`) are quasiparticles created by superpositions of fermionic creation and annihilation operators invariant under charge conjugation. This motivates the term Majorana particle. Majorana particles are also zero energy excitations and therefore can be created at topological defects as pairs with degenerate energies. This is due to the fact that momenta $p = G/2$ and $p = -G/2$, where G is a lattice momentum, correspond to the same energy.

The valence and conduction bands for a topological insulator must intersect at its boundary: this is the topological singularity at the level of the momentum space. This can happen at boundaries of insulators and at topological defects. The single point intersection of Fermi bands at a single point looks locally like a double cone and at the tip the normal space is non-unique and the normal normal spaces span a circle in 3-D momentum space.

TGD counterpart for the notion of Majorana quasiparticle

Consider now the situation in the TGD framework.

1. The counterparts of Majorana fermions should correspond to superpositions of ordinary and dark fermions at different energy bands - just like the Boboliuv particles of superconductors in the BCS model. These states cannot be C invariant. Kind of half dark-half visible, perhaps gray - fermions would be in question.

2. The momenta of the occupied fermion states of the momentum space of fermion (mass shell $H^3 \subset M^8$) define what I call cognitive representation consisting of a discrete set of points in an extension of rationals) $M^8 - H$ duality maps the points of $H^3 \subset M^4 \subset M^8$ to the points of the boundary δcd of 4-D causal diamond $cd \subset M^4 \subset H$ and therefore to the points of space-time surface. In particular, the boundaries of energy bands in M^8 are mapped to boundaries of the image in $\delta cd \subset H$ and define 2-D surfaces containing the edge states. In M^8, the touching of two bands corresponds to a single point intersection of algebraic surfaces. These surfaces can be continued to the interior of X^4 by the flow defined by qv generalized Beltrami field.

3. The direction of the quaternionic normal spaces in M^8 at the tip should have all directions parametrized by a circle. This suggests that the tip is not be mapped to a single point, but to a circle formed by the set of CP_2 points. The conical topological singularity in M^8 would correspond to a closed circle $S^1 \subset CP_2$.

4. If Majorana particles have a counterpart in TGD, they should correspond to superpositions of ordinary and dark fermion with the special property that the fermions have identical energies i.e. momenta are $G/2$ and $-G/2$. This condition guarantees that these states have identical energies as required by the condition $E^2 - p^2 = m^2$ holding true in H^3.

   At the level of M^8 the polynomial defining the space-time surface would characterize topological defects as singularities. Various lower-D surfaces in momentum space and position space should be isometric surfaces as surfaces of H^3, which looks a rather non-trivial prediction.

Remark: Note that the product of polynomials defines a disjoint set of spacetime surfaces [L129]. Also a single irreducible polynomial can have several space-time surfaces as roots and possibly intersecting at a discrete set of points in the generic situation.

Majorana quasiparticles and topological quantum computations

TGD leads to a general vision about topological quantum computation TQC [?]ased on braids formed by magnetic flux tubes. The reconnection of flux tubes brings in a new topological element and corresponds to the formation of 2-knots. The proposal is that TQC in this sense is a basic aspect of living matter. Also the hierarchy of effective Planck constants making possible long range quantum coherence and ZEO making possible time reversals of TQCs represent new elements.

The bound states of Majorana quasiparticles located at the ends of superconducting wire are analogous to Cooper pairs entangling non-locally and have been proposed by Kitaev to make possible TQC without a need for massive error correction procedure [D138]. The association with the ends of wire would give rise to non-locality and long range quantum entanglement making it difficult to destroy entanglement by local measurements.

In an effectively 2-D system, the braid group defines non-standard statistics. The braid group must be non-Abelian so that higher than 1-D representations are possible and can be utilized in TQC. $SU(2)$ is the minimal option. The states of braid group representation are robust against perturbations destroying the entanglement

If I have understood correctly, the two energy degenerate states of the bound state of Majoranas would correspond to SU(2) doublet with energy degeneracy, which vanishes when the zero of energy corresponds to the middle point of the band gap.

1. In the TGD framework, the Majorana property does not seem to be absolutely essential. It is essential to have non-commutativity and energy degeneracy. Galois groups act as number theoretical symmetries and all non-trivial representations of the Galois groups allow this degeneracy. One might therefore speak of a hybrid of number theoretic and topological quantum computation. There seems to be no reason preventing the representations of discrete subgroups of the braid group defined by some Lie group acting in the cognitive representations defined by algebraic integer valued momenta at the intersection of mass shell and $X^4 \subset M^8$, that is at the level of M^8 on the cognitive representations. The quantum variants Gal_q of Galois groups could be involved.

2. $SU(2)$ has an interpretation as automorphisms of quaternions and acts in E^4 factor of M^8, could be in a special role physically in TGD and also because its discrete subgroups appear in the hierarchy of hyper-finite factors of type II_1 (HFFs). The discrete subgroups E_6, E_7 and E_8 (tetrahedral, octahedral and icosahedral groups). These groups could have representations as Galois groups. Momenta as algebraic integers correspond to the vertices of corresponding Platonic solids and total momenta for many-quark states vanish for the states. Also spinor representations are involved bringing in spin and electroweak degrees of freedom. Galois confinement requires that the states as a whole are Galois singlets. TQC would also be a basic process of quantum cognition.

3. In TGD superpositions of fermion and hole correspond to superpositions of fermion states at the ordinary and dark space-time sheet. Could the entanglement between dark and ordinary fermions (more generally, with different values of h_{eff}) with the same energy give rise to the analogs of Majorana quasiparticles?

17.3.6 Condensate of electron quadruplets as a new phase of condensed matter

Formation of fermion quadruplet condensates [D136] (`https://cutt.ly/TRcxQtz`) is a new exotic condensed matter phenomenon discovered by Prof. Egor Babaev almost 20 years ago and 8 years after publishing a paper predicting it. Recently Babaev and collaborators presented in Nature Physics evidence of fermion quadrupling in a series of experimental measurements on the iron-based material, $Ba_{1-x}K_xFe_2As_2$.

The abstract of the article summarizes the finding.

> The most well-known example of an ordered quantum state—superconductivity—is caused by the formation and condensation of pairs of electrons. Fundamentally, what distinguishes a superconducting state from a normal state is a spontaneously broken symmetry corresponding to the long-range coherence of pairs of electrons, leading to zero resistivity and diamagnetism.
>
> Here we report a set of experimental observations in hole-doped $Ba_{1-x}K_xFe_2As_2$. Our specific-heat measurements indicate the formation of fermionic bound states when the temperature is lowered from the normal state. However, when the doping level is $x \sim 0.8$, instead of the characteristic onset of diamagnetic screening and zero resistance expected below the superconducting phase transition, we observe the opposite effect: the generation of self-induced magnetic fields in the resistive state, measured by spontaneous Nernst effect and muon spin rotation experiments. This combined evidence indicates the existence of a bosonic metal state in which Cooper pairs of electrons lack coherence, but the system spontaneously breaks time-reversal symmetry. The observations are consistent with the theory of a state with fermionic quadrupling, in which long-range order exists not between Cooper pairs but only between pairs of pairs.

Fermion quadruplets are proposed to be formed as pairs of Cooper pairs are formed somewhat above the critical temperature T_c for a transition to superconductivity. Breaking of the time reversal symmetry T is involved.

The question is why quadruplets are stable against thermal noise above the critical temperature. Superconductivity is thought to be lost by the thermal noise making the bound states of electrons in Cooper pair unstable. Is the binding energy for quadruplets larger than for Cooper pairs so that quadruplet condensate is possible below higher critical temperature. What is the mechanism of binding?

The discovery is highly interesting from the TGD point of view.

1. TGD leads to a model of super-conductivity involving new physics predicted by TGD.

2. Adelic physics number theoretic view about dark matter as $h_{eff} > h$ phases h_{eff} proportional to the order of the Galois group. This leads to the notion of Galois confinement. Galois confinement could serve as a universal mechanism for the formation of bound states including also Cooper pairs and even quadruplets. In quantum biology triplets of protons representing genetic codons and even their sequences representing genes would be formed by Galois confinement.

3. The finding also allows to develop more preices view of TGD view concerning discrete symmetries and their violation.

Time reversal symmetry in TGD

What do time reversal symmetry and its violation mean in TGD.

1. The presence of magnetic field causes violation of T in condensed matter systems.

2. Second, not necessarily independent, manner to violate T in TGD framework is analogous to that in strong CP breaking but different from it many crucial aspects. Vacuum functional is exponent of Kähler function but exponent can contain also an instanton term I, which is equal to a divergence of topological instant current which is axial. so that non-vanishing I suggests parity violation. The fact that exponent of I is imaginary while exponent of Kähler action is real, means C violation. If instanton current is proportional to conserved Kähler current its divergence is vanishing and M^4 projection is less than 4-D.

   I is non-vanishing only if the space-time sheet in $X^4 \subset M^4 \times CP_2$ has 4-D CP_2 or M^4 projection. The first case corresponds to CP_2 instanton term $I(CP_2)$ and second case to $I(M^4)$ present since twistor lift forces also M^4 to have an analog of Kähler structure. The two Kähler currents are separately conserved.

3. These two mechanisms of T violation might be actually equivalent if the T violation is caused by the M^4 part of Kähler action. Consider a space-time surface with 2-D string world sheet as M^4 projection carrying Kähler electric field but necessarily vanishing Kähler magnetic field B_K. If it is deformed to make M^4 projection 4-D, B_K is generated and T is violated. Therefore generation of B_K in M^4 can lead to a T violation.

Generalized Beltrami currents

Generalized Beltrami currents are nother key notion in TGD based view about superconductivity [L131].

1. The existence of a generalized Beltrami current $j = \Psi d\Phi$ implies the existence of global coordinate Φ varying along the flow lines of the current. Also the condition $dj \wedge j = 0$ follows. The 4-D generalization states that Lorentz force and electric force vanish. In effectively 3-D situation, j could correspond to magnetic field B and dj to current as its rotor and the Beltrami condition fof B implies that Lorentz force vanishes.

2. The proposal of [K14] is that for the preferred extremals CP_2 *resp.* M^4 Kähler current is proportional to instanton current $I(CP_2)$ *resp.* $I(M^4)$ and therefore topological for $D(CP_2) = 3$ *resp.* $D(M^4) = 3$. For $D = 2$ the contribution to instanton current vanishes. In this case the Lorentz force vanishes so that the divergence of the energy momentum tensor is proportional to I and vanishes so that dissipation is absent. One can verify this result using the effective 3-dimensionality of the projection and using 3-D notations [K14]: in this formulation the vanishing of Lorentz force reduces to Beltrami property for B as 3-D vector. With this assumption, dissipation for the preferred extremals of Kähler action just as it is absent in Maxwell's theory. An open question is whether this situation is true always so that dissipation and the observed loss of quantum coherence would be due to the finite size of space-time sheet of the system considered.

3. Beltrami property would serve as a classical space-time correlate for the absence of dissipation and presence of quantum coherence. Beltrami property allows defining of a supra current like quantity in terms of Ψ and Φ. Usually the superconducting order parameter Ψ is actually not an order parameter for a coherent state as a superposition of states with a varying number of Cooper pairs. Now the geometry of the space-time sheets (magnetic flux tube carrying dark Cooper pairs) allows the identification of this order parameter below the quantum coherence scale. The TGD interpretation is that the coherent state is an approximation, which does not take into account the fact that the system is not closed. There is exchange of electron pairs between ordinary and dark space-time sheets with $h_{eff} > h$ [L131]. Dark Cooper pairs would form bound states by Galois confinement.

4. In the superconducting state space-time regions would have at most 3-D M^4 projection at fundamental level and T would not be violated. There is no dissipation and pairs are possible below critical temperature.

   One can also understand the Meissner effect. According to the TGD view, the monopole flux tubes generate the analog of the field H perhaps serving as an approximate average description for the field of monopole flux tubes. This field induces the analog of magnetization M involving non-monopole flux tubes. Also M would be an average field. For superconductors in the diamagnetic phase, the sum would be zero: $B = H + M = 0$. If the Cooper pairs have spin, the supracurrents of Cooper pairs at monopole flux tubes could generate the compensating magnetization.

TGD view about quadruplet condensate

How could one understand quadruplet condensate in the TGD framework?

1. T violation could be accompanied by the presence of Kähler instanton term $I(M^4)$ or $I(CP_2)$ requiring 4-D M^4 or CP_2 projection: this would also generate M^4 magnetic fields. The

M^4 option would bring in new physics for which also the Magnus effect of hydrodynamics suggesting Lorentz forces serves as an indication [L146].

For 4-D M^4 projection, the divergence of the axial instanton current would be non-vanishing and the proportionality of Kähler current and instanton current implying a vanishing classical dissipation would be impossible. The instanton number can be expressed as instanton flux over 3-D surfaces, which would be "holes".

2. For the quadruplet condensate M^4 projection is 4-D and T is violated. Kähler magnetic fields originating from M^4 part of Kähler action would be present as also dissipation. For quadruplet condensate M would not compensate for H so that net magnetic fields B would be generated and correspond to space-time sheets with 4-D M^4 projection.

3. Dark matter as phases with $h_{eff} > h$ would however be present and quadruplets would correspond to bound states of 4 electrons formed by Galois confinement [L147, L145] stating that the total momentum of the bound state as sum of momenta, which are algebraic - possibly complex - integers, is a rational integer in accordance with the periodic boundary conditions.

4. What prevents the formation of Cooper pairs? Above T_c thermal energy exceeds the gap energy so that Cooper pairs are thermally stable. If the binding energy for quadruplets is larger, they are stable.

5. In what sense the quadruplets could be regarded as bound states of Cooper pairs? Since the ordinary Cooper pairs are Galois singlets, bound state formation does not look plausible since Cooper pairs themselves are unstable. A more plausible option is that Cooper pairs involved are "off-mass-shell" in that they have momenta, which are non-trivial algebraic integers and that the sum of these momenta is a rational integer in the bound state.

Remark: Four-momenta as algebraic integers are in general complex. Usual charge conjugation involves complex conjugation in CP_2 degrees of freedom. Is it accompanied by conjugation of the complex 4-momenta. Kähler currents of M^4 and CP_2 are separately conserved: should one regard complex conjugations in M^4 and CP_2 as independent charge conjugation like symmetries. $C(M^4)$ would however leav Galois singlets invariant.

17.3.7 Does the phenomenon of super oscillation challenge energy conservation?

The QuantaMagazine popular article "Puzzling Quantum Scenario Appears Not to Conserve Energy" (`https://cutt.ly/QXylTIr`) told about puzzling observations the quantum physicists Sandu Popescu, Yakir Aharonov and Daniel Rohrlich made 1990 [D130] (`https://cutt.ly/3XylIY5`). These findings challenge energy conservation at the level of quantum theory.

The experiment of authors starts from the purely mathematical observation that a function can behave faster than any of the Fourier components in its Fourier transform when restricted to a volume smaller than the domain of Fourier transform. This is rather obvious since representing the restricted function as a Fourier transform in the smaller domain one obtains faster Fourier components. This phenomenon is called super oscillation.

Does this phenomenon have a quantum counterpart? The naive replacement of Fourier coefficients with oscillation operators for photons need not make sense. If one makes the standard assumption that classical states correspond to coherent states, also super-oscillations should correspond to a coherent state.

Coherent states are eigenstates of the annihilation operator and proportional to exponential $exp(\alpha a^\dagger)|0\rangle$, where "0" refers to the ground state an a^{dagger} to creation operator. These states contain N-photon states with an arbitrarily large photon number. For some number of photons the probability is maximum.

This raises several questions.

1. Coherent states are not eigen-states of energy: can one really accept this? This kind of situation is encountered also in the model of superconductivity assuming coherent state of Cooper pairs having an ill-defined fermion number.

2. Could the super oscillation correspond to the presence of N-photon states with a large number of photons? Could the state of n parallel photons behave like a Bose-Einstein condensate having N-fold total energy in standard physics or its modification, such as TGD.

Authors tested experimentally whether the super-oscillation has a quantum counterpart. In an ideal situation one would have a single photon inside an effectively 1-D box. One opens the box for time T and inserts a mirror inside the box to the region where super oscillation takes place and the photon looks like a short wavelength photon. The mirror reflects the photon with some probability out of the box. If T is long one expects that the procedure does not affect the photon appreciably. What was observed were photons with the energy of a super photon rather than energy of any of its low energy components.

In the experiment described in the popular article, red light would correspond to photons with energy around 2 eV and gamma rays to photons with energies around MeV, a million times higher energy. The first guess of standard quantum theorists would be that the energies of mirrored photons are the same as for the photons in the box. Second guess would be that, if the coherent state corresponds to the super oscillation as a classical state, then the measured high energy photons could correspond to or result from collinear n-photon states present in the coherent state.

In the TGD framework zero energy ontology (ZEO) provides a solution to the problem related to the conservation of energy. In ZEO, quantum states are replaced by zero energy states as pairs of states assignable to the boundaries of causal diamond (intersection of light-cones with opposite time directions) with opposite total quantum numbers. By Uncertainty Principle this is true for Poincare charges only at an infinite volume limit for the causal diamond but this has no practical consequences. The members of the pair are analogs of initial and final states of a particle reaction. In ZEO, it is possible to have a superposition of pairs for which the energy of the state at either boundary varies. In particular, coherent states have a representation which does not lead to problems with conservation laws.

What about the measurement outcome? The only explanation for the finding that I can invent in TGD is based on the hierarchy phases of ordinary matter labelled by effective Planck constants and behaving like a hierarchy of dark matter predicted by the number theoretical vision of TGD.

1. Dark photons with $h_{eff} = nh_0 \geq h$ can be formed from ordinary photons with $h_{eff} = h$. The energy would be by a factor h_{eff}/h larger than for an ordinary photon with the same wavelength. Note that dark photons play a key role in the TGD based view of living matter.

   TGD also predicts dark N-photons as analogs of Bose-Einstein condensates. They are predicted by number theoretic TGD and there is empirical evidence for them [L166]. This would require a new kind of interaction and number theoretical view about TGD predicts this kind of interaction based on the notion Galois confinement giving rise to N-photons as Galois confined bound states of virtual photons with energies give by algebraic integers for an extension of rationals defined by a polynomial defining the space-time region considered.

   I have proposed an analogous energy conserving transformation of dark photon or dark N-photon to ordinary photon as an explanation for the mysterious production of bio-photons in biomatter. The original model for dark photons is discussed in [K13]. Now the value of h_{eff} could be much larger: as large as $h_{eff} \sim 10^{14}$: in this case the wavelength would be of order Earth size scale.

2. What comes to mind is that an N-photon state present in the coherent state can transform to a single photon state with N-fold energy. In the standard model this is not possible. On the other hand, in the experiments discussed in [L166] it is found that N-photon states behaving like a single particle are produced. Could the N-photon states present in a coherent state be Galois confined bound states or could they transform to such states with some probability?

   In the recent case, the dark photons would have the same wavelength as red photons in the box but energy would be a million times higher. Could a dark photon or N-photon with $Nh_{eff}/h \sim 10^6$ be reflected from the mirror and transform to an ordinary photon with gamma ray energy.

   One must notice that the real experiment must use many-photon states N-photons might be also formed from N separate photons.

To sum up, new physics would be involved. ZEO is needed to clarify the issues related to energy conservation and the number theoretic physics predicting dark matter hierarchy is needed to explain the observation of high energy photons.

17.3.8 Possible connections with quantum biology

The flux tube networks assignable spin ice and spin glass phase in general are in the central role in the TGD based vision about quantum biology [L194, L137] [K84, K83, K59, K41, K89].

TGD view about bio-catalysis

TGD leads to a new view about biocatalysis, which is one of the mysteries of standard biology. The general TGD inspired model for bio-catalysis involves the following elements.

1. Reconnections of U-shaped flux tubes of reactants and catalyst make it possible for them to find each other. Cyclotron resonance for flux tubes of same thickness and therefore having the same Kähler magnetic field and the same cyclotron frequency allows reactants and catalyst is an essential element. Both frequency and energy resonance would occur between systems with the same h_{eff} whereas energy resonance would be possible between systems with different values of h_{eff}. This resonance would be the quintessence of what it is to be alive and all communications between various levels of MB having an onion-like hierarchical structure and also between MBs and ordinary biomatter would take place in this manner.

2. A reduction of h_{eff}, leading to a shortening of the flux tubes and bringing catalyst particles and reactants connected by flux tubes together would be also a natural step of the catalytic process.

3. The energy liberated in the reduction of h_{eff} would be used to kick the reactants over the potential energy wall preventing the reaction.

The spin glass type systems formed by flux tubes would be ideal for realizing bio-catalysis and the TGD based view about living matter indeed relies on hierarchical flux tube networks.

Pollack effect and ZEO

The formation of negatively charged regions in the Pollack effect leads to a similar phenomenon. Pollack effect would be behind formation of cells, DNA etc which are indeed negatively charged. Protons would transform to dark protons as magnetic flux tubes and realize genetic codons as Galois confined states of dark protons forming triplets. Genes would be Galois confined sequences of these triplets. These tubes would be parallel to DNA and chemical realization of the genetic code would be only a secondary one.

The regions called exclusion zones (EZs) self-clean themselves. This is in a sharp conflict with the second law. The explanation is that at MB time has a non-standard arrow and self-cleaning is actually dissipation but in a reversed time direction. What would be remarkable would be the long duration of the classical counterpart of BSFR as a deterministic time evolution leading to the final 3-D state of BSFR.

Quite generally, the self-cleaning property would serve as a signature of systems for which the MB stays for long times in a time reversed state making possible self-organization as time reversed dissipation. Large values of h_{eff} would be involved and the largest candidate in the solar system is $\hbar_{gr}(Sun)$.

One must of course also consider the possibility of the Milky Way blackhole with a mass about $4.6 \times 10^6 M_{Sun}$. This would correspond to the scaling up of dark wormhole throat size given by CP_2 size to the scale of 4.6 cm! The Milky Way with a mass of $10^{12} M_{Sun}$ would give a dark wormhole throat with size about 4.6×10^4 km!

This raises spin-ice type systems to a preferred role. They are indeed ideal for the demands of living systems since the ground state degeneracy makes it possible to represent the state of the external world as the state of the system. Also quantum computation requires large degeneracy of states possibly realized in terms of Galois representations and flux tube spaghettis would provide this degeneracy.

A finding challenging the standard theory of electrolytes

I received a link to an interesting article "Double-layer structure of the Pt(111)–aqueous electrolyte interface" about the findings of Ojha *et al* [D63] (https://cutt.ly/oOE6czY). The reader can also consult the popular representation of the finding (https://cutt.ly/VORqeoK).

The experiments demonstrate that the physics of electrolytes is not completely understood.

1. Pt(111)-aqueous electrolyte interface is studied in a situation in which there is a circulation of H_2 molecules part of which decay to H ions and electrons at the interface of the first electrode.

2. Electrons give rise to a current flowing to the second electrode, which also involves the Pt(111) interface. There is also a proton transfer between the electrodes. At the second interface there is a circulation of O_2 molecules: part of them transforms to water molecules at the interface.

3. A double layer of positive and negative charges of some thickness acting like a capacitor at the first interface is formed. Two plates of this kind plus electrolyte between them form an analog of a continually loaded battery and electron current is running when wire connects the plates.

4. The prediction of the standard theory is that when the salt concentration of the electrolyte is lowered, the current should eventually stop running at some critical salt concentration determined by the potential between the electrodes. There would be no free electrons anymore. OThis critical potential is called the potential of zero charge.

5. The experimental findings produced a surprise. The potential of zero charge did not appear for the predicted salt ion concentration. The reduction of ion concentration by a factor 1/10 was needed to achieve this. It would seem that the actual concentration of ions is 10 times higher! What are these strange, invisible, salt ions?

I have confessed to myself and also publicly in [L19, L54] that I do really understand how ionization takes place in electrolytes. The electrostatic energies in atomic scales associated with the electrolyte potential are quite too small to induce ionization. I might be of course incredibly stupid but I am also incredibly stubborn and wanted to understand this in my own way.

The attempt to do something for this situation, and also the fact that "cold fusion" also involves electrolytes, which no nuclear physicist in his right mind would associate with electrolysis, led to a totally crazy sounding proposal that electrolysis might involve some new physics predicted by TGD and making possible "cold fusion" [L27, L54, L117] [L4]. Electrolytes actually involve myriads of anomalous effects [K95, K24]. Theoretical physicists of course do not take them seriously since chemistry is thought to be an ancient, primitive precursor of modern physics.

Part of the ions of the electrolyte would be dark in the TGD sense having effective Planck constant $h_{eff} \geq h$ so that their local interactions (describable using Feyman diagrams) with the ordinary matter with $h_{eff} = h$ would be very weak. There these ions behave like dark matter so that the term "dark ion" is well-motivated. This does not however mean that the galactic dark matter would be dark matter in this sense. TGD based explanation for the galactic dark matter could be actually in terms of the dark energy assignable to cosic strings thickened to magnetic flux tubes carrying monopole flux [L83, L91, L149].

1. The presence of dark ions in water would explain the ionization in electrolytes. Water would be a very special substance in that the magnetic body of water carrying dark matter would give rise to hundreds of thermodynamic anomalies characterizing water [D104].

2. Biology is full of electrolytes and biologically important ions are proposed to be dark ions [L194]. As a matter of fact, I ended the TGD based notion of dark matter from the anomalies of biology and neuroscience [J7]. This notion emerged from the number theoretic vision about TGD much later [L63, L64, L147]. Pollack effect [I18, L24, I29, I26] would involve dark protons and would be in a key role in biology. The realizations of genetic codons in terms of dark proton and dark photon triplets would also be central.

3. "Cold fusion" is one application for TGD view about dark matter [L27, L54, L117]. The formation of dark proton sequences gives rise to dark protons and perhaps even heavier nuclei for which the binding energies would be much smaller than for ordinary nuclei. The subsequent transformation to ordinary nuclei would liberate essentially the ordinary nuclear binding energy.

The notion of dark matter also leads to concrete ideas about what happens in electrolysis [K95]. In the TGD framework, the finding of Ojha *et al* would suggest that 90 per cent of ions are dark in the electrolyte considered.

17.4 A revolution in lithium-sulphur battery technology?

The last weeks have been full of surprises. The most recent surprise was the popular article published in Big Think (`rebrand.ly/wootoqn`), which told about an accidental discovery [D118] (`rebrand.ly/ye9nt4g`), which could revolutionize battery technology. The so-called γ-sulphur is a phase of sulphur stops the degradation of lithium-sulphur batteries and this could give electric vehicles a range of thousands of kilometers.

17.4.1 The discovery

It is good to start from the problems of lithium batteries.

1. Also other materials than lithium, which is a very light material, such as cobalt are needed in lithium batteries but their mining is very environmentally very damaging. There are also humanitarian problems: the working conditions are bad and even child labor is used.

2. Lithium batteries quickly lose their capacity and charging times are long. lithium batteries also suffer degradation.

3. The energy density is low so that the lithium batteries tend to be very heavy, which limits their commercial use in electric planes and ships.

4. Damaged cells can spontaneously catch on fire.

Lithium-sulphur batteries might provide a cure of all these problems but there is a new very serious problem. Polysulfides Li-S-...-S-Li are formed in the dielectric between the Li and sulphur containing capacitor platers and this reduces the number of charge cycles by one half from about 2000 cycles.

The completely unexpected discovery was that somehow the presence of γ-sulphur as a phase of sulphur, unstable at room temperature but stabilized in presence of Li, prevents the formation of polysulphides Li-S-...S-Li. γ-S crystals are produced by dropping hot sulphur to water at temperatures above 95 degrees Celsius. They are smooth elastic and resemble rubber.

17.4.2 Some questions with possible answers

The findings raise some questions.

1. What in their structure prevents the formation of considerable amounts of polysulfides L-S-....-S-Li with more than one S? Could the presence of γ-S crystals prevent the formation of S-S bonds or are they formed but split very rapidly? Why is γ-S stabilized in the presence of Li?

2. One thing to notice is the chemical analogy with water: H$\leftrightarrow$Li and O$\leftrightarrow$ S. Could this help? What prevents the formation of H-O-...-O-H sequences in water and one has only H-O-H? Could this be a good question?

Let us try to answer these questions.

1. The first thing to notice is that γ-S is not stable at room temperature. Somehow the presence of Li must stabilize it. The γ-S crystals should grow by addition of S to compensate for the spontaneous decay occurring at room temperature. This could give rise to flow equilibrium.

2. Could it be that the presence of γ-S crystals competes with the formation of Li-S-...S-Li sequences. Could S prefer to join to a γ-S crystal rather than to add to the sequences of S:s in Li-S-...S-Li? The formation of sequences would stop at Li_2-S. This does not yet explain the stability of γ-S at room temperature: differs from that in the absence of Li only in that Li competes with γ-S crystal for S atoms. The mechanism must be more delicate.

3. Li-S....-S-Li polysulphides must be produced at a considerable rate but they provide the S:s for the crystal growth of new γ-S. Li atoms are like servants carrying the food S at plate to γ-S, which eats it. There is a flow equilibrium and the total amount of Li-S...-S-Li stays very small although Li-S....-S-Li is produced with a high rate!

17.4.3 TGD view of the situation

I have not yet said anything about TGD and quantum but in the presence of γ-S Li_2-S is a chemical analog of water.

Basic questions

One must start from fundamentals and ask what batteries really are.

1. What causes the ionization in the electrolyte? In fact, almost 40 years ago I had discussions with a researcher studying batteries and realized that electrolysis is not actually understood in standard chemistry! Ionization is the mystery. It requires large energies measured in electron volts. The electric voltage between the batteries is low and generates extremely weak electric fields so that it should have no effects in the atomic length scales. I have discussed this problem in an article about "cold fusion" [K24].

2. If ionization occurs, electric field makes possible charge separation. But what makes this charge separation and therefore batteries so stable? They are of course not completely stable since the voltage decreases gradually. An analog of metabolic energy feed is necessary.

Could Pollack effect make batteries possible?

Ionization is necessary for the formation of batteries. I have discussed the problem of ionization in an article about "cold fusion" [K24].

1. The hint comes from the fact that electric voltages involved are measured in electron volts as are measured also the voltages associated with the molecular bonds associated with the salts of electrolytes used.

2. TGD view forces us to ask whether a phase transition in which ordinary particles, say positive ions of a salt, could become dark in the sense that the effective Planck constant h_{eff} characterizing it becomes very large.

   Could the length of the valence bond or hydrogen bond, or more generally, molecular bonds generalizing hydrogen bond to say Li bond between two Li_2-S molecules, become so long that the voltage along it is measured in electron volts so that it can lead to a genuine or effective ionization.

3. Before continuing, one must clarify what meanings the darkness can have. A dark proton associated with a dark very long hydrogen bond could be formed in the charge separation giving rise to batteries. The hydrogen bonds would be U-shaped and connect to the magnetic body (MB) of the positively charged electrode. After loading the flux tube pairs could split and become U-shaped flux tubes again and the positive would remain at the monopole flux tubes. If hydrogen bonds generalize to say lithium bonds, the notion of positive dark ion formed from a salt would generalize. Needless to say, this would mean generalization of chemistry.

Also dark atoms in the sense that an unpaired valence electron becomes dark as it is transferred to a magnetic flux tube with large value of h_{eff} are possible. Also valence bonds can be dark and I have proposed that ordinary valence bonds are dark and have relatively small $h_{eff} > h$ [L60]. The mysterious disappearance of unpaired valence electrons from rare earth metals under heating [L61] could be an example of this phenomenon [L61].

Could the formation of dark protons correspond to Pollack effect [I18, L24, I29, I26] taking place in presence of gel phase and energy feed, by say IR radiation. Pollack effect is discussed from the TGD point of view in [L24, L124, L133, L176].

1. The TGD based proposal is that in the Pollack effect ordinary protons associated with hydrogen bonds would transform to dark protons at monopole magnetic flux tubes. The U-shaped dark hydrogen bonds would be very long and could reconnect with a second similar bond to form a pair of flux tubes forming a connection to a MB outside the exclusion zone. Dark protons could be transferred to the MB. The formation and splitting of a flux tube pair is the basic mechanism in the TGD inspired model of biocatalysis.

2. If the Pollack effect generalizes to biologically important positive alkali ions, it could serve as a general mechanism giving rise to the storage of energy as electrostatic energy and cell membranes could be seen as analogs of batteries. Hydrogen bond or its generalization as a monopole flux tube is necessary for this.

3. Why is the presence of the gel phase needed? The simplest explanation is that it also involves an exclusion zone as $H_{1.5}O$ phase and is accompanied by a MB carrying dark proton sequences. These dark proton flux tubes could serve as a seed for the formation of dark protons sequences outside the exclusion zone.

4. In the case of batteries, external voltage during the loading of the battery causes charge separation by providing the needed energy to induce ionization and to drive the ions to the oppositely charged electrodes of the battery.

What makes possible a metastable charge separation in the case of the Pollack effect in biology? The molecular binding energy of hydrogen in water molecules is measured in eVs and should be compensated.

1. IR photons with energies below eV scale are needed to generate Pollack effect but is their energy too small?

2. Could the Coulomb binding energy between the exclusion zone and the magnetic flux tubes compensate for the binding energy? How could one achieve a stable situation preventing the collapse of the flux tubes if only Coulomb energy is involved? The Coulomb repulsion between dark protons at the monopole flux tubes is a further serious problem.

3. Dark proton sequences are analogous to atomic nuclei. Could the analog of nuclear binding energy compensate for the molecular binding energy? If the dark protons, or more generally, positively charged dark ions, form analogs of dark nuclei bound together by bonds between nucleons in the TGD inspired nuclear string model, they could be stable and their formation would be also energetically favored if the binding energy scale correspond to that for atoms. These bonds could be analogs of mesons consisting of color quark and antiquark forming a color singlet.

   A large value of h_{eff} could make possible scaling of the bond length L as $L \propto h_{eff}$ or even $L \propto h_{eff}^2$ is might be the case for dark valence bonds. If the nuclear binding energy assignable to the bond scales as $1/L$ as function of bond length L, the scale could correspond to a nanometer scale in biology. One would have a scaled up version of nuclear physics or rather, and perhaps even its generalization obtained by replacing dark protons with dark variants of dark nuclei appearing in salts.

   Note that the spontaneous decay of dark proton nuclei to ordinary nuclei would liberate almost all nuclear binding energy and explain "cold fusion". In TGD framework, the large value of h_{eff} for weak bosons would scale up their Compton length to biological length scales, and in length scales shorter than Compton length they would behave as massless particles and weak interactions would be as strong as electromagnetism making possible weak interactions transforming dark protons to dark neutrons. The same scaling up applies also to color interactions.

What guarantees the stability of the charge separation? There are situations in which the charge separation has lasted such a long time [L38] that it is very difficult to understand in the framework of standard chemistry. Batteries must be loaded, that is energized, now and then and cell membranes as their biological analogs require a continual metabolic energy feed. This suggests that thermal non-equilibrium systems require a metabolic energy feed.

The energy transfer is the first step of photosynthesis. In the TGD based model it would take place by pairs of holes and dark valence electrons. This raises the question whether it is convenient to talk about a pair of a proton hole and dark proton assignable to the hydrogen bond and even a generalization of this notion.

Li-S batteries and generalized Pollack effect

Could the counterpart of the Pollack effect be involved with lithium-sulphur batteries?

1. Water is the dominating element of living systems. The MB of the water gives water its very special properties and makes it very special at physiological temperatures at which Pollack effect in presence of say IR radiation and gel phase gives rise to the formation of negatively charged exclusion zones by driving protons to Li_2S is the chemical analogue of water.

   One can use this as an analogue in an attempt to understand Li-S batteries in terms of a generalized Pollack effect. If the notions of Li-bond and Li-bonded Li_2S molecule clusters make sense, the model for the Pollack effect as a way to generate a metastable charge separation might work.

2. Note that the formation of H-O-O-...-H is not a problem in the ordinary Pollack effect and the role of the γ-S would be only to make possible stable exclusion zones and magnetic flux tubes. Without it the dark Li-ions at flux tubes would transform to ordinary Li-atoms forming fingers, Li-S-...-S-Li sequences would form and the battery would degrade also otherwise. This can be understood in terms of reduction of h_{eff} inducing the reduction of complexity and scale of quantum coherence at the positive electrode.

3. The counterpart of the exclusion zone with an effective stoichiometry $H_{1.5}O$ and negative charge would be negative electrode with effective stoichiometry $Li_{1.5}O$. Dark Li^+ ion would take the role of dark proton. Every fourth Li^+ would go as dark ion to the magnetic flux tube and end up to the positively charged electrode or its MB. It would create the same voltage along the space-time sheet associated with the electrolyte as along possibly still existing flux tubes connecting it to the negatively charged electrode.

Pollack effect, cold fusion and protostars

"Cold fusion" (for the recent situation see `rebrand.ly/ui7xoig`) is an anomaly, whose existence very many colleagues still find difficult to accept. "Cold fusion" also involves dielectric plates and the proposed TGD based model [L27, L54, L117] involves dark proton currents at magnetic flux tubes.

"Cold fusion", or more precisely dark fusion in the TGD framework, can be initiated at rather low temperatures and involves the formation of dark proton sequences at monopole flux tubes. Dark nuclei are essentially scaled up variants of nuclei but much smaller binding energy and can be generated in the Pollack effect, which plays a key role in the TGD inspired quantum biology. Dark nuclei can spontaneously decay to the ordinary nuclei and also protons can transform to neutrons. This liberates essentially all nuclear binding energy.

For instance, in the case of heavy water D_2S, the dark protons would be replaced by Deuterons and $H_{1.5}O$ would be replaced by $D_{1.5}O$. Dark proton sequences would correspond to dark D^+ sequences as dark nuclei. They would spontaneously decay to ^4He and deuteron nuclei in consistency with the observations.

There is also evidence for biotransmutations [C32, C33, C150] occurring in living systems discussed from TGD point of view in [L4, K95]. For instance, Kervran found that hens are able to produce Ca needed in egg shells. These findings might allow interpretation in terms of dark fusion based on the Pollack effect or its generalization.

Dark fusion would generate protostars [L91, L103, L54] in which there is no ordinary fusion yet. The temperature increases because essentially nuclear binding energy is liberated when the dark nuclei transform to ordinary nuclei and eventually ordinary fusion is ignited. It is quite possible that all nuclei heavier than Fe are generated in this way outside stellar cores rather than in supernova explosions. Also many anomalous abundances of lighter nuclei could be understood.

Pollack effect and DNA

Capacitors involve both negatively and positively charged plates. Pollack effect is central in the TGD view of living matter and generates negatively charged entities such as cell interior and DNA double strand.

In the case of DNA, Pollack effect would mean that negatively charged phosphates giving constant charge of -1 units per nucleotide act as negative electrode and screen the positive dark proton charge per DNA strand inside the fundamental region of icosa-tetrahedral tessellation [L174] having size scale given by the p-adic length scale $P_p = L(151) = 10$ nm, $p = M_{151} = 2^k - 1$, $k = 151$. It would contain 10 DNA codons and correspond to 3 full turns for DNA double strand. This picture differs from the original one in which dark DNA strands were assumed to reside outside the double strand.

What could be the detailed mechanism?

1. Has the O-H group of phosphate have lost dark proton into the interior of the fundamental region where it belongs to dark proton triplet defining genetic codon. One would have $P-O^-$ phosphate ions at the negative electrode.

2. Does the O-H group of phosphate have a hydrogen bond with the water molecule of the cell exterior and has the flux tube transformed to dark flux tube extending to the interior of the fundamental region? Has it lost its dark proton to the interior of the fundamental region via a reconnection process?

3. The answer to the question comes from the consistency with the realization of the dark genetic codons as dark proton triplets considered in [L174]. The dark protons of the codon should be associated with the vertices of triangular tetrahedral or icosahedral faces of the fundamental region of the icosa-tetrahedral tessellation.

   This would suggest that the monopole flux tubes representing hydrogen bonds have (de-)reconnected and left the dark proton to the vertices of the triangular face. The small closed flux tube produced in the de-reconnection would naturally correspond to the required closed flux tubes connecting icosahedron, tetrahedron, and octahedron assignable to a given dark proton of the codon. The magnetic field for the flux tube would determine the cyclotron frequency and cyclotron frequency triplet would characterize the codon and provide the icosa-tetrahedral realization of the genetic code [L22, L121].

Pollack effect and cell membrane

In the model of the cell membrane as a battery, the rough first picture could be as follows. The original model involved the Pollack effect for protons but the generalization of the effect to biologically important positive ions is suggestive and involved with the cell membrane.

1. In the simplest model, dark positively charged alkali ions reside always outside the cell membrane at monopole flux tubes. The negative ions resulting from the transfer of positive ions to the U-shaped monopole flux tubes defining analogs of hydrogen bonds would reside inside the cell membrane.

   The connections between exterior and exterior by pairs of flux tubes from U-shaped flux tubes could be permanent but one can also consider the possibility of U-shaped flux tubes extending to the exterior with delocalized ions at them.

The transfer of dark ions permanently to the exterior would involve a (de-)reconnection generating a transfer of dark ions to the exterior and subsequent reconnection isolating splitting the flux tube pair and isolating exterior from the interior. Reconnections could control the transfer of dark ions between interior and exterior.

Membrane resting potential would be controlled by the transfer of dark ions to the exterior generating a hyperpolarization. This would suggest permanent flux tube connections.

2. Gel phase would be a natural candidate for the analog for the negatively charged $H_{1.5}O$ involving corresponding phases for various ions. In gel-to-sol transition this phase would transform to ordinary water and the battery charge would decay. Metabolic energy feed is needed to prevent this since the value of h_{eff} increases with energy and tends to be spontaneously reduced.

   It is unclear whether one could understand the nerve pulse in terms of the gel-to-sol phase transition in which ohmic currents would be generated leading to the reduction and change of the sign of the membrane potential. That Hodkin-Huxley model works satisfactorily suggests that ohmic currents are present during the nerve pulse.

3. In the Josephson junction model of the cell membrane [K41, K89, K88], there is a permanent Sine-Gordon soliton sequence based on the phase difference $\Delta\Phi$ for superconducting phases residing at monopole flux tubes at the two sides of the membrane.

   One has $d\Delta\Phi/dt \equiv \Omega = E/\hbar_{eff}$, where E is the sum of the ordinary Josephson energy ZeV and difference of cyclotron energies over the junction. Very large value of $\hbar_{eff}$ is required to give Josephson frequency in EEG range and gravitational Planck constant $\hbar_{gr}$, introduced first by Nottale [E9], central in TGD view of quantum gravitation [L163, L161, L180, L181, L186], is highly suggestive.

   The cyclotron frequencies are associated with the flux tubes parallel to the cell membrane. If there are no flux tubes in the interior, the corresponding cyclotron frequency vanishes. Josephson junctions are associated with the membrane proteins. Josephson junctions could correspond to pairs of flux tubes between interior and exterior so that bosonic dark ions or Cooper pairs of fermionic ions would give rise to Josephson currents between interior and exterior.

   The system is mathematically equivalent to a sequence of rotating gravitational penduli assignable to various ions. The simplest model assumes that all bosonic dark ions are at the magnetic flux tubes in the exterior of the cell membrane and parallel to it.

4. What about the nerve pulse in the simplest picture? The nerve pulse could be induced by a propagation of a perturbation changing the sign of the local rotation direction of some fictitious gravitational penduli at the point in which the sine of the phase vanishes so that also Josephson current vanishes. Formally this corresponds to a change of the arrow of time and could correspond to a pair of "big" state function reductions (BSFRs). Could this change of the arrow of time induce reduction of the voltage and ordinary Ohmic currents changing the sign of the membrane potential temporarily?

17.4.4 Dark matter and new energy technologies in the TGD framework

The motivation for summarizing a general vision of future energy technologies based on dark matter in the TGD sense came from the video of Sabine Hossenfelder titles "Sulfur Better than Hydrogen for Energy Storage, Engineers Find" (see this).

TGD view of dark matter

Number theoretic view of TGD predicts a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant $h_{eff} = nh_0$. The simplest assumption is that n is the dimension of algebraic extension of rationals. For a more complex option it is a product of dimensions of two algebraic extensions.

These phases behave like dark matter and would be located at monopole magnetic flux tubes and also electric flux tubes. They would not be galactic dark matter but correspond to the missing baryonic matter whose fraction has been increasing during the cosmological evolution. Galactic dark matter would correspond to the energy of cosmic strings (space-time surfaces with 2-D M^4 and CP_2 projections). The unavoidable mumber theoretical evolution implies the increase of the number theoretical complexity and therefore increase of n. The larger the value of n the longer the quantum coherence scale of the system.

1. The predicted huge values of h_{eff} assignable to classical gravitational and electric fields of astrophysical objects [L175] mean that weak interactions become as strong as em interactions below the scale up Compton length of weak bosons, which, being proportional to h_{eff}, can be as large as cell size. This amplifies parity violation effects visible for instance in hydrodynamics [K2].

2. Large h_{eff} phases behave like dark matter: they do not however explain the galactic dark matter, which in the TGD framework is dark energy assignable to cosmic strings (no halo and an automatic prediction of the flat velocity spectrum). Instead, large h_{eff} phases solve the missing baryon problem. The density of baryons has decreased in cosmic evolution (having biological evolution as a particular aspect) and the explanation is that evolution as unavoidable increase of algebraic complexity measured by h_{eff} has transformed them to $h_{eff} \geq h$ phases at the magnetic bodies (thickened cosmic string world sheets, 4-D objects), in particular those involved with living matter.

3. The large value of h_{eff} has besides number theoretical interpretation [L114, L115, L182, L187] also a geometric interpretation. Space-time surface can be regarded as many-sheeted over both M^4 and CP_2. In the first case the CP_2 coordinates are many-valued functions of M^4 coordinates. In the latter case M^4 coordinates are many-valued functions of CP_2 coordinates so that QFT type description fails. This case is highly interesting in the case of quantum biology. Since a connected space-time surface defines the quantum coherence region, an ensemble of, say, monopole flux tubes can define a quantum coherent region in the latter case: one simply has an analog of Bose-Einstein condensate of monopole flux tubes.

Why dark matter is so excellent for energy storage?

The basic observation is that the energies of quantum states as a function of h_{eff} increase. For instance, cyclotron energies are proportional to $\hbar_{eff}$ and atomic binding energies are proportional to $1/\hbar_{eff}^2$.

This suggests that the transformation of ordinary particles, say protons or electrons, to their dark variants at the magnetic body (MB) of the system allows to store energy and also information at MB. Due to the large value of h_{eff} the dissipation would be slow.

One can imagine a practically endless variety of ways to achieve this.

1. In the Pollack effect the solar radiation would kick part of the protons of the water molecules to the gravitational MB of Earth. Pollack effect creates negatively charged exclusion zones (EZs) with strange properties suggesting time reversal which is indeed predicted to occur in the TGD Universe if its TGD counterpart corresponds to an ordinary state function reduction.

   In the case of protons the scale of the reduction of the gravitational energy is of order .5 eV if the flux tubes have the scale of Earth radius. For reasonably small h_{eff} these flux tubes could be long hydrogen bonds carrying protons. The flux tubes can also carry several protons and one ends up to a proposal for the genetic codes in terms of dark proton triplets. These dark DNA molecules would be paired with ordinary DNA. Same could be true for other basic information molecules.

2. Dark cyclotron states with energy proportional to $\hbar_{gr}$ or $\hbar_{eff}$ assignable to long range gravitational fields of Sun and planets and electric fields of Sun and Earth and also smaller systems such as cell and DNA would allow the storage of energy to the energy of dark particles.

3. Pollack effect generalizes in the TGD framework. Also electrons could be kicked to the gravitational MB: in this case the energy scale would be meV scale [L163, L161]. Both protonic and electronic energy scales appear in cell biology. Especially interesting systems

are charged conductors: their electric bodies could consist of flux tubes which are deformed gravitational magnetic flux tubes carrying dark electrons.

The proposed realization of genetic code for dark protons generalizes to the case of dark electrons and suggests that genetic code realized in terms of a completely exceptional icosa tetrahedral tessellation of H^3 and theref also life is much more general phenomenon than thought hitherto. Therefore both energy and information storage without the problems caused by dissipation would be in question.

4. In principle, the energy needed to kick the protons to the MB could come from practically any source. For instance, the formation of atomic or molecular bound states would liberate energy stored as energy of dark particles at the MB. This energy would be liberated when dark protons transform to ordinary protons but the system need not transform back to the original energy so that the liberated energy could be used [L175].

   The molecular energy storage in living matter to proteins could rely on this mechanism and could use relatively small values of h_{eff} assignable to valence bonds. High energy phosphate bonds could correspond to short term storage, perhaps at the gravitational magnetic body.

Cold fusion and energy storage

TGD leads also to a second proposal for energy storage based on another key aspect of number theoretical physics. The polynomials associated with a given extension of rationals are characterized by ramified primes whose spectrum depends on the polynomials. These ramified primes define preferred p-adic number fields characterizing the cognitive aspects of these systems. The p-adic length scale characterizes the mass/energy scale of the system and the prediction is that a given system can appear in several p-adic length scales with different mass/energy scales. TGD suggests the existence of p-adically scaled variants of hadron physics, nuclear physics and even atomic and molecular physics.

The so-called "cold fusion" could rely on dark fusion, as the formation of p-adically scaled atomic nuclei from dark protons which can also transform to dark neutrons by emission of dark weak bosons. This process could produce, not only energy, but also basic elements. One would avoid the kicking of nuclei from the bottom of the nuclear energy valley by nuclear collisions requiring high energies.

The dark proton sequences at monopole flux tubes defining dark DNA could be seen as dark nuclei. Their binding energies would scale down and they could form even at low temperatures and in living matter (biofusion for which there is evidence). They could spontaneously transform to ordinary nuclei and liberate practically all ordinary nuclear binding energy. This process could give rise to prestellar evolution heating the system to the ignition temperature of ordinary nuclear fusion. This process could produce elements with atomic numbers even higher than that of iron. Usually supernova explosions are believed to be responsible for this.

17.5 Testing of the vision

Eventually the basic concepts of TGD applied to condensed matter physics should be tested. The following lists some challenges.

17.5.1 Observation of dark matter

The observation of dark matter as $h_{eff} = nh_0$ phases in condensed matter systems is one basic goal (`allb`qcritdark1,qcritdark2,qcritdark3,qcritdark4). Macroscopic quantum phases, emergence of additional degrees of freedom, and the effective increase of the dimension of the momentum space from 3 $3k(n,K)$, where k is a numerical factor determined by the number K of particles forming the Galois confined states and by the dimension n of the extensionof rationals, are possible. Also photon scattering via the formation of polaritons could allow us to "see" the structure of dark matter at the level of MB as an interference pattern. The analog of X-ray diffraction would be in question.

17.5.2 Topological physics at space-time and embedding space levels

The basic new physics element is the topological physics in the TGD sense based on non-trivial space-time topology at the fundamental level.

Some examples are in order.

1. Magnetic flux tubes are always closed, which means non-trivial first homotopy making possible the topological variant of the geometric phase.

2. Flux tube braidings would be a basic concept of topological hydrodynamics. Reconnections as changes of braid topology would be central and bring in 2-braids and knots of 2-D flux sheets in 4-D space-times (also intersections at discrete points replace links of 1-braids).

3. In TGD inspired biology systems have U-shaped flux tubes as tentacles with which they generate connections to the environment by reconnecting in which two U-shaped flux tubes of different systems such as molecules form a pair of flux tubes.

   For instance, friction could be due to the formation of flux tube pairs. Static friction would be generated and the de-reconnection of flux tube pairs would require energy.

Also topological defects due to the embedding space topology are possible. The monopole flux reflects the non-trivial topology of CP_2. Skyrmions result from the constraint that the ball $B^3 \subset M^4$ is mapped to the sphere S^3 of $E^4 \subset M^8$ or equivalently of CP_2.

Neutrons form bound state with nanocrystals: support for the notion of magnetic flux tube?

A very interesting observation is described in MIT News. The original article [D73] telling about the discovery. What has been found that neutrons form bound states with nanocrystals of size about 13 nm and are located outside the crystals.

In wave mechanics, the de Broglie wavelength for a neutron gives an idea of its quantum coherence scale, which should be on the order of 10 nanometers for quantum dots. The energy of the neutron must be above the thermal energy. The temperature must be at most milli Kelvin for this condition to be fulfilled.

The range of strong interactions is of order $10^{-14} - 10^{-15}$ meters and extremely short as compared to the 10 nanometer scale of nanocrystals. I don't really understand how strong interactions could produce these states. Another strange feature is that neutrons are outside these quantum dots. Why not inside, if nuclear power is involved somehow?

Contrary to what the popular article claims, neutrons interact electromagnetically. They have no charge but have a magnetic moment related to the neutron's spin so that they interact with the magnetic fields. How is this option ruled out? Is it really excluded?

In the TGD Universe, the new view of space-time implies that the magnetic fields of Maxwell's theory are replaced by magnetic flux quanta, typically flux tubes. Also monopole flux tubes are possible and explain quite a large number of anomalies related to the magnetic fields. The monopole flux tubes are actually basic objects in all scales.

Could the neutrons reside at the monopole flux tubes associated with the nanocrystal? Could the neutrons be bound to the magnetic fields of the magnetic flux tubes and form cyclotron states? If so, the de Broglie wavelength would be related to the free motion in the direction of the necessarily closed monopole flux tube.

More generally, neutrons could have an effective Planck constant larger than the ordinary Planck constant and behave like dark matter. In the TGD based model of biomatter, phases of protons with very large effective Planck constant behaving like dark matter are in an essential role.

17.5.3 The new view of gauge fields

TGD view of gauge fields differs in several respects from the standard view.

1. The new view about gauge fields and also electromagnetic fields relies on flux tubes. Flux tubes appear as two types: monopole flux tubes and non-monopole ones. Monopole flux tubes require no current to preserve the magnetic field.

This would explain magnetic fields in cosmic scales, why Earth's magnetic field has not disappeared [L30], and also the huge magnetic fields of magnetars and neutron stars. Could the fields H, M, and B of Maxwell's theory correspond to monopole fields, non-monopole fields induced by the motion of their flux quanta, and to their sum $B = M + H$.

2. The twistor lift of TGD [L65, L85] predicts that also M^4 should have Kähler structure defined by a self-dual constant Kähler form for which the electric part would be imaginary. This implies a global CP breaking in M^4 that could induce a matter-antimatter asymmetry. 3 quarks would prefer to form baryons and antiquarks to form leptons as 3 antiquarks composites in primordial Universe and after the annihilation the remaining baryons would represent matter and leptons antimatter. This is possible only by the TGD view about color [L106, L130].

   The mechanism of CP (T) violation could be essentially the same as in the topological insulators destroying the boundary conductivity by T violation. In the condensed matter case the magnetic field would receive $U(1)$ contributions from both CP_2 and M^4 degrees of freedom. The magnetic interaction energy with spin would have opposite signs for opposite spin directions and lead to CP and T violation. For cosmic strings and flux tubes the M^4 magnetic part would be small, which would explain the smallness of the CP violation. Since M^4 Kähler form contributes also to the $U(1)$ part of em and Z^0 fields, it could have small effects also at the level of condensed matter if M^4 projection of the flux tube is 4-D.

3. Wormhole contacts identified as pieces of deformed CP_2 type extremals serve as basic building bricks of elementary particles. The wormhole throats are identified as partonic surfaces and their orbits are light-like curves performing zitterbewegung. One can assign to them a Kac-Moody type algebra with non-negative conformal weights. This algebra is very much like gauge algebra but not quite. For instance, there is a hierarchy of representations for which only the generators with conformal weight larger than some maximal conformal weight h_{max} annihilate the physical states. Could these analogs of gauge algebras assignable to $M^2 \times CP_2$ isometries allow a realization of synthetic gauge groups acting also in M^4 spin degrees of freedom [D46] (`https://cutt.ly/4Wy39B5`?

17.5.4 Number theoretical physics

Number theoretical physics brings in new elements and involves in an essential manner $M^8 - H$ duality.

1. The hierarchy of effective Planck constants and p-adic physics as physics of cognition involving p-adic length scale physics means a completely new element of quantum theory central for understanding of various supra phases.

2. Galois confinement is a central notion. Quantum states would be Galois singlets above the quantum coherence scale defined by h_{eff} and become unconfined states below this scale. The situation is highly reminiscent of color confinement. At M^8 level, the assumption that momenta are algebraic integers for the extension of rationals considered implies that confined states have total momenta, which are ordinary integers and that the rational integer parts momenta of K composite particles are identical. This implies a reduction of translational degrees of freedom so that the density dn/dE of confined states increases and among other things leads to a reduction of Fermi energy.

   Galois confinement could serve as a universal mechanism for the formation of bound states: this includes atoms and molecules, atomic nuclei, and hadrons. Color confinement can be one particular example of this if Galois group is represented as a subgroup of color group: Z_3 is the obvious guess but also more general discrete subgroups of $SU(3)$ are possible. Also the discrete subgroups of the rotation group $SO(3)$ and its covering group $SU(2)$ could be representable as Galois groups and appear in the ADE hierarchy for inclusions of HFFs. $M^8 - H$ duality would give a very concrete ideas about the momentum space and space-time geometries of the bound states. Momenta in M^8 would form a representation of Galois group mapped to H by $M^8 - H$ duality.

3. The number theoretical phase transitions changing the polynomial that determines $X^4 \subset M^8$ and therefore the extension of rationals and the Galois group as symmetry group would be a new element. Discrete degrees of freedom would appear or disappear. The scaling of the number of states within the Fermi ball could be one signature. Extensions could also give rise to quasicrystals.

   The change of the fidelity described as the metric of the parametrized space of quantum states would take place. Fidelity would be coded by the Kähler metric of WCW and geometric phase by the Kähler form of WCW. This is because, the WCW Kähler metric induces the metric of quantum states depending on the parameters coding for the X^4 as a point of WCW.

4. Negentropy Maximization Principle (NMP) and adelic physics provide a new view about quantum measurements and about second law. In particular, a vision about how the information about measurement is stored in the space-time geometry modified in the measurement, emerges.

17.5.5 ZEO and new view about quantum measurement theory and thermodynamics

ZEO allows "big" state function reductions (BSFRs) in long scales. If time reversal indeed occurs, it induces a long lasting effective time reversal at the level of ordinary matter (genuine time reversals at this level last a very short time). Dissipation would effectively occur with an opposite arrow of time and lead to the formation of self-organization patterns [L102]. The findings of Minev *et al* discussed in [L90] support the new view about quantum theory.

The most dramatic implications would be to biology. In particular, homeostasis could be understood as self-organized quantum critical (SOQC) [L139]. Condensed matter systems in the presence of energy feed playing the role of metabolic energy feed could exhibit primitive aspects of living systems.

Note that at the QFT limit most of the information about the TGD based new physics is lost since both space-time topology and number theoretic structure is lost so that QFT is not able to test the relevant effects. However, it might be possible to make this hidden level visible.

17.6 Kondo effect from the TGD perspective

I have tried to learn some condensed matter physics from the TGD point of view and have even written a book [K97] containing a chapter [L145], which summarizes my most recent efforts.

Although I have only a superficial understanding of condensed matter physics, I can agree with Anderson when he says that there is no theory of condensed matter physics. There are models based typically on a Hamiltonian in a spin lattice but somehow it seems that there is no attempt to understand the basic physics. With TGD as a background, the reductionist view does not force me to believe that condensed matter physics is mere complexity, so that I cannot avoid the intuition that a lot of new physics is waiting to be discovered.

17.6.1 Kondo effect

I realized that the Kondo effect (`https://rb.gy/gm5bom`) could involve new physics predicted by TGD. Kondo effect relates to the scattering of s-orbital conduction electrons scattering on d-orbital electrons of magnetic impurities. A low temperature phenomenon is in question. Electrical resistivity is given by the general formula

$$\rho(T) = \rho_0 + aT^2 + c_m log(\frac{\mu}{T}) + bT^5 \quad . \tag{17.6.1}$$

Here T^2 term comes from Fermi liquid properties, T^5 term corresponds to the scattering from lattice vibrations and the logarithmic Kondo term corresponds to the scattering from the magnetic impurities. Kondo term increases at low temperatures and diverges logarithmically at the $T = 0$

limit and begins negligible at a temperature of a few Kelvins. The reason is resonant scattering at low temperatures. This would suggest formation of resonances.

Transformation of a conduction electron to an impurity electron and vice versa is essential as also the bilocal Coulomb interaction term for the conduction electrons, which makes the system non-linear in the description using electron's oscillator operators. Hybridization as a mixing valence electrons and conduction electrons occurs: valence electron transforms to an impurity electron or vice versa in the 2-vertex. Screening of the impurity spin by the spins of the conduction electron cloud takes place so that a system with a vanishing spin is formed is essential. At high temperatures impurity electrons appear as free particles.

There is an analogy with low energy QCD. Logarithmic increase of the resistivity towards $T = 0$ is analogous to the logarithmic increase of the QCD coupling strength α_s as the mass scale corresponding to QCD Λ is approached and hadronization takes place. Resonances in Kondo scattering correspond to the formation of hadrons. At high temperatures the impurity spins seem to behave like free spins and there is an analogy with asymptotic freedom. The screening of impurity spin by conduction electrons is analogous to color confinement.

Kondo's original model was based on third order perturbative calculation. Anderson's impurity model, combined with Wilsonian renormalization theory, provides another approach and in this model the Kondo effect occurs in the regime, where the perturbation series fails to converge. Since hybridization terms are quadratic, this must be caused by the Coulomb interaction term. The analogy with QCD becomes more obvious.

How could one understand the increase of the hybridization coupling towards low temperatures? Is it a secondary phenomenon caused by the non-linearity of the Hamiltonian? Somehow the increase of the Coulomb term induced by the increase of the size of the volume containing the conduction electron cloud should cause the increase of the coupling and lead to the analog of hadronization as a formation of spin singlets?

The total Coulomb interaction energy is proportional to Q^2, Q the total charge of the conduction electron cloud, increases and if the system is quantum coherent it could lead to the failure of perturbation theory containing $Q^2\alpha$ as a coupling parameter.

17.6.2 TGD view of Kondo effect

TGD view of the Kondo effect relies on the basic notions discussed in the introduction. It is best to start by making questions.

TGD view based on the notion of magnetic body and h_{eff} hierarchy

Consider now the system from the TGD point of view assuming the view that impurity spin as valence electron is accompanied by a magnetic body (MB) consisting of magnetic flux tubes representing the approximate dipole field and that the conduction electrons interacting with impurity spin can have a value of effective Planck constant h_{eff}, which is larger than h so that quantum coherence in length scales longer than the atomic length scales becomes possible at the MB and induces ordinary coherence of ordinary matter.

It is good to list the general ideas first.

1. Impurity electrons are accompanied by magnetic flux tubes and some fraction of conduction electrons ends up at the flux tubes as dark *valence* electrons, which are localized in a longer scale. The formation of resonances corresponds to the formation of conduction electron clouds around impurities as association of conduction electrons to the magnetic flux tubes and is analogous to the formation of hadrons.

   Magnetic moments sum up to zero and spin screening takes place as an analog of color confinement. Magnetic moment interaction becomes strong at the limit $T = 0$.

2. The original theoretical motivation for the $h_{eff} = nh_0$ hierarchy is the following. When the interaction strength $\alpha alpha = Q_1Q_2g^2/4pi\hbar$ for a quantum coherent system consisting of charges Q_1 and Q_2 becomes too large, the perturbation series fails to converge. Nature is however theoretician friendly and induces the phase transition $h \rightarrow h_{eff}$ making a perturbation theory possible. The size of the MB and associated quantum coherence length

inducing coherence at the level of ordinary matter, increases and bound states with larger size become possible.

3. Nottale's proposal [E9] [K96, K78, **?**] for the notion of gravitational Planck constant generalizes to other interactions. When the perturbation series fails, the electromagnetic counterpart of gravitational Planck constant would increase to $\hbar_{eff} = \hbar_{em} = Q_1Q_2\alpha/\beta_0$, $\beta_0 = v_0/c < 1$. The perturbative coupling parameter for quantum coherent states would be $Q_1Q_2e^2/\hbar_{em} = \beta_0/4\pi$ and would be universal. This would be the situation for all interactions. The value of β_0 is by number theoretical arguments proposed to be an inverse integer [L161].

4. h_{eff} should increase as some relevant coupling constant increases. Number theoretic interpretation implies that more complex states are generated. $n = h_{eff}/h_0$ corresponds to the degree of extension of rationals defined by a given polynomial [L114, L115]. For a given polynomial, the largest and smallest ramified primes associated with an extension with dimension $n = h_{eff}/h_0$ are physically preferred and could be seen as fixed points of the coupling constant evolution assignable to this polynomial [L162]. Also for the set of polynomials with fixed degree k and coefficients smaller than k, one can identify smallest and largest p-adic length scales. They define fixed points of coupling constant evolution in this set.

There is a general objection against the idea that particles, could be permanently dark.

1. The energies of quantum states increase as a function of h_{eff}/h_0 defining the dimension of extension of rationals. These tend to return back to ordinary states. This can be prevented by a feed of metabolic energy.

2. One way out of the situation is that the dark particles form bound states and the binding energy compensates for the feed of energy. This would take place in the Galois confinement. This would occur in the formation of Cooper pairs in the transition to superconductivity and in the formation of molecules as a generation of chemical bonds with $h_{eff} > h$.

3. In living matter quantum criticality is essential and the energy liberated in the phase transition could provide the needed metabolic energy feed. Physiological temperature, which correspond to energy scale of about .03 eV (the scale of the Coulomb energy defined by membrane potential) would correspond to an energy needed to induce a phase transition in which H_2O transforms to to $H_{1.5}O$ [L24] as part of protons become dark and are transferred to monopole magnetic flux tubes. The thermal energy could serve as the metabolic energy feed making possible free dark protons and the formation of bound states of dark protons at magnetic flux tubes would make it possible to pay the energy bill.

4. In the Kondo effect thermal energy could serve as the needed energy feed. The formation of bound states would allow the return of the thermal energy needed to generate the dark electrons.

Why the spin confinement occurs only at low temperatures?

One should understand why the spin confinement occurs at low temperatures only.

1. The value of h_{eff} associated with the MB of the impurity spins surrounded by valence spin cloud should increase at the limit $T = 0$. h_{eff} and p-adic length scale are correlated so that also p-adic length scale measuring the size of the system would increase: larger spin singlets are formed.

2. The energies of states increase with h_{eff}. The increase of h_{eff} requires energy feed and h_{eff} can decrease spontaneously. Thermal energy can serve as an energy feed by inducing h_{eff} increasing transitions. Why does this increase not occur at higher temperatures and lead to larger spin singlet states than at low temperatures?

   Since this does not occur, thermal energy must exceed the binding energy of the state above a critical temperature and make it unstable. This requires that the binding energy of the state must decrease with increasing h_{eff}. Atomic binding energies satisfy this condition. They are proportional to $1/\hbar_{eff}^2$ and approach zero like $1/\hbar_{eff}^2$ and are stable only below a critical temperature determined by the ground state energy. Something similar should happen also now, which suggests that atomic binding energy of dark valence electrons is important.

What interactions should be taken into account?

In the Anderson's impurity model, Coulomb interaction between valence electrons and the interaction describing the hybridization are taken into account. In the TGD framework the situation can be more complex.

1. Certainly the coupling between dark valence electrons is important. In the presence of quantum coherence, one could perhaps approximate this interaction by using interaction strength Q^2e^2, where Q is the total charge of dark valence electrons of the cloud. Could one assume that Q^2e^2 defines in a good approximation the effective Planck constant as $\hbar_{em} = Q^2\alpha/\beta_0$? Could $\hbar_{em}$ define the binding energy scale of the dark valence electrons and reduce it by a factor $(\hbar/\hbar_{em})^2$ so that a thermal instability would be the outcome and the model would be in many respects be similar to the Anderson's impurity model.

   Since the spin spin-interaction is essentially the interaction energy between two magnetic moments, it should be proportional to $\hbar_{eff}$ and would increase as dark valence electrons with increasing values of $\hbar_{eff}$ are stabilized. The stable value of $\hbar_{eff}$, determined by the Coulomb interaction terms for conduction electrons, should depend logarithmically on the temperature. The generalization of the Nottale hypothesis [E9] to the electromagnetic case implies $\hbar_{eff} \propto Q^2\alpha/\beta_0$. Therefore the parameter Q^2/β_0 measuring also the charge of the dark valence electron cloud should increase logarithmically with the inverse temperature.

2. In Anderson's impurity model, the attractive interaction between the conduction electrons and atoms is not taken into account. Can one forget the presence of atoms in the TGD framework? Assume that the dark valence electrons of the cloud behave like a single quantum coherent unit with total charge Q. The interaction strength for the mutual interactions of valence electrons would be Q^2e^2.

   If each dark valence electron is associated with a single atom (rather than with the atoms associated with the cloud), the effective charge Q_{eff} of the atom screened by the inner electrons is equal to $Q_{eff} = -1$ in the first approximation. The interaction strength for dark valence electron charge and atomic charge would be $QQ_{eff}e^2 = -Qe^2$. The interaction strength for the mutual interaction of valence electrons would dominate. Situation would be similar to that in the Anderson model.

Hadron physics analogy in the TGD framework

Ordinary hadron physics need not be enough as an analogy of Kondo effect in the TGD framework.

1. TGD predicts a hierarchy of scaled up versions of hadron physics associated with Mersenne primes and their Gaussian analogs [K66, K67]. Color confinement would occur always but at high energies the scale of confinement decreases as the size of the quarks decreases. The MB of the hadron would not disappear at high energies but its size decreases in a stepwise manner at p-adic length scales corresponding to Mersennes.

2. The possibility of having $h_{eff} > h$ allows to have a situation in which the Compton length and geometric size of say M_{89} hadron with 512 times higher mass than that of ordinary M_{107} hadron is the same as that of ordinary hadron [K66, K67].

   The model assumes that the p-adic length scale is not completely fixed by h_{eff}. The transition $h \rightarrow h_{eff} = 512h$ for M_{89} hadrons could serve as a TGD counterpart of color deconfinement for quarks, whose masses have increased by this factor.

   The number theoretic vision allows us to formulate this idea in a rather detailed way [L162].

(a) A given extension of rationals with dimension $n = h_{eff}/h_0$ allows several ramified primes, which define possible p-adic length scales [L162] tentatively identified as p-adic lengths scales associated with the many-particle state assigned with the polynomial. For elementary particles there would be only a single ramified prime.

(b) For a given value of p-adic length scale, one can have several values of $h_{eff}/h_0 = n$. Particles with different values of $h_{eff}/h_0 = n$ can have the same unique ramified prime. For two particles with the same ramified prime but with different values n_i, the ratio of p-adic length scales would be n_1/n_2.

(c) If the particle belongs to a many-particle system possessing several ramified primes, also the ramified prime and the p-adic length scale characterizing the particle can change.

(d) Assuming this picture, one can formulate the assumption that M_{89} hadrons appear as their dark variants in the situations, where indications for their existence can be found [K66, K67]. Dark variant of M_{89} hadron would have h_{eff} related by factor 512 to its non-dark variant.

3. Color confinement involves the increase of the strong coupling strength α_s. The proposed vision predicts a parton-hadron phase transition in which α_s is replaced by the coupling parameter $\beta_0/4\pi$ of the perturbation theory based on hadrons as fundamental objects.

   One can apply the analogy between color confinement and the Kondo effect also in the opposite direction. One can argue that valence quarks are analogous to the impurity electrons whereas sea quarks and gluons are analogous to the conduction electrons, which have transformed to dark valence electrons. Valence quarks would correspond to ordinary matter and sea partons to dark matter at MB. This suggests a new approach to hadron physics.

   As a matter of fact, the notion of a color magnetic body as a structure much larger than hadron itself has already made its appearance in TGD. The reason is that the Compton wavelengths of u and d current quarks are much longer than nucleus size and even nuclear size so that their proper place is naturally at the MB if the Compton length has geometric size as a classical space-time correlate.

4. Galois confinement [L125, L156, L157, L145] generalizes the notion of color confinement in the TGD framework, and is an essential element of the number theoretical view of TGD. It can be formulated at the level of 4-momenta of fermions and corresponds to momentum space description. Obviously, this description is especially well-suited in condensed matter physics.

   The extreme form of Galois confinement [L125, L172, L136, L159, L156, L157] states that all bound states are Galois confined. The Galois bound states are characterized by their binding energy. For a given extension they can exist only below a certain temperature and have a temperature dependent sice. The size of MB should increase and binding energy should decrease with the size so that the stable size of MB decreases with increasing temperature.

5. The energetics based objection against dark variants free particles can be circumvented in two ways. The trivial option is that all partons have $h_{eff} = h$. The non-trivial option is that bound states of dark partons are formed by Galois confinement and binding energy prevents spontaneous decay. The dark partons would be generated in the color confinement and become a part of a dark bound state or form a separate bound state as sea. Color confinement is closely related to Galois confinement. Does it make sense to say that it prevents the escape of the sea partons even if they are not Galois confined. In the collisions of hadrons, the collision energy can provide the metabolic energy feed and induce a phase transition increasing h_{eff} and this would indeed happen in the high energy collisions generating dark M_{89} hadrons interpreted in QCD as phase transition liberating quarks.

Consider now the application of this picture to the Kondo effect.

1. The hadronic analogy suggests that the logarithmic increase of the coupling between valence electron and impurity spins is a secondary phenomenon induced by the increase of $\hbar_{em}$ to which the magnetic interaction energy is proportional. One cannot speak of conduction electron scattering anymore. Rather, one should speak of the scattering of spin singlets as analogs of hadrons, whose size decreases at high temperatures as they approach impurity spins.

2. Assume that the sizes of MB of the spinless bound state increase at the $T = 0$ limit. The reduction of the size of MB would be due to both due the discrete p-adic length scale evolution and $h_{eff} = h_{em}Q^2\alpha/\beta_0$ evolution of the coupling strength for mutual interactions of valence-electrons as a quantum coherent unit. At high temperatures one would obtain free impurity spins as analogs of free quarks. Here one must take into account the possibility that some fraction of spins are genuinely free simply because the dark valence electron clouds contain only a fraction of valence electrons.

Some applications of the Kondo effect

Kondo effect according to TGD involves only very general assumptions such as hierarchy of Planck constants, the idea about $h \rightarrow h_{eff}$ when perturbation theory fails, and the instability of the bound states with $h_{eff} > h$ against too large thermal perturbations. Therefore the Kondo effect should generalize and have a strong resemblance with color confinement.

The Kondo effect indeed has several applications.

1. In heavy fermion systems (`https://rb.gy/hpkcyh`) the effective mass of electrons can increase by several orders. Also in hadron current quarks transform to much more massive consituent quarks, which involve not only the current quark but also the flux tube with color magnetic energy and the mass of the sea partons.

   Could the situation be the same now? The impurity spin valence electron is bound to conduction electrons, which have transformed to a sea of dark valence electrons. The effective mass of the impurity electron involves also the contribution from the magnetic energy and dark valence electrons.

2. In Kondo insulators (`https://rb.gy/ikl33x`) the valence electrons are bound to the flux tubes associated with the impurities and localization occurs. Current would not flow. There is an analogy with the state with no free quarks, which carry no color currents. Note however that now only spin currents vanish. This could allow charge currents as currents formed by the bound states of impurities and dark valence electron clouds.

17.7 Appendix

17.7.1 Comparison of TGD with other theories

Table 18.1 compares GRT and TGD and **Table 18.2** compares standard model and TGD.

17.7.2 Glossary and figures

The following glossary explains some basic concepts of TGD and TGD inspired biology.

- ***Space-time as surface***. Space-times can be regarded as 4-D surfaces in an 8-D space $M^4 \times CP_2$ obtained from empty Minkowski space (M^4) by adding four small dimensions (CP_2). The study of field equations characterizing space-time surfaces as "orbits" of 3-surfaces (3-D generalization of strings) forces the conclusion that the topology of space-time is non-trivial in all length scales.

- ***Geometrization of classical fields***. Both weak, electromagnetic, gluonic, and gravitational fields are known once the space-time surface in H as a solution of field equations is known.

	GRT	TGD
Scope of geometrization	classical gravitation	all interactions and quantum theory
Spacetime		
Geometry	abstract 4-geometry	sub-manifold geometry
Topology	trivial in long length scales	many-sheeted space-time
Signature	Minkowskian everywhere	also Euclidian
Fields		
classical	primary dynamical variables	induced from the geometry of H
Quantum fields	primary dynamical variables	modes of WCW spinor fields
Particles	point-like	3-surfaces
Symmetries		
Poincare symmetry	lost	Exact
GCI	true	true - leads to SH and ZEO
	Problem in the identication of coordinates	$H = M^4 \times CP_2$ provides preferred coordinates
Super-symmetry	super-gravitation	super variant of H: super-surfaces
Dynamics		
Equivalence Principle	true	true
Newton's laws and		
notion of force	lost	generalized
Einstein's equations	from GCI and EP	remnant of Poincare invariance at QFT limit of TGD
Bosonic action	EYM action	Kähler action + volume term
Cosmological constant	suggested by dark energy	length scale dependent coefficient of volume term
Fermionic action	Dirac action	Modified Dirac action for induced spinors
Newton's constant	given	predicted
Quantization	fails	Quantum states as modes of WCW spinor field

Table 17.1: Differences and similarities between GRT and TGD

	SM	TGD
Symmetries		
Origin	from empiria	reduction to CP_2 geometry
Color symmetry	gauge symmetry	isometries of CP_2
Color	analogous to spin	analogous to angular momentum
Ew symmetry	gauge symmery	holonomies of CP_2
Symmetry breaking	Higgs mechanism	CP_2 geometry
Spectrum		
Elementary particles	fundamental	consist of fundamental fermions
Bosons	gauge bosons, Higgs	gauge bosons, Higgs, pseudo-scalar
Fundamental fermions	quarks and leptons	quarks: leptons as local 3-quark composites
Dynamics		
Degrees of freedom	gauge fields, Higgs, and fermions	3-D surface geometry and spinors
Classical fields	gauge fields, Higgs	induced spinor connection
	SU(3) Killing vectors of CP_2	
Quantal degrees of freedom	gauge bosons,Higgs,	quantized induced spinor fields
Massivation	Higgs mechanism	p-adic thermodynamics with superconformal symmetry

Table 17.2: Differences and similarities between standard model and TGD

Many-sheeted space-time (see **Fig. 18.1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by ***wormhole contacts*** (see **Fig. 18.3**) identified as the building bricks of elementary particles. The sizes of wormhole contacts vary but are at least of CP_2 size (about 10^4 Planck lengths) and thus extremely small.

Many-sheeted space-time replaces reductionism with ***fractality*** . The existence of scaled variants of physics of strong and weak interactions in various length scales is implied, and biology is especially interesting in this respect.

- ***Topological field quantization (TFQ)*** . TFQ replaces classical fields with space-time quanta. For instance, magnetic fields decompose into space-time surfaces of finite size representing flux tubes or -sheets. Field configurations are like Bohr orbits carrying "archetypal" classical field patterns. Radiation fields correspond to topological light rays or massless extremals (MEs), magnetic fields to magnetic flux quanta (flux tubes and sheets) having as primordial representatives "cosmic strings", electric fields correspond to electric flux quanta (e.g. cell membrane), and fundamental particles to CP_2 type vacuum extremals.

- ***Field body*** (FB) and ***magnetic body*** (MB). Any physical system has field identity - FB or MB - in the sense that a given topological field quantum corresponds to a particular source (or several of them - e.g. in the case of the flux tube connecting two systems).

  Maxwellian electrodynamics cannot have this kind of identification since the fields created by different sources superpose. Superposition is replaced with a set theoretic union: only the *effects* of the fields assignable to different sources on test particle superpose. This makes it possible to define the QFT limit of TGD.

- ***p-Adic physics*** [K70] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.

- ***Adelic physics*** [L64, L69] is a fusion of real physics of sensory experience and various p-adic physics of cognition.

- ***p-Adic length scale hypothesis*** states that preferred p-adic length scales correspond to primes p near powers of two: $p \simeq 2^k$, k positive integer.

- A ***Dark matter hierarchy*** realized in terms of a hierarchy of values of effective Planck constant $h_{eff} = nh_0$ as integers using $h_0 = h/6$ as a unit. Large value of h_{eff} makes possible macroscopic quantum coherence which is crucial in living matter.

- ***MB as an intentional agent using biological body (BB) as a sensory receptor and motor instrument*** . The personal MB associated with the living body - as opposed to larger MBs assignable with collective levels of consciousness - has a hierarchical onion-like layered structure and several MBs can use the same BB making possible remote mental interactions such as hypnosis [L20].

- ***Cosmic strings Magnetic flux tubes*** belong to the basic extremals of practically any general coordinate invariant action principle. Cosmic strings are surfaces of form $X^2 \times Y^2 \subset M^4 \times CP_2$. X^2 is analogous to string world sheet. Cosmic strings come in two varieties and both seem to have a deep role in TGD.

  Y^2 is either a complex or Lagrangian 2-manifold of CP_2. Complex 2-manifold carries monopole flux. For Lagrangian sub-manifold the Kähler form and magnetic flux and Kähler action vanishes. Both types of cosmic strings are are simultaneous extremals of both Kähler action and volume action: this holds true quite generally for preferred extremals.

  Cosmic strings are unstable against perturbations thickening the 2-D M^4 projection to 3-D or 4-D: this gives rise to monopole (see **Fig. ??**) and non-monopole magnetic flux tubes. Using $M^2 \times Y^2$ coordinates, the thickening corresponds to the deformation for which $E^2 \subset M^4$ coordinates are not constant anymore but depend on Y^2 coordinates.

- ***Magnetic flux tubes and sheets*** serve as "body parts" of MB (analogous to body parts of BB), and one can speak about magnetic motor actions. Besides concrete motion of flux quanta/tubes analogous to ordinary motor activity, basic motor actions include the contraction of magnetic flux tubes by a phase transition possibly reducing Planck constant, and the change in thickness of the magnetic flux tube, thus changing the value of the magnetic field, and in turn the cyclotron frequency. Transversal oscillatory motions of flux tubes and oscillatory variations of the thickness of the flux tubes serve as counterparts for Alfwen waves.

  Reconnections of the U-shaped flux tubes allow two MBs to get in contact based on a pair of flux tubes connecting the systems and temporal variations of magnetic fields inducing motor actions of MBs favor the formation of reconnections.

  In hydrodynamics and magnetohydrodynamics reconnections would be essential for the generation of turbulence by the generation of vortices having monopole flux tube at core and Lagrangian flux tube as its exterior.

  Flux tube connections at the molecular level bring a new element to biochemistry making it possible to understand bio-catalysis. Flux tube connections serve as a space-time correlates for attention in the TGD inspired theory of consciousness.

- ***Cyclotron Bose-Einstein condensates (BECs)*** of various charged particles can accompany MBs. Cyclotron energy $E_c = hZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $h \rightarrow h_{eff}$ E_c is scaled up by a fractor $h_{eff}/h = n$. For sufficiently high value of h_{eff} cyclotron energy is above thermal energy $E = h_{eff}\ ZeB/m$. Cyclotron Bose-Einstein condensates at MBs of basic biomolecules and of cell membrane proteins - play a key role in TGD based biology.

- ***Josephson junctions*** exist between two superconductors. In TGD framework, ***generalized Josephson junctions*** accompany membrane proteins such as ion channels and pumps. A voltage between the two super-conductors implies a ***Josephson current***. For a constant voltage the current is oscillating with the ***Josephson frequency*** . The Josephson current emits ***Josephson radiation***. The energies come as multiples of ***Josephson energy***.

In TGD generalized Josephson radiation consisting of dark photons makes communication of sensory input to MB possible. The signal is coded to the modulation of Josephson frequency depending on the membrane voltage. The cyclotron BEC at MB receives the radiation producing a sequence of resonance peaks.

- ***Negentropy Maximization Principle*** (NMP). NMP [K65] [L139] is the variational principle of consciousness and generalizes SL. NMP states that the negentropy gain in SFR is non-negative and maximal. NMP implies SL for ordinary matter.

- ***Negentropic entanglement*** (NE). NE is possible in adelic physics and NMP does not allow its reduction. NMP implies a connection between NE, the dark matter hierarchy, p-adic physics, and quantum criticality. NE is a prerequisite for an experience defining abstraction as a rule having as instances the state pairs appearing in the entangled state.

- ***Zero energy ontology (ZEO)*** In ZEO physical states are pairs of positive and negative energy parts having opposite net quantum numbers and identifiable as counterparts of initial and final states of a physical event in the ordinary ontology. Positive and negative energy parts of the zero energy state are at the opposite boundaries of a ***causal diamond*** (CD, see **Fig. 18.2**)) defined as a double-pyramid-like intersection of future and past directed light-cones of Minkowski space.

  CD defines the "spot-light of consciousness": the contents of conscious experience associated with a given CD is determined by the space-time sheets in the embedding space region spanned by CD.

- ***SFR*** is an acronym for state function reduction. The measurement interaction is universal and defined by the entanglement of the subsystem considered with the external world [L105] [K125]. What is measured is the density matrix characterizing entanglement and the outcome is an eigenstate of the density matrix with eigenvalue giving the probability of this particular outcome. SFR can in principle occur for any pair of systems.

  SFR in ZEO solves the basic problem of quantum measurement theory since the zero energy state as a superposition of classical deterministic time evolutions (preferred extremals) is replaced with a new one. Individual time evolutions are not made non-deterministic.

  One must however notice that the reduction of entanglement between fermions (quarks in TGD) is not possible since Fermi- and als Bose statistics predicts a maximal entanglement. Entanglement reduction must occur in WCW degrees of freedom and they are present because point-like particles are replaced with 3-surfaces. They can correspond to the number theoretical degrees of freedom assignable to the Galois group - actually its decomposition in terms of its normal subgroups - and to topological degrees of freedom.

- ***SSFR*** is an acronym for "small" SFR as the TGD counterpart of weak measurement of quantum optics and resembles classical measurement since the change of the state is small [L105] [K125]. SSFR is preceded by the TGD counterpart of unitary time evolution replacing the state associated with CD with a quantum superposition of CDs and zero energy states associated with them. SSFR performs a localization of CD and corresponds to time measurement with time identifiable as the temporal distance between the tips of CD. CD is scaled up in size - at least in statistical sense and this gives rise to the arrow of time.

  The unitary process and SSFR represent also the counterpart for Zeno effect in the sense that the passive boundary of CD as also CD is only scaled up but is not shifted. The states remain unchanged apart from the addition of new fermions contained by the added part of the passive boundary. One can say that the size of the CD as analogous to the perceptive field means that more and more of the zero energy state at the passive boundary becomes visible. The active boundary is however both scaled and shifted in SSFR and states at it change. This gives rise to the experience of time flow and SSFRs as moments of subjective time correspond to geometric time as a distance between the tips of CD. The analog of unitary time evolution corresponds to "time" evolution induced by the exponential of the scaling generator L_0. Time translation is thus replaced by scaling. This is the case also in p-adic thermodynamics. The idea of time evolution by scalings has emerged also in condensed matter physics.

- ***BSFR*** is an acronym for "big" SFR, which is the TGD counterpart of ordinary state function reduction with the standard probabilistic rules [L105] [K125]. What is new is that the arrow of time changes since the roles of passive and active boundaries change and CD starts to increase in an opposite time direction.

  This has profound thermodynamic implications. Second law must be generalized and the time corresponds to dissipation with a reversed arrow of time looking like self-organization for an observed with opposite arrow of time [L102]. The interpretation of BSFR is as analog of biological death and the time reversed period is analogous to re-incarnation but with non-standard arrow of time. The findings of Minev *et al* [L90] give support for BSFR at atomic level. Together with h_{eff} hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

17.7.3 Figures

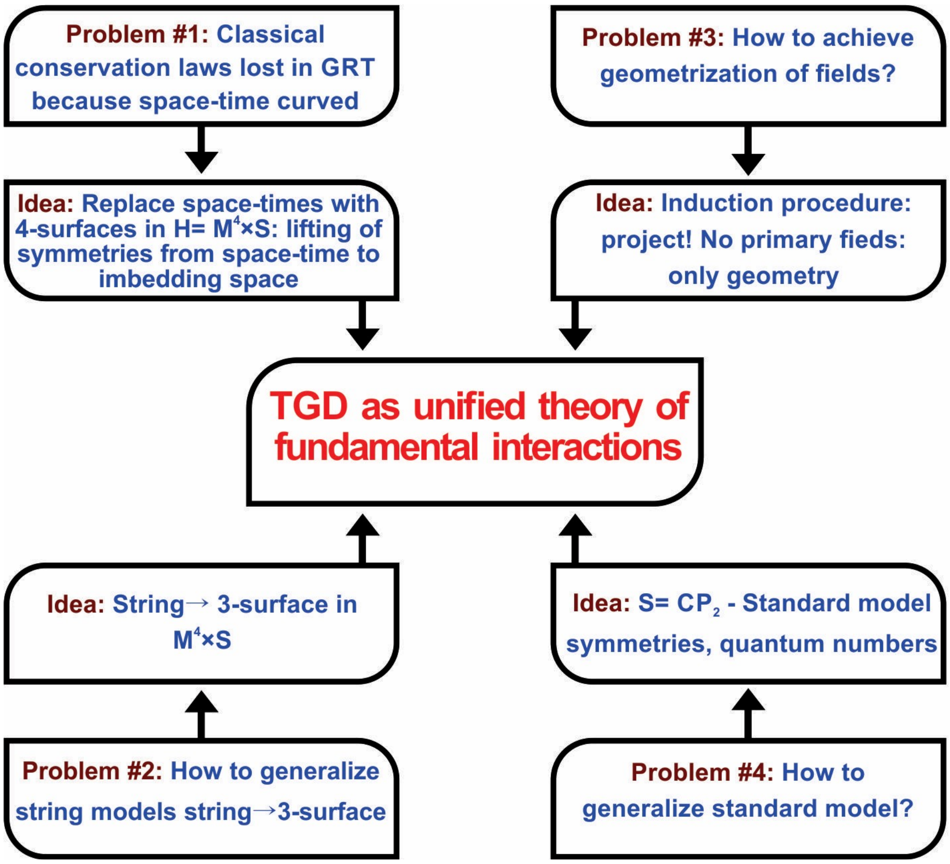

Figure 17.1: The problems leading to TGD as their solution.

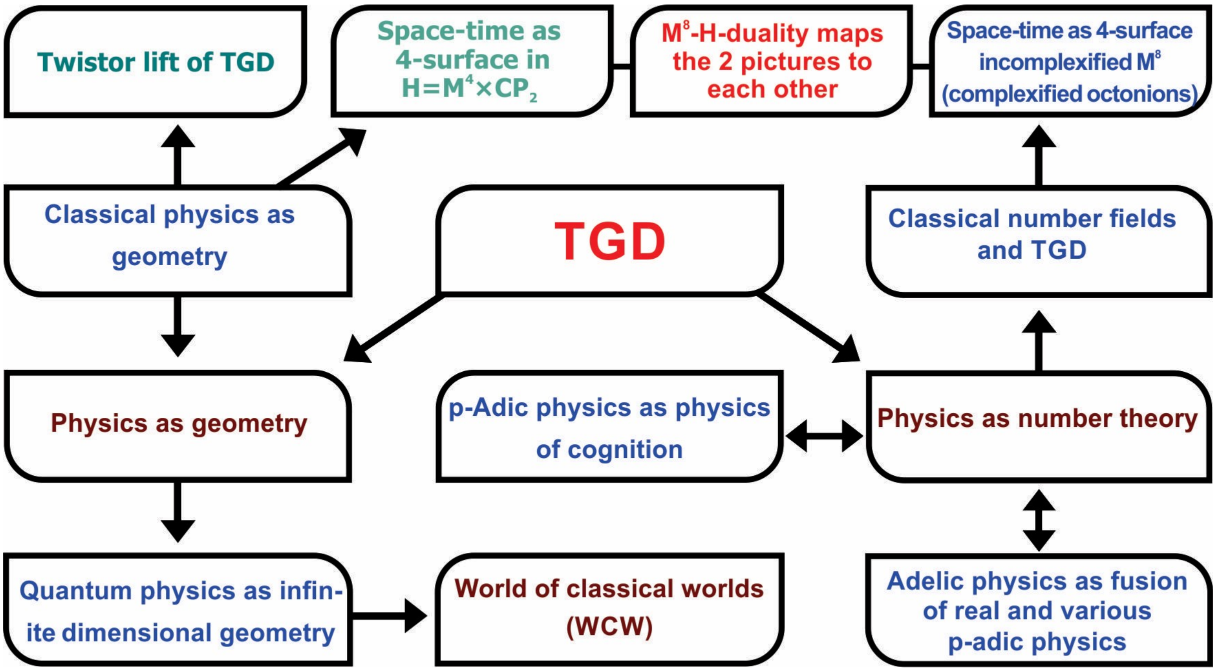

Figure 17.2: TGD is based on two complementary visions: physics as geometry and physics as number theory.

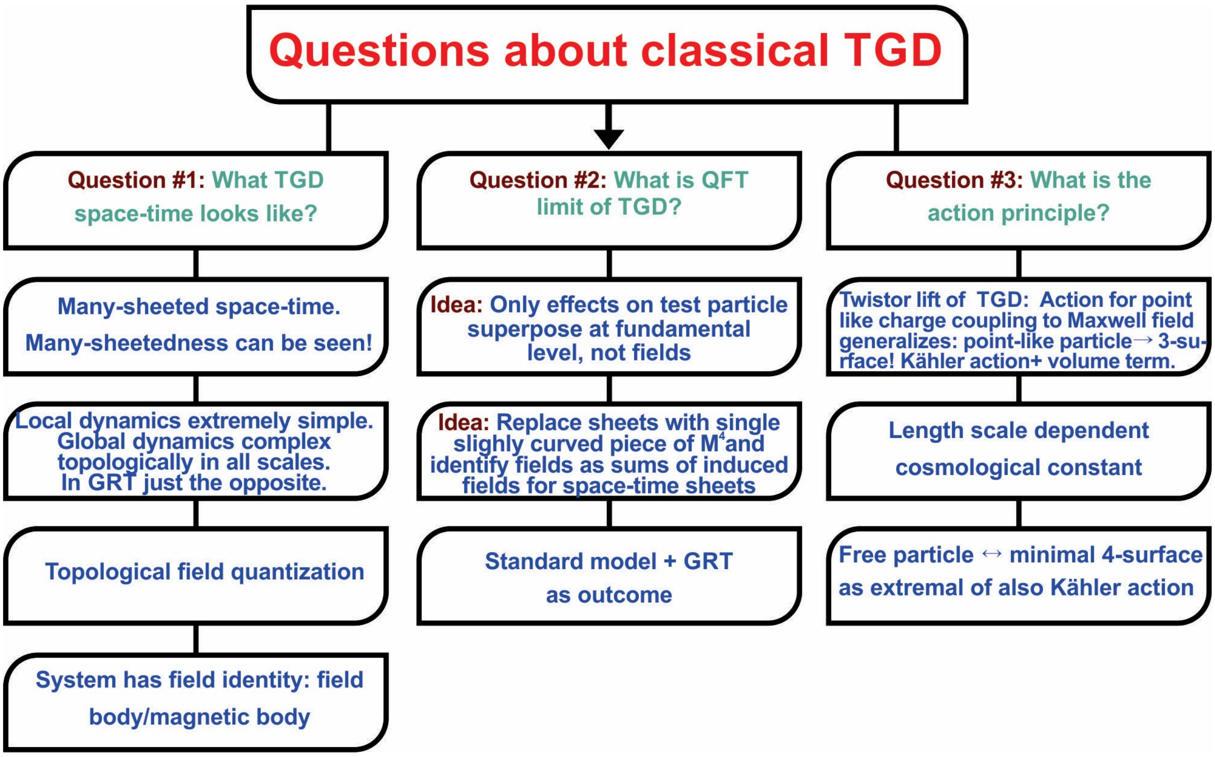

Figure 17.3: Questions about classical TGD.

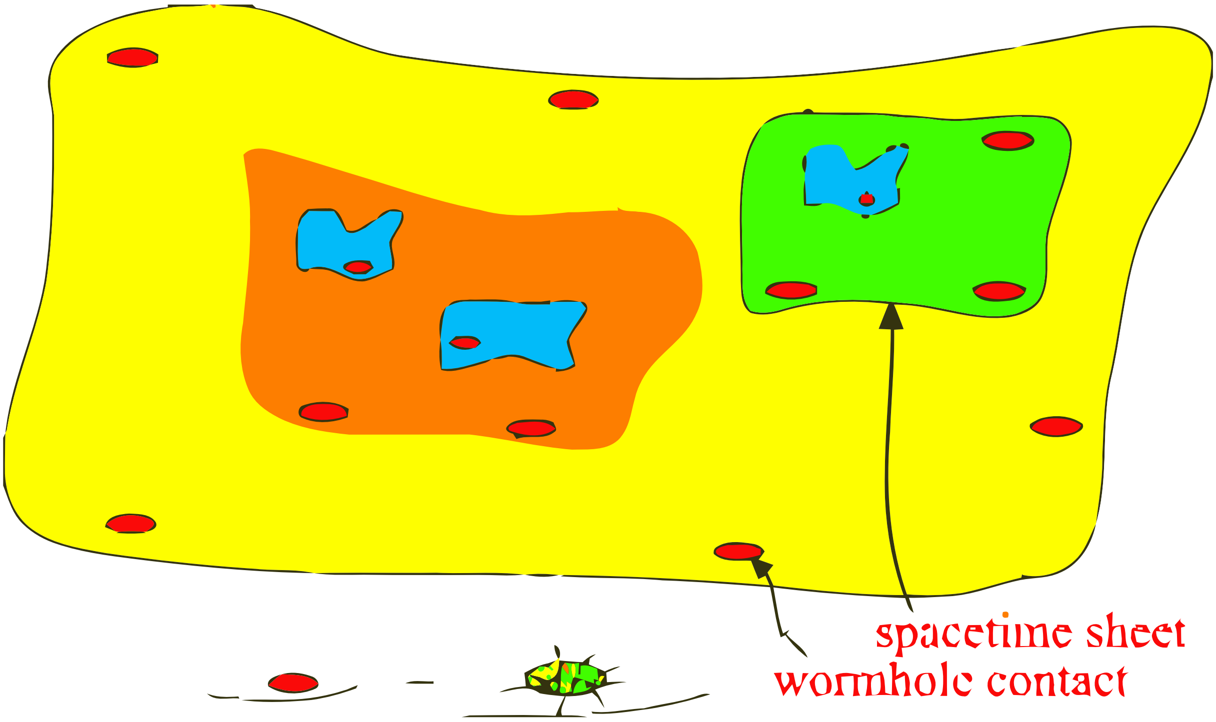

Figure 17.4: Many-sheeted space-time.

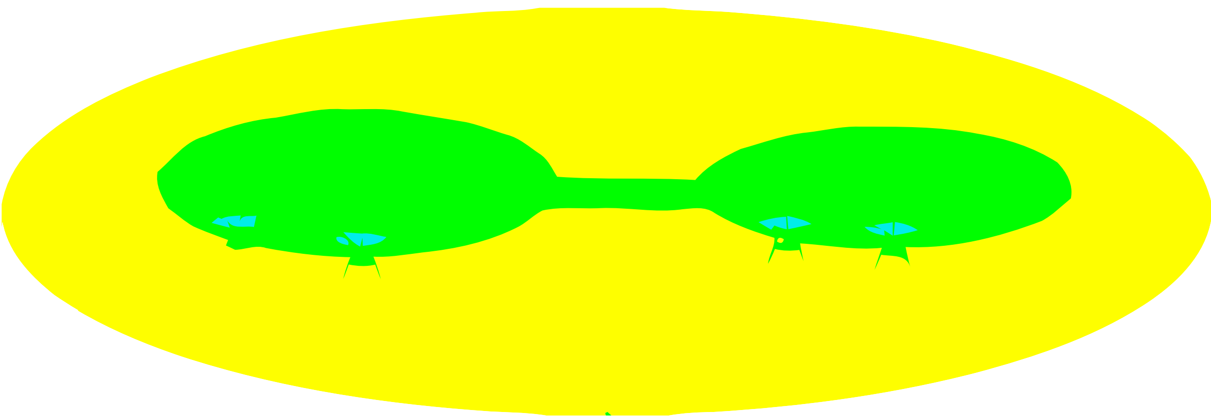

Figure 17.5: Wormhole contacts.

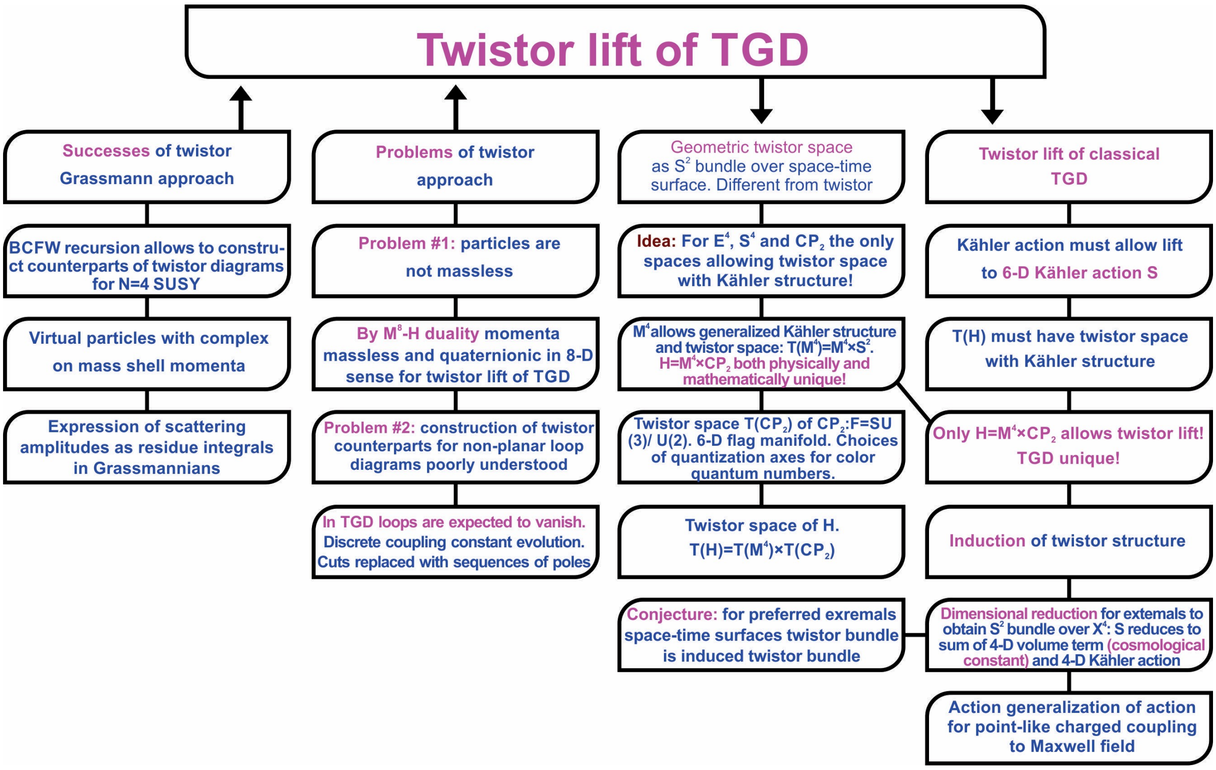

Figure 17.6: Twistor lift

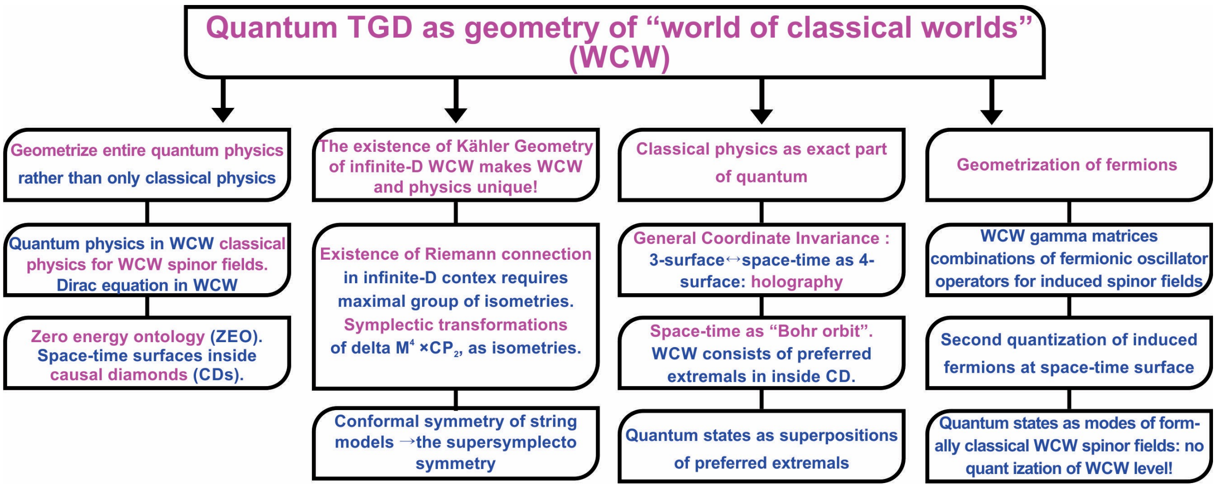

Figure 17.7: Geometrization of quantum physics in terms of WCW

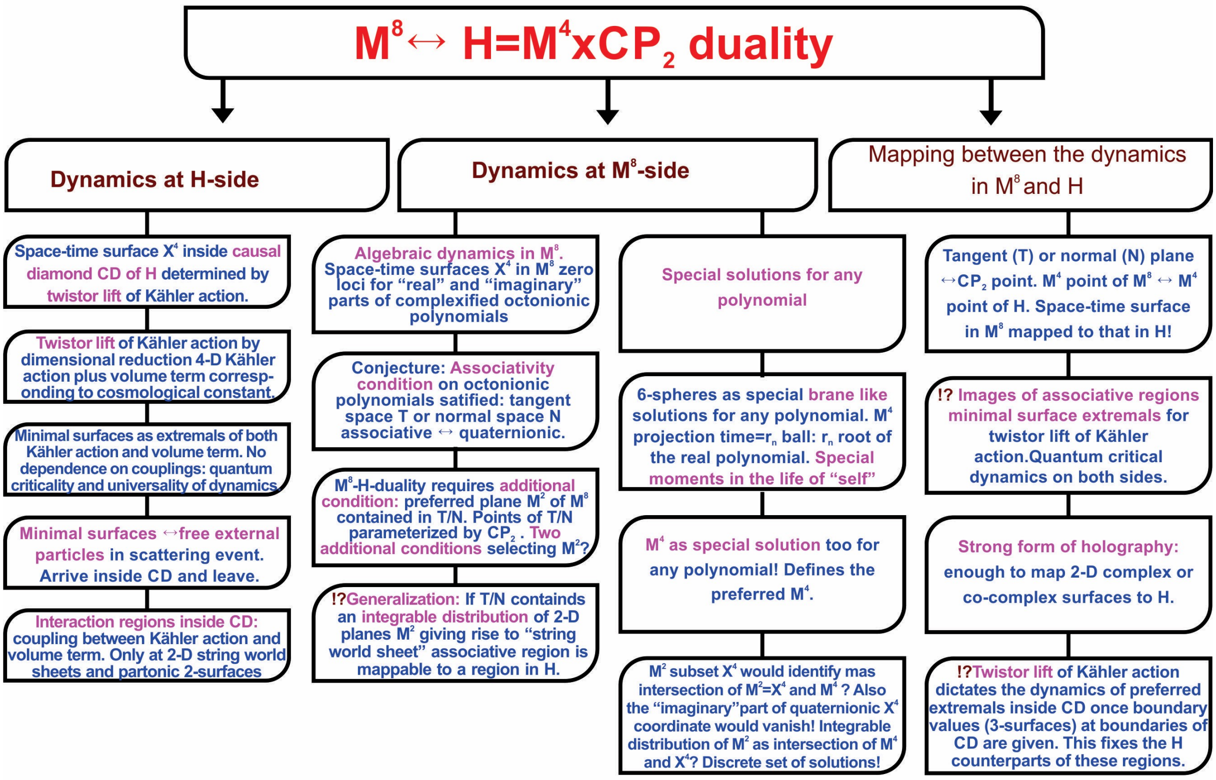

Figure 17.8: $M^8 - H$ duality

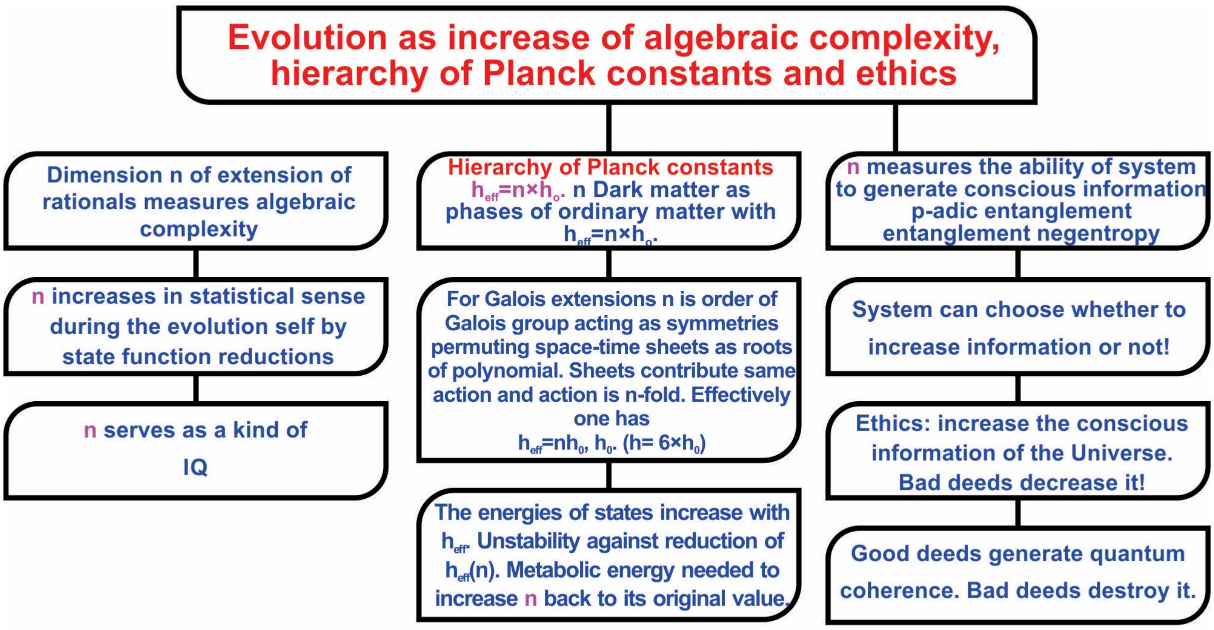

Figure 17.9: Number theoretic view of evolution

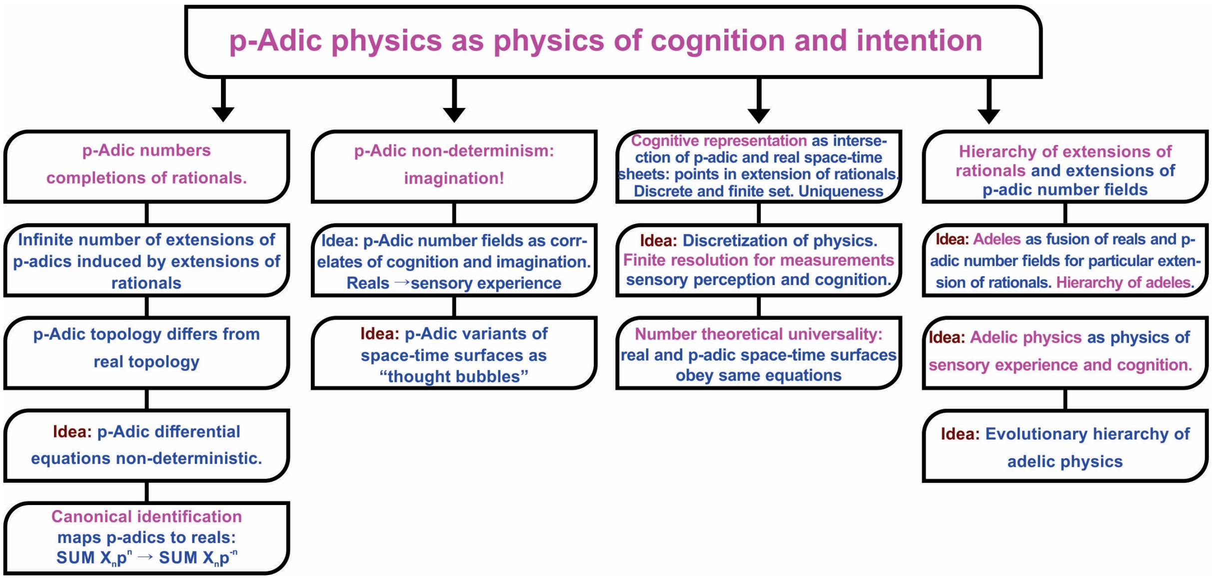

Figure 17.10: p-Adic physics as physics of cognition and imagination.

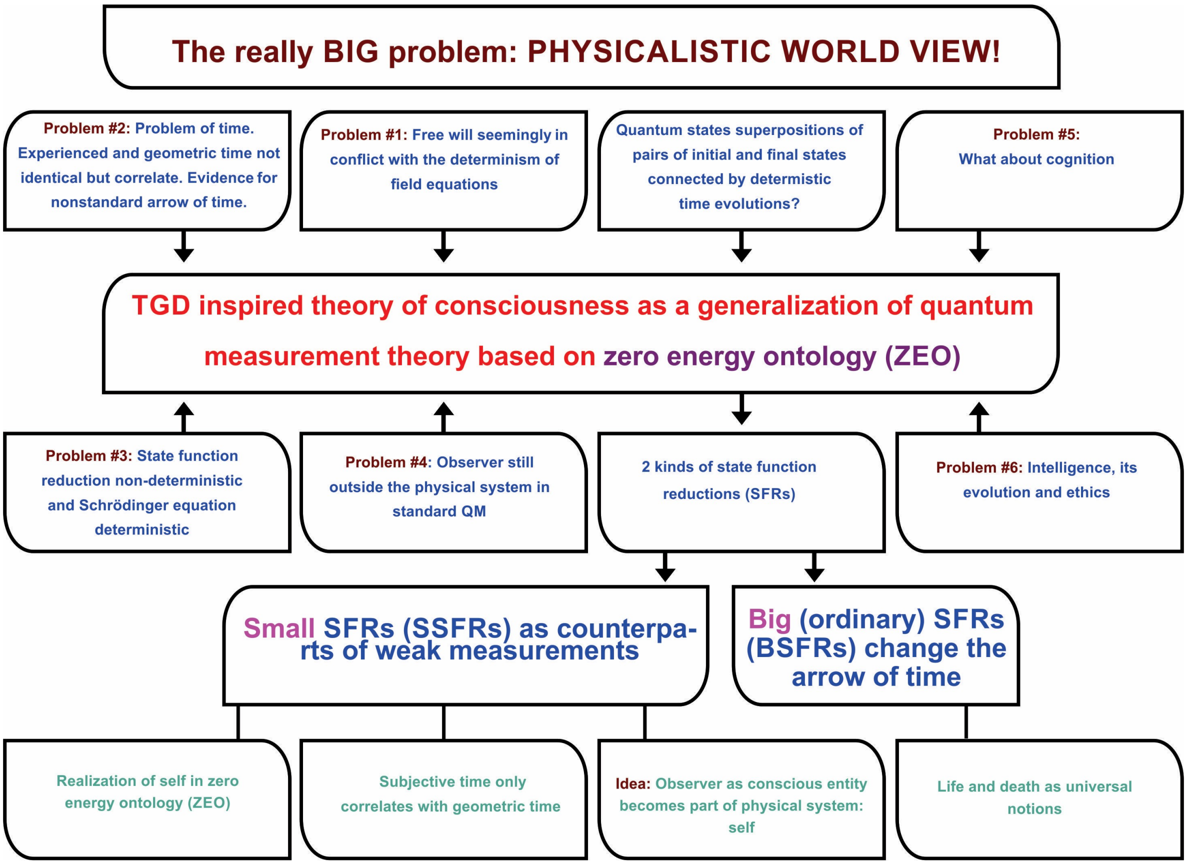

Figure 17.11: Consciousness theory from quantum measurement theory

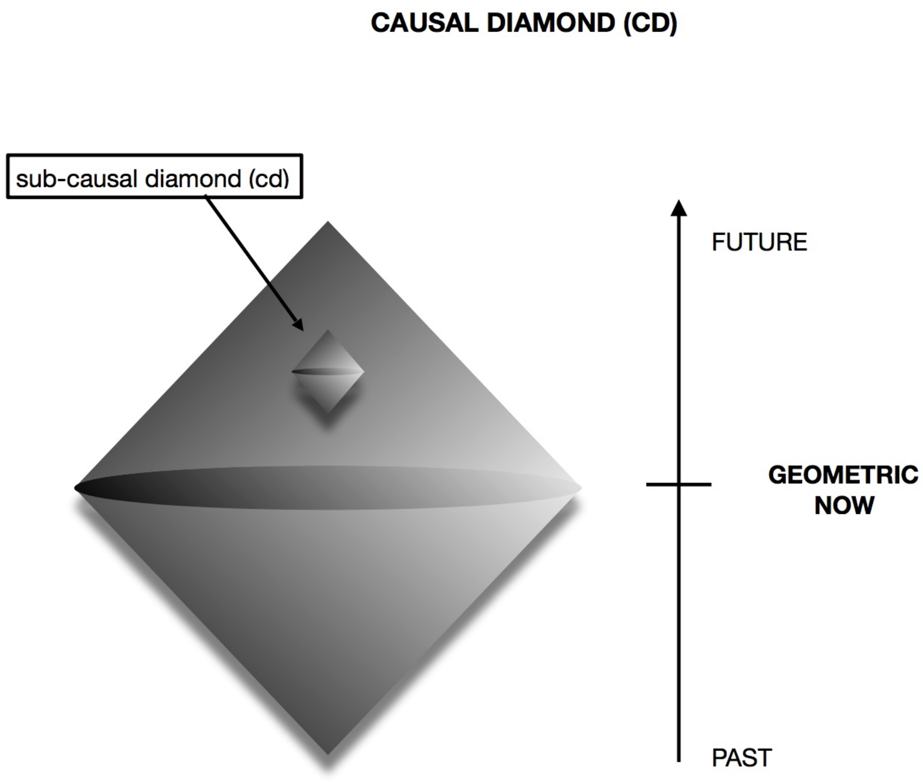

Figure 17.12: Causal diamond

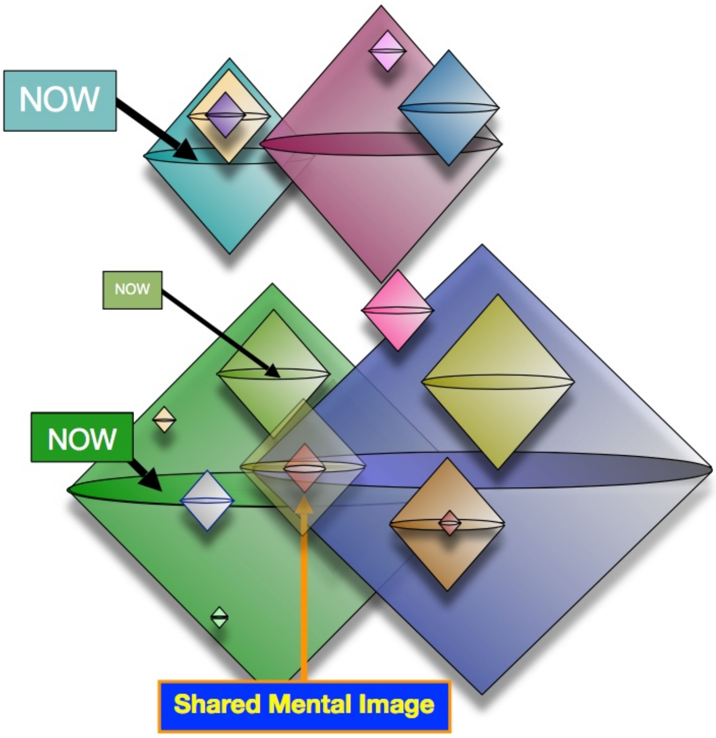

Figure 17.13: CDs define a fractal "conscious atlas"

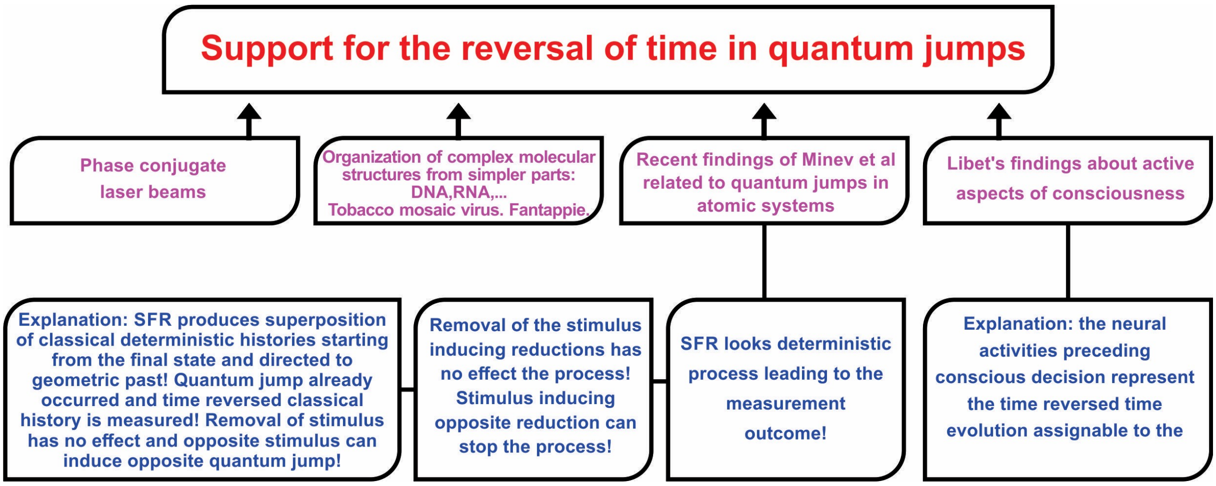

Figure 17.14: Time reversal occurs in BSFR

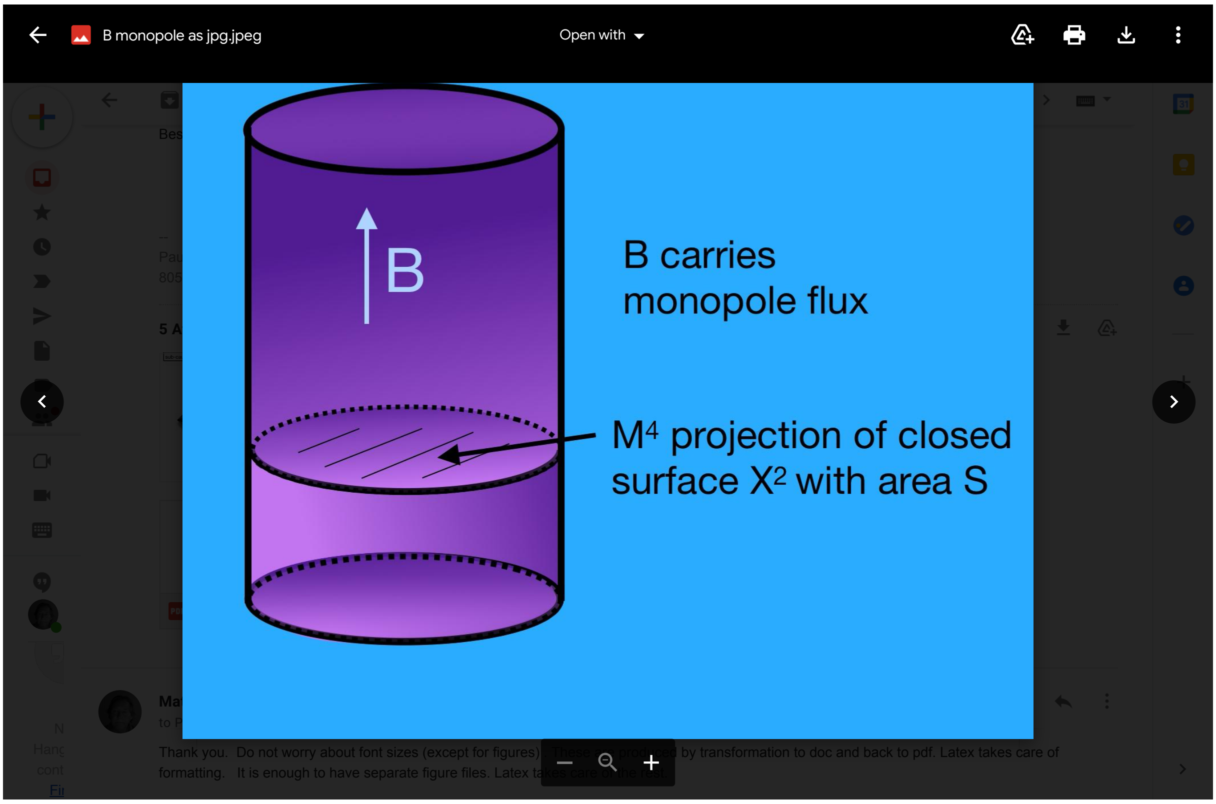

Figure 17.15: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e\oint B\cdot dS = eBS = kh$ at single sheet of n-sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

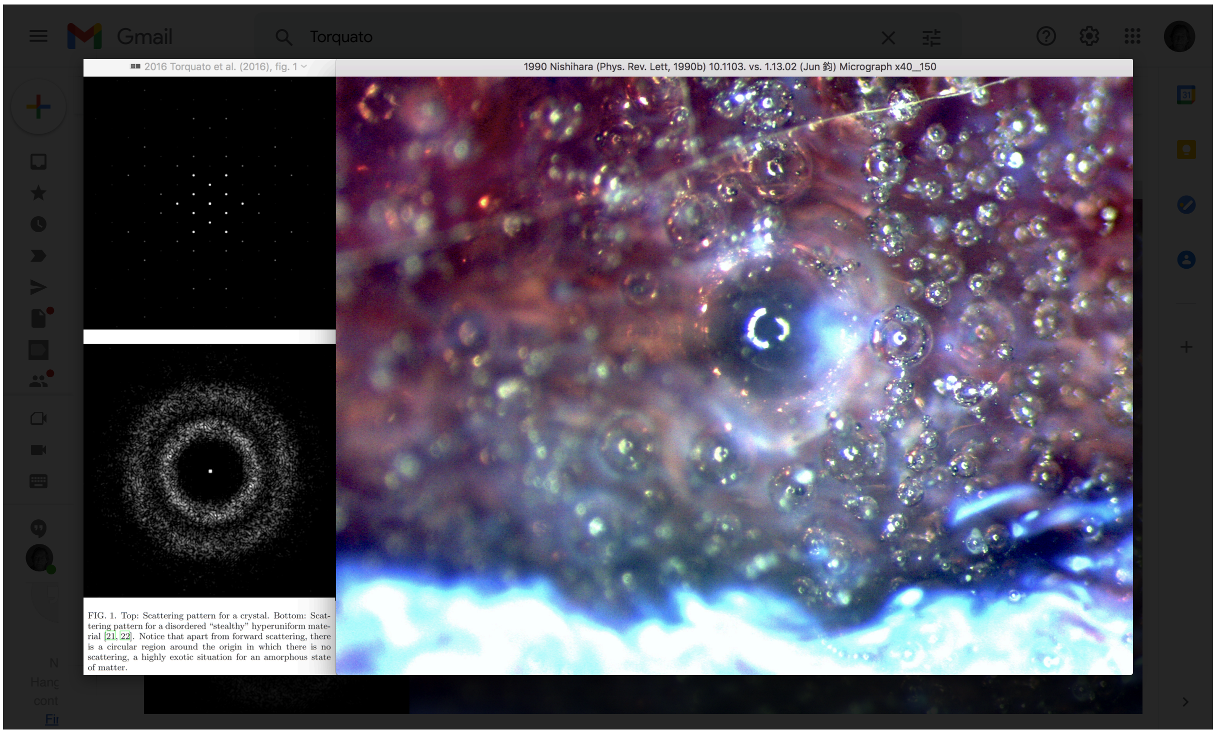

Figure 17.16: The scattering from a hyperuniform amorphous material shows no scattering in small angles apart from the forward peak (`https://cutt.ly/ZWyLgjk`). This is very untypical in amorphous matter and might reflect the diffraction pattern of dark photons at the magnetic body of the system.

Chapter 18

TGD and Quantum Hydrodynamics

18.1 Introduction

This work is devoted to the question of what quantum hydrodynamics could mean in the TGD framework. In the standard picture quantum hydrodynamics (`https://cutt.ly/JEAumRZ`) is obtained from the hydrodynamic interpretation of the Schrödinger equation. Bohm theory involves this interpretation.

1. Quantum hydrodynamics appears in TGD as an *exact* classical correlate of quantum theory [K7]. Modified Dirac equation forces as a consistency condition classical field equations for X^4. Actually, a TGD variant of the supersymmetry, which is very different from the standard SUSY, is in question.

2. TGD itself has the structure of hydrodynamics. Field equations for a single space-time sheet are conservation laws. Minimal surfaces as counterparts of massless fields emerge as solutions satisfying simultaneously analogs of Maxwell equations [L155]. Beltrami flow for classical Kähler field defines an integrable flow [L131]. There is no dissipation classically and this can be interpreted as a correlate for a quantum coherent phase.

3. Induced Kähler form J is the fundamental field variable. Classical em and Z^0 fields have it as a part. For $S^3 \subset CP_2$ em and Z^0 fields are proportional to J: which suggests large parity breaking effects. Hydrodynamic flow would naturally correspond to a generalized Beltrami flow and flow lines would integrate to a hydrodynamic flow.

4. The condition that Kähler magnetic field defines an integrable flow demands that one can define a coordinate along the flow line. This would suggest non-dissipating generalized Beltrami flows as a solution to the field equations and justifies the expectation that Einstein's equations are obtained at QFT limit.

5. If one assumes that a given conserved current defines an integrable flow, the current is a gradient. The strongest condition is that this is true for all conserved currents. The non-triviality of the first homotopy group could allow gradient flows at the fundamental level. The situation changes at the QFT limit.

6. Beltrami conditions make sense also for fermionic conserved currents as purely algebraic linear conditions stating that fermionic current is a gradient of some function bilear in oscillator operators. Whether they are actually implied by the classical Beltrami conditions, is an interesting question.

7. The requirement that modified Dirac operator at the level of space-time surface is in a well-defined sense a projection of the Dirac operator of H implies that for preferred extremals the isometry currents are proportional to projections of the corresponding Killing vectors with proportionality factor constant along the projections of their flow lines [L147]. This

implies as generalization of the energy conservation along flow lines of hydrodynamical flow ($\rho v^2/2 + p = constant$).

This also leads to a braiding type representations for isometry flows of H in theirs of their projections to the space-time surface and it seems that quantum groups emerge from these representations. Physical intuition suggests that only the Cartan algebra corresponding to commuting observables allows this representation so that the selection of quantization axes would select also space-time surface as a higher level state function reduction.

One also ends up to a generalization of Equivalence Principle stating that the charges assignable to "inertial" or "objective" representations of H isometries in WCW affecting space-time surfaces as analogs of particles are identical with the charges of "gravitational" or subjective representations which act inside space-time surfaces. This has also implications for $M^8 - H$ duality.

8. Minimal surfaces as analogs of solutions of massless field equations and their additional property of being extremals of Kähler action gives a very concrete connection with Maxwell's theory [L155].

In the sequel some key challenges of hydrodynamics are considered from TGD point of view.

1. The generation of turbulence is one of the main problems of classical hydrodynamics and TGD inspired quantum hydrodynamics suggests a solution to this problem. Not only "classical" is replaced with "quantum" but also quantum theory is generalized.

   The key notion is magnetic body (MB): MB carries dark matter as $h_{eff} = nh_0$ phases and controls the flow at the level of ordinary matter. Magnetic flux tubes would be associated with the vortices. The proposal inspired by super-fluidity is that velocity field is proportional to Kähler gauge potential and that the cores of vortices corresponds to monopole flux tubes whereas their exteriors would correspond to Lagrangian flux tubes with a vanishing Kähler field so that velocity field is gradient. Vorticity field would correspond to the Z_0 magnetic field so that a very close analogy with superconductivity emerges.

   The model is applied to several situations. The generation of turbulence and its decay in a flow near boundaries is discussed. ZEO suggests that the generation of turbulence could correspond to temporary time reversal associated with a macroscopic "big" (ordinary) state function reduction (BSFR).

   Also the connection with magnetohydrodynamics (MHD) is considered. The reconnection of the field lines is replaced with the reconnection of flux tubes. The fact that monopole flux tubes require no current to generate the magnetic field provides a new insight to the problem of how magnetic fields in astrophysical scales are generated.

   The topological picture based on flux tubes can be applied to the collisions of circular vortices. Also the violations of the circulation theorem of Kelvin is discussed.

2. Second section is devoted to hydrodynamic quantum analogs studied by Bush *et al* [D40]. These intriguing phenomena, in particular Couder walker bounces along a Faraday wave that it generates. Also surfing mode is possible. The energy feed comes from shaking the water pool and plays a role of metabolic energy feed leading to self-organization. This phenomenon allows in the TGD framework a modelling based on quantum gravitational hydrodynamics. MB serves as a "boss" and therefore takes the role of the pilot wave proposed by Bush. The key prediction that the Faraday wave length analogous to Compton wavelength equals to the gravitational Compton length $\Lambda_{gr} = GM/v_0$ is correct.

3. Also the electromagnetic and Z^0 analogs of $\hbar_{gr}$ make sense and one can ask whether in these scales the gravitational, Z^0 and electromagnetic Compton lengths are identical at gravitational flux tubes and that particles are at flux tubes with length of order this wavelength.

   The twistor lift predicts that also M^4 has Kähler structure and M^4 Kähler form could give contribution to electromagnetic and Z^0 fields. Kähler currents for M^4 and CP_2 parts are separately conserved and this leads to ask whether Magnus forces resembling Lorentz force could reflect the presence of classical Z^0 force or M^4 contribution to the Kähler force.

4. One section is devoted to the attempt to understand the origin of viscosity and interpret critical Reynolds numbers in the TGD framework. In TGD quantum gravitation involves quantum coherence in astrophysical scales so that it is not totally surprising that the critical Reynolds numbers associated with the turbulence in pipe flow and flow past a plate relate directly to the gravitational Compton lengths of Earth and Sun. In the case of Sun $\hbar_{gr}$ involves two values of the velocity parameter β_0 appearing in the Nottale formula. This would suggests that the turbulence has very little to do with ordinary viscosity. Also a model for the ordinary viscosity and its increase with a decreasing temperature is discussed.

5. Also nuclear and hadron physics suggests applications for QHD. The basic vision about what happens in high energy nuclear and hadron collisions is that two BSFRs ("big" state function reductions changing the arrow of time) take place. The first BSFR creates the intermediate state with $h_{eff} > h$: the entire system formed by colliding systems need not be in this state. In nuclear physics this state corresponds to a dark nucleus which decays in the next BSFR to ordinary nuclei. The basic notions are the notion of dark matter at MB and ZEO, in particular the change of the arrow of time in BSFR.

6. Some comments about quantum hydrodynamics for condensates of quasiparticles are represented.

18.2 TGD view about quantum hydrodynamics

In this section the general ideas of quantum hydrodynamics in TGD framework are introduced.

18.2.1 Some problems of the existing theories of turbulence

Hydrodynamical turbulence represents one of the unsolved problems of classical physics and therefore as an excellent test bench for the TGD based vision.

Turbulence is generated in many other systems besides hydrodynamical flow. Exotic systems consisting of quasiparticles of a condensed matter system (supra phases, atomic BECs, exciton-polariton BECs, magnon BECs, etc...) involve generation of vortices as the basic element of turbulence. Turbulence appears also in astrophysical systems such as neutron stars. All this suggests the generation of vortices as a universal mechanism in the generation of turbulence.

The understanding of the generation of turbulence is usually regarded as a problem of classical physics. TGD however predicts quantum coherence in all scales so that this assumption must be challenged. Both the new view about space-time and of classical fields (the notion of magnetic body (MB), the hierarchy of effective Planck constants predicting the possibility of quantum coherence in all scales, and the zero energy ontology (ZEO) predicting time reversal in ordinary ("big") state function reductions (BSFRs) could be involved. Even quantum physics in its recent form would not be enough to understand the generation of turbulence.

18.2.2 The problems of the existing theories of turbulence

The best starting point is to look for the problems of the existing theories. The many problems of the classical theories of turbulence are described in the article of Chaoqun Liu and Shuhyi Chen [D28] (`https://cutt.ly/xWMiMV3`). As the authors notice, a single wrong prediction in principle kills theory but the theories of turbulence make numerous wrong predictions. Also a general vision of Liu based on empirical facts is discussed.

The phase transition leading to turbulence involves a generation of vortices.

1. Vortex consists of a core region, where the flow has non-vanishing vorticity $\nabla \times v$ and an outer region, where the rotational flow is gradient flow and characterized by a conserved circulation. The gradient flow outside the core is a special case of a Beltrami flow: there is current conservation besides the existence of a global coordinate along the flow lines.

   Rigid body motion with a constant angular velocity is a reasonable approximation allowing to avoid singularity (infinite rotational velocity at the axis of the vortex).

There are many vortex anatomies. The ends of hair-pin vortices are attached to the boundary and they tend to move with the flow. Λ vortices deserve their name from their shape. There are also circular vortices.

2. No-slippage boundary condition (velocity vanishes at the boundary) for a flow past a body or other medium forces a transversal gradient of the velocity, which is parallel to the boundary and this generates vorticity $\nabla \times v \neq 0$.

   The flow past a body with an over-critical Reynolds number R leads to a generation of vortices. Vortices are coherent structures and clearly separate units and one cannot superpose them as one can superpose eddes. Hairpin vortices are the simplest vortices (`https://cutt.ly/nWMiHrJ`). It would seem that Nature tends to avoid too large shears (velocity gradients) implying large dissipation and achieves this by generating vortices.

3. This mechanism can be used to generate vortex rings so that one can study the collisions of vortex rings demonstrating the basically topological dynamics of vortices (see the beautiful video at `https://cutt.ly/DWMiK3f`). The thesis of Ali Dasouqi [D23] (`https://cutt.ly/aWMiXWt`) gives an overall view about the formation of gas jets and vortex rings in various situations. In particular, collisions of vortex rings and the formation of vortex rings in the bursting of bubbles are discussed.

4. The proposal of Chaoqun Liu [D28] (`https://cutt.ly/kWMiVbj`) is that the vorticity near the boundary is transferred to the vorticity of the vortex cores. A separation of the flow from the boundary seems to take place. This allows it to avoid large shears and minimize dissipation.

   The generation of turbulence could be regarded as a self-organization process made possible by the energy feed from the flow and not a dissipative process.

5. Turbulence as the decay of vortices is a dissipative process - in a well-defined sense it looks like a reversal of the self-organization process.

   The proposal of Kolmogorov is that the decay of turbulence involves the decay of vortices to smaller ones. The authors argue that this process has not been observed for a single vortex. Presumably it is meant that a linear vortex tube should split into thinner parallel parallel flux tubes. In principle there is no obvious reason why conservation of circulation would prevent this process but this process is highly non-local and does not look plausible.

   It is however possible that a single vortex reconnects and emits a closed vortex ring. This has been observed in the collisions of two vortex rings. The decay process can also involve the reconnection of two vortices as happens in the collision of two vortex rings. This can lead to the decay of larger vortices to smaller vortices such as vortex rings and eventually to so small vortices that they are below measurement resolution.

18.2.3 Superflow as a starting point

TGD predicts quantum coherence at MB in arbitrarily long length scales. Hence one can motivate the TGD based model by starting from an observation related to the notion of conserved vorticity and its quantization in superfluid flow.

1. For supra flows the conserved vorticity $\Gamma = \oint v \cdot dl$ as integral over a closed flux line associated around the vortex axis in vorticity free region, is quantized as a multiple of $\hbar/m$, where m is the mass of the particle of flow.

2. A possible quantum interpretation could be in terms of a covariant constancy of the Schrödinger amplitude or of spinor field stating $(p_t - qA_t)\Psi = 0$ along flow lines. Here A_t is a projection of an effective $U(1)$ gauge potential, not necessarily electromagnetic.

   The condition $p = mv_t = qA_t$ effectively, where v_t is well-defined for a generalized Beltrami flow as a classical space-time counterpart of quantum coherence, could hold true as a classical correlate of the covariant constancy condition.

The velocity projection $v_t = A_t/m$ would be proportional to a component of an effective $U(1)$ gauge potential quite generally along flow lines of Beltrami flows and their 4-D time dependent generalizations applicable to non-stationary flows.

3. $B = dA$ would define an effective $U(1)$ magnetic field and could be assigned to any flow. For a gradient flow, one would have $B = dA = 0$ and B would be non-vanishing only inside the vortex core. By Stokes theorem the circulation $\oint v \cdot dl$ would reduce to a conserved magnetic flux $\int BdA$ over the cross section of the vortex core.

   The quantization of the velocity circulation $\oint p \cdot dl = \oint v \circ dl = n\hbar$ is obtained from flux quantization $exp(iq \oint Adl/\hbar) = exp(i \oint d\Phi) = 1$ required by the existence of proper gauge structure. Apart from a gradient $\nabla\psi$ of a single valued function Φ is a multiple of angular coordinate ϕ changing by $n2\pi$ in 2π rotation.

4. It is important to notice that one cannot have a genuine gauge invariance. The gauge transform $A \rightarrow A + d\phi$ gives a new flow with the same circulation. Therefore the identification of A as a standard model gauge field, say U(1) part of the em field does not make sense in the standard model framework but could be sensible in TGD.

5. In Maxwellian electrodynamics B should have some current j as a source: $\nabla \times B = j$, which gives $D^2A \equiv \nabla^2 A - \nabla(\nabla \cdot A) = j$.

   The simplest assumption is that B is constant inside the core and in the direction of the vortex, and can be therefore generated by a current rotating around the vortex axis at the surface of the core. The current would be parallel to A. Vortex core would act like a current coil. The vector potential is effectively massive at the surface of the core since D^2A is proportional to A: mass is formally infinite due to delta-function singularity. This is analogous to the "massivation" of the electromagnetic field in superconductivity for the vortex core inside which the super-conductivity fails.

6. The situation would be essentially quantum mechanical. If the commutator of covariant derivatives $D_i = p_i - qA_i$ given by $[D_i, D_j] = qJ_{ij} = q(\partial_i A_j - \partial_j A_i)$, is non-vanishing, spinors can be eigenstates of only a linear combination D_i, which acts along the flow lines of the integrable Beltrami flow. The classical condition $v_i = qA_i/m$ makes sense only for these components of velocity and about the other components one cannot say anything unless J vanishes or is degenerate. If J vanishes or is degenerate, one can say that some other components of the velocity vanish. This means genuine quantum hydrodynamics. One could perhaps say that $J = 0$ corresponds to classical hydrodynamics.

18.2.4 Is velocity field proportional to Kähler gauge potential of M^4, of CP_2 or to the sum of both?

The assumption that velocity field is proportional to Kähler gauge potential implies that it is gradient for the Lagrangian situation prevailing outside the vortex cores.

Cores would have non-vanishing Kähler field and Kähler action. What about the Beltrami property in the vortex core? If the CP_2 projection of the vortex core is 2-D complex surface, $A(CP_2)$ is Beltrami field. For instance, for a projection with is geodesic sphere S^2, the Kähler gauge potential is proportional to $A = cos(\Theta)d\Phi$ in the spherical coordinates and Φ defines the global coordinate along flow lines. $D > 2$-D deformations spoil the Beltrami property. Similar situation is true for the M^4 projection: when the projection as a string world sheet is deformed to a $D > 2$-dimensional surface, the Beltrami property of $A(M^4)$ is lost.

It took some time to realize that the velocity field, and in the compressible case generally mass current, could be proportional

1. to the Kähler gauge potential $A(M^4)$ of M^4,
2. to the Kähler gauge potentia $A(CP_2)$ of CP_2,
3. or to the sum $A(M^4) + (CP_2)$, which at first looks natural if Kähler covariant constancy along flow lines is the basic condition.

These options lead to dramatically different physical pictures, especially so for incompressible flows.

1. For option 1 *resp.* 2, Beltrami or gradient flow in M^4 *resp.* CP_2 is enough. Furthermore, if the velocity field is proportional to $A(M^4)$, there is no need to assume large h_{eff} implying that Z^0 field is massless below scaled up weak length scale and electroweak symmetry breaking is absent in long scales.

2. For option 3, the assumption that both M^4 and CP_2 projections are at most 2-D is a necessary condition and looks unrealistic. But this is not enough for Beltrami or gradient flow. These conditions alone would give a Kähler gauge potential, which is the sum $A(M^4)+A(CP_2)$ of two contributions $A(M^4) = \Psi_1 d\Phi_1$ and $A(CP_2) = \Psi_2 d\Phi_2$ satisfying the conditions separately.

   Besides this, the gradients $d\Psi_1$ and $d\Psi_2$ must be proportional to each other so that Ψ_1 and Ψ_2 are functionally dependent. This however implies that the space-time surface is actually 3-dimensional: the conditions can hold only for effectively 2-D flows at surfaces.

   For incompressible flow velocity and mass flow are proportional and this leads to the unrealistically strong conditions. For incompressible flow the situation changes. If the mass current is proportional to the sum of Z^0 currents of nucleons and neutrinos with same density guaranteeing local neutralization and having velocities proportional to each other, Beltrami/gradient property is possible. One would obtain essentially neutral Z^0 plasma formed by nucleons and neutrinos.

   A possible objection is that the required density of neutrinos is too large as compared to their estimated average density of 10^{-22} Angstrom^{-3}. However, the average density of nuclei is equivalent to nucleon density of 5×10^{-30} Angstrom^{-3}.

   Could one give up the assumption of incompressibility and require that the flow lines of the mass current are globally defined and the mass flow is proportional to Kähler current containing separately conserved contributions from M^4 and CP_2? The mass flow would vanish if both M^4 and CP_2 contributions are Lagrangian. This leaves only $A(M^4)$ and $A(CP_2)$ options.

How does this relate to dissipation? The first naive guess was that the classical dissipation is present if Beltrami property fails? One must however look at the situation more carefully.

1. It is is Kähler current, not Kähler gauge potential, which is proposed to have the generalized Beltrami property guaranteeing that the Kähler 4-force vanishes so that ordinary Lorentz forces and electric force compensate each other and there is no power consumption.

2. This condition does not require the strong conditions posed on the velocity field and Kähler gauge potential. The two conditions are equivalent only if Kähler gauge potential is proportional to current which would be analogous to the massivation of Kähler field. For instance, Kähler current can be vanishing although Kähler gauge potential is non-vanishing.

3. Whether the dissipative option is realized at all for preferred extremals is not at all clear. Dissipative effects might be solely due to the finite sizes of space-time surfaces, which are proportional to h_{eff}. What is however clear is that the loss of Beltrami property for the velocity field does not imply dissipation.

18.2.5 Could the velocity field be proportional to Kähler gauge potential of CP_2?

What could be the counterpart of the vector potential A in the TGD framework? It was found that there are 3 options corresponding to the proportionality of the velocity field v to $A(M^4)$, $A(CP_2)$ or $A(M^4) + A(CP_2)$. In this section only the option $A(CP_2)$ is considered.

1. A natural identification of A would be as Kähler gauge potential for CP_2. The symplectic transformations of CP_2 act like $U(1)$ gauge transformations and are isometries of WCW but

do not (can not) leave Kähler action invariant since the induced metric changes. One can say that classical gravitation breaks the genuine gauge symmetry but the breaking is very small.

Note in particular that both induced electromagnetic and Z^0 fields can be non-vanishing even if the Kähler form vanishes.

At the level of fluid flows this means that addition of global gradient to the velocity field indeed gives a new flow but leaves the topology of the flow invariant. Preferred extremal property however restricts strongly the allowed symplectic transformations: one possibility is that they must act as Galois transformations in the cognitive representation so that the Galois images of the space-time surface would be identical in the measurement resolution defined by the cognitive representation. Note that the zero modes characterized by induced Kähler form and not contributing to Kähler metric of WCW remain invariant.

2. Single space-time sheet is certainly not a realistic approximation for a physical situation, and one has actually many-sheeted space-time. Standard model and general relativity would be obtained as an approximation as one replaces the space-time sheets with a single region of M^4 and identifies standard model gauge potentials with the sum over the induced gauge potentials for the space-time sheets. Same applies to the induced metric. This conforms with the idea that a small test particle of CP_2 size necessarily touches all space-time sheets and experiences the sum of the forces.

   If one assumes that various sheets in the experimental situations considered correspond to the same induced Kähler form J defining a symplectic invariant, i.e. have same values of zero modes, then the sum of the induced Kähler forms is a multiple of Kähler form since the sum of global gradients give no contribution: there would be no destructive interference. Both em and Z^0 gauge fields contain a part proportional to J.

What about the contributions from $SU(2)_L$ and $U(1)_R$ parts of the induced gauge fields to the sum [L2]. For the induced W boson fields the contributions are affected by symplectic transformations and the physics inspired guess is that they sum up to zero. This would conform with the short range of the charged weak fields. Note however that the dark weak scale is proportional to h_{eff} and p-adic length scales longer than weak scale in standard model can be considered, in particular in biological systems [K59].

What about the contributions to induced em and Z^0 fields?

1. Conserved vector current hypothesis is the starting point of the standard model. Induced em field γ is sum of $U(1)$ part proportional to J and part proportional to vectorial isospin generator Σ_{12}. Both contributions must be non-vanishing. Z^0 contributions should sum up to zero (note that Z^0 contains both left-handed and vectorial contributions).

2. Using the formulas of [L2], one can express the neutral part F_{nc} of the induced electroweak gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \tag{18.2.1}$$

   $n_+ = 1$ and $n_- = 3$ refer to quark and lepton chiralities: both were assumed to be present in the original view about fermions. If only quarks are fundamental spinors [L106, L130], one must drop the $n+ = 3$ contribution. Leptons as composites of 3 antiquarks however effectively behave like opposite H-chirality.

3. The axial part R_{03}, vectorial part R_{12} and $U(1)$ part are

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{18.2.2}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - pQ_{em}) \quad p = sin^2(\theta_W) \ . \tag{18.2.3}$$

4. Here θ_W is Weinberg angle. Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - pR_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{18.2.4}$$

Note that for $p = sin^2(\theta_W) = 0$ one has $\gamma = 3J$ and Z^0 has purely left handed coupling.

What condition should one pose on Z^0 and γ magnetic fields at the monopole flux tubes in hydrodynamics?

1. If one assumes that there are practically no parity breaking effects in long length scales as the standard model predicts, $\sum Z^0 = 0$ looks natural but implies that $\sum_\gamma$ is non-vanishing. Since no em currents are needed to generate the monopole magnetic field this might make sense.

2. $\sum_\gamma = 0$ looks however more natural and implies $\sum_{sheets} Z^0 \neq 0$. Also now one can argue that this makes sense since no currents carrying Z^0 charges are needed to generate Z^0 magnetic monopole fields. This would imply parity violation, which should be observable for vortices. In biology the chirality selection for the basic biomolecules is assumed to be induced by magnetic flux tubes.

This inspires the question whether ordinary hydrodynamics could be magnetohydrodynamics (MHD) for Z^0 magnetic fields at monopole flux tubes and whether MHD in the usual sense could be HD replacing Z^0 fields with ordinary magnetic fields. This question was also motivated a nice lecture about MHD of Alexander Schekochihin (`https://cutt.ly/RW24bTN`) suggesting that the generation of MHD is very similar to the generation of hydrodynamic turbulence in the TGD picture.

Could the basic difference between HD and MHD be that plasma flow replaces mass flow and Z^0 monopole flux tubes are replaced by electromagnetic monopole flux tubes? One can also consider the possibility that both kinds of flux tubes are present in MHD in the usual sense.

With this question in mind, one can consider the condition for the vanishing of $\sum Z^0$ and $\sum \gamma = 0$ at monopole flux tubes. It is important to notice that the induced Kähler form is given by $\sum(J_{M^4} + J_{CP_2})$ and weak fields receive contributions only from CP_2.

1. The condition $\sum Z^0 = 0$ perhaps relevant to MHD implies

$$\textstyle\sum_{sheets} 2(2Y + X) = 0 \ , \quad Y = e^0 \wedge e^3 \ , \quad X = e^1 \wedge e^2 \ . \tag{18.2.5}$$

There is no obvious reason for why this should be the case automatically.

This would give

$$\sum_{sheets} e^1 \wedge e^2 = \sum_{sheets} J_{CP_2} \ . \tag{18.2.6}$$

This implies

$$\begin{aligned} &\sum_{sheets} e^1 \wedge e^2 = \sum_{sheets} J_{CP_2} \ , \\ &\sum_{sheets} R_{12} = \sum_{sheets} 3J_{CP_2} \ , \\ &\sum_{sheets} \gamma = \sum_{sheets} 3(1-p))J_{CP_2} + 3JM^4 \ . \end{aligned} \tag{18.2.7}$$

The vanishing of $\sum J_{CP_2}$ (Lagrangian surface in CP_2) implies $\sum Z^0 = 0$ and $\sum \gamma = 3J_{M^4}$.

2. The condition $\sum \gamma = 0$ perhaps relevant for ordinary hydrodynamics can be treated in a similar manner. One obtains

   This gives

$$\sum_{sheets} 2(2X+Y) = 0 \ . \tag{18.2.8}$$

   From this one obtains

$$\begin{array}{lll} \sum_{sheets} X = -aY - bJ_{M^4} \ , & a = -\frac{3-p}{3-2p} \ , & b = -\frac{3}{2(3-2p)} \ . \\ J_{CP_2} = 2(cY + dJ_{M^4}) & c = -\frac{2p}{6-4p} - \frac{6}{6-4p} \ . & \end{array} \tag{18.2.9}$$

   From the latter equation one can solve Y in terms of J_{CP_2} but at the limit $p=0$, Y diverges unless one has $J = J_{CP_2} + J_{M^4} = 0$. For $p=0, J=0, \gamma=0$ case, one has

$$Z^0 = 2(-Y - J_{M^4}) = 2(-Y + J_{CP_2}) \ . \tag{18.2.10}$$

   If this case corresponds to a Lagrange manifold of CP_2 it also corresponds to Lagrange manifold of M^4. This case might be interesting from the hydrodynamics point of view.

   The $\gamma = 0$ condition quite generally implies parity violation and an interesting question is whether the large parity violation in living matter could be due to the long range classical Z^0 field. Could parity violation be present at MB and become chemically visible via the chiral molecules assignable to the helical monopole flux tubes serving as the templates for the formation of these molecules?

3. One can also argue that the sum vanishes for the part of $R_{03} = 2(2e^0 \wedge e^3 + e^1 \wedge e^2)$ orthogonal to J since it is not a symplectic invariant. The natural inner product is the one in which $e^0 \wedge e^3$ and $e^1 \wedge e^2$ are orthogonal and have norm $1/N = 1/8$ implying $(J,J) = 8/N = 1$. This would give $\sum Z^0 = \sum R_{03} = \sum R_{12} = (3/2) \sum J_{CP_2}$ and $\sum \gamma = 3(1-p/2) \sum J_{CP_2} + 3J_{M^4}$. This would imply parity violation. Could this condition be relevant for MHD?

4. If one poses only the condition $\sum J_{CP_2} = 0$, both $\sum Z^0$ and $\sum \gamma$ are non-vanishing , and one has $\sum \gamma = -p \sum Z^0 + 3J_{M^4}$. Magnetohydrodynamics could correspond to this situation but does $\sum \gamma \neq 0$ make any sense in hydrodynamics?

   Could the value of Weinberg angle in hydrodynamical scales differ from its value in particle physics? For $p=0$ Z^0 would be massless like γ suggesting that electroweak symmetry breaking is absent. For Lagrangian flux tubes $\sum Z^0$ would be non-vanishing and $\sum \gamma$ could vanish as one might expect.

   Large value of h_{eff} means scaling up of the weak scale and the proposal has been that in living matter the weak scale can be as large as the cell scale. This would be allowed if one has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. The expectation is that below the scaled-up weak scale weak bosons are massless, electroweak symmetry is not broken, and $p=0$ holds true.

It must be however emphasized that the identification as v in terms of $A(M^4)$ or $A(M^4) + A(CP_2)$ can be also considered.

18.2.6 Description in terms of monopole- and non-monopole flux tubes

In a condensed matter system the classical em field and weak fields should vanish in long length scales.

Kähler gauge potential is not associated with gauge invariance

In many-sheeted space-time, the standard model counterpart of em field is in the above model proportional to J so that the space-time surfaces in question should have at most 2-D Lagrangian manifold as CP_2 projection with the property that induced J vanishes. Kähler action would vanish and the space-time surface would be a minimal surface.

What is of central importance, is that $J = 0$ does not imply the vanishing of the induced Kähler gauge potential A. Since one does not have a genuine $U(1)$ gauge invariance, the situations corresponding to different Kähler potentials are physically different and correspond to space-time surfaces related by symplectic transformation and also to different hydrodynamical flows. Not all symplectic transformations are possible since symplectic transformations are not volume preserving.

Kähler magnetic structure of the vortices

Outside the core regions, A would be a gradient field but inside the core region J would be non-vanishing. The notion of many-sheeted space-time suggests a description in terms of two kinds of cosmic strings and their deformations giving rise to flux tubes is highly suggestive. Both cosmic strings are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is a minimal surface. M^4 projection is 2-D but for the flux tubes as deformations it becomes at least 3-dimensional.

1. For the first option Y^2 is a complex submanifold of CP_2 and the cosmic string carries a monopole flux (see glossary at 18.8.2 and **Fig. ??**) . Homologically non-trivial geodesic sphere represents the simplest example. Monopole flux tubes distinguish TGD from Maxwell's theory and for instance explain why the magnetic field of Earth has not disappeared long time ago and how magnetic fields in cosmic scales are possible. They play a crucial role in TGD inspired quantum biology as carriers of dark matter as $h_{eff} = nh_0$ phases controlling ordinary biomatter.

2. For the second option Y^2 is a Lagrangian manifold of CP_2 with a vanishing Kähler form. The simplest example corresponds to a homologically trivial geodesic sphere.

One can assign to MB consisting of monopole flux tubes the role of external controlling field H, which can induce magnetization M assignable to the controlled magnetic flux tubes of non-monopole type so that one has at the standard model limit $B = H + M$. Monopole flux tubes could have a similar role in condensed matter physics.

The core of the vortex would be associated with a monopole flux tube and the exterior of the core would be associated with the non-monopole flux tube. The monopole flux tube needs no current to generate its magnetic field. The cross section is a closed 2-surface rather than a 2-surface with a boundary (say disk).

The current at the surface of the vortex core creating the magnetic field B inside the core in Maxwellian framework would be replaced with a non-trivial topology of 3-space. If monopole flux tubes with larger h_{eff} control the space-time sheets carrying ordinary matter, the latter space-time sheets could contain a current creating magnetic field with non-mopole flux.

Magnus force as a direct evidence for the classical Z^0 force or for M^4 Kähler force?

Magnus force (`https://cutt.ly/MEGn3TQ`) means that a spinning object moving in fluid suffers a force, which tends to lift in a direction orthogonal to the spin axis and the direction of motion. Boomerang effect is the most dramatic example of Magnus effect and the effect is utilized in various ball games.

One manner to intuitively understand the Magnus force is in terms of friction at the surface of the spinning object. The drag of the liquid implies that the velocities of the liquid at the opposite sides of the spinning object differ and the conservation of the energy density $p + \rho v^2/2$ along the flow lines of the fluid flow, causes a pressure difference inducing the force. Actually, Magnus force is the sum of several effects and even its sign can change.

Here an example of the Magnus force known as a Kutta-Joukowski lift is considered. The idealized situation involves a long cylinder spinning in the liquid. The lift involves also the generation of a turbulent wake which also contributes to the effect. This situation could also apply to linear vortices.

The force per length of the cylinder is

$$\frac{F}{L} = \rho v\Gamma \ , \quad \Gamma = \oint v \cdot dl = \int (\nabla \times v) \cdot dA \ . \tag{18.2.11}$$

Here ρ and v are the density and velocity of the liquid at the cylindrical surface containing the cylindrical object.

The form of the expression brings in mind the Z^0 Lorentz force with Z^0 force proportional to Kähler force affecting vortex cores in hydrodynamics as Z^0 MHD.

The second option is that $A(M^4)$ or $A(M^4) + A(CP_2)$ gives rise to the Magnus force. Since the M^4 Kähler charges of leptons and quarks are opposite if leptons are composites of 3 antiquarks, the total charge density could vanish, and one would have a neutral plasma like state and the analog of MHD would describe hydrodynamics.

1. Z^0 option

In the following, only the Z^0 option is considered in detail since the discussion is similar for the M^4 case.

1. The first thing to notice is that the density is that of the fluid. This suggests that one must look at the situation using linear superposition property and regard the lack of the fluid inside the spinning cylinder as the effective presence of fluid with Z^0 current compensating that of the fluid. Z^0 current would reduce to Kähler current at the QFT limit.

   The Z^0 and Kähler charge densities would be opposite for nuclei and neutrinos but flow velocities would be of opposite sign. to that of the fluid and having inertial mass density of the object. The spinning object effectively would correspond to a fluid with a Z^0 charge density opposite to that of the fluid.

   Remark: One cannot exclude the possibility that also the spinning object carries Z^0 current. This would give rise to a force which would depend on the mass of the object since nuclear Z^0 charge is proportional to mass.

2. Suppose that the liquid particles have Z^0 charges of the same sign and average charge q_z so that the Z^0 charge density ρ_Z is given by $\rho_Z = (q_Z/m)\rho$. This assumption can be challenged. At which length scale do dark neutrinos neutralize the nuclear Z^0 charges and is also the nuclear Z^0 charge dark?

3. Suppose that the assumption $v = q_Z A_Z/m$ inspired by super-fluidity holds true at the MB. This implies that the vorticity is given by $\nabla \times v = q_Z B_Z/m$. This gives $\Gamma = (m/q_Z)\Phi_Z = (m/q_Z)\oint A_Z \cdot dl$. On the other hand, the Z^0 Lorentz force per unit length is $F/L = q_Z\rho_Z v \times B_Z dA = \int \rho v \times (\nabla \times v) dA$. Since v can be taken spatially constant inside the cylinder, one obtains $F/L = \rho v\Gamma$ by Stokes theorem.

If the dynamics of Z^0 fields controls fluid dynamics this picture can be generalized by allowing also Z^0 electric fields. The Z^0 charge densities and Z^0 currents of neutrinos and nuclei cancel each other, they move with the same velocity and one has a neutral Z^0plasma, and HD reduces Z^0 MHD.

For the Z^0 option, the appearance of the density of the fluid in the Magnus force has highly non-trivial implications since it means that *all* nucleons in the liquid flow are effectively dark with large value of h_{eff}, not only those, which reside at magnetic flux tubes. This might well kill this option where as the options in which $A(M^4)$ is involved, survive.

1. At the fundamental level, darkness must reduce to a property of weak bosons propagating along magnetic flux tubes. If magnetic flux tubes are dark also the particles, which touch

them are dark. Already earlier it has been concluded that the coupling of ordinary matter to dark gravitational flux tubes by touching makes them effectively dark. For instance, in the case of fountain effect of superfluidity [K35] [L152], this seems to be the only possible interpretation: only superfluid particles touch to dark gravitational flux tubes: it is misleading to say that they are at magnetic flux tubes.

2. Darkness implies that the weak scale is scaled up by $\hbar_{eff}$. What does this mean from the point of view of particle masses? Weak bosons are effectively massless below their dark Compton scale, which for $\hbar_{gr}$ associated with M_E and $\beta_0 = .9$ would be $\Lambda_{gr} \simeq .9$ mm.

   In the standard model framework, this would imply that the Higgs mechanism is realized only in length scales longer than the dark weak scale so that below weak scale quarks would be massless if the Higgs mechanism determines the masses.

   This would not have a considerable effect on the nucleon masses since the contribution of quarks to their masses is only few per cent. In the TGD framework most of the nucleon mass comes from the mass of color magnetic flux tubes. Neutron and proton masses would be identical below the dark weak scale.

3. However, the prediction that electron mass vanishes below say Λ_{gr} looks unrealistic. The situation is saved by the fact that in the TGD framework Higgs mechanism does not determine masses of elementary fermions. Rather, p-adic mass calculations [K61, K27] based on p-adic thermodynamics predict them and weak interactions have nothing to do with the massivation of elementary fermions. Higgs vacuum expectation does not cause massivation but the gradient couplings of Higgs to fermions are naturally proportional to the fermion masses.

4. A further objection against the Z^0 option is following. If ordinary nuclei are dark in hydrodynamical flow, one can wonder what distinguishes between hydrodynamical and super-fluid flows. For instance, why has the fountain effect not been observed? For M^4 and M^4 plus CP_2 options macroscopic quantum coherence is not required but is possible and would explain super-fluid flow and be due to $h_{eff} = h_{gr}$.

2. $A(M^4)$ and $A(M^4) + A(CP_2)$ options

The discussion of the $A(M^4)$ and $A(M^4) + A(CP_2)$ options proceeds along similar lines. Now however large values of h_{eff} would not be necessary and their presence for a super-fluid flow would distinguish it from the ordinary fluid flow.

M^4 contribution to the Kähler charge would replace the Z^0 charge. In this case, nuclei and leptons would screen each other's Kähler charges and in liquid flow their velocities would have opposite directions but magnitudes could be different.

Quantum hydrodynamics is in question

For Lagrangian manifolds associated with non-monopole flux tubes the operators $D_i = p_i - qA_i$ commute and momentum components as eigenvalues determined by $(p_i - qA_i)\psi = 0$ are well-defined so that the interpretation as a classical limit makes sense. The irony is that in this case the value of h_{eff} would be large.

For monopole flux tubes, the Kähler form $J(CP_2)$ is non-trivial. The degeneracies of J determine how many components of v are well-defined.

Besides CP_2 Kähler form also the Kähler form of M^4, strongly suggested by the twistor lift, contributes. The notion of Kähler structure must be modified so that one has a slicing of M^4 by surfaces Y^2 and X^2 such that a given Y^2 with Minkowskian signature intersecting X^2 at point x is orthogonal to X^2 and vice versa.

Y^2 has a hypercomplex structure with an imaginary unit e satisfying $e^2 = 1$ rather than $i^2 = -1$. The square of $J(X^2) + J(Y^2)$ is naturally equal to $g(Y^2) - g(X^2)$. This gives a positive contribution to energy. The Kähler gauge potential contributing to the total Kähler gauge potential is real. The condition would $J^2 = -g$ would force imaginary Kähler gauge potential for Y^2 and make the contribution to energy negative.

Cosmic strings are not realistic models for hydrodynamics but their M^4 deformations could be so since the string tension of the flux tube having interpretation as a length scale dependent cosmological constant depends on the p-adic scale and approaches to zero in long scales. This gives motivation for looking more closely at the situation for cosmic strings $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$. Assume Hamilton-Jacobi structure in M^4 defining an M^4 Kähler form.

1. For a general stationary cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$, the covariant derivatives $D_i = p_i - qA_i$ do not commute in Y^2 and X^2 unless X^2 or Y^2 or both are Lagrangian submanifolds. There are 4 basic cases depending on whether X^2 (Y^2) is Lagrangian (L) or non-Lagrangian (n-L). These correspond to pairs (L,L), (n-L,L)(L,n-L),(L,L). In these situations the number of well-defined velocity components is 1+1=2, 2+1=3, 1+2=3, and 2+2.

   For instance, if $X^2 \times Y^2 \subset M^4 \times CP_2$ is a product of Lagrangian 2-surfaces for a given Hamilton-Jacobi structure, the action reduces to a volume term and there is maximum number 4 of well-defined velocity components.

   Only the component D_ϕ along the flow line can be diagonalized for non-Lagrangian $Y^2 \subset CP_2$ and the classical velocity $v_\phi = A_\phi/m$ along the flow line is well-defined. In the n-L situation in $X^2 \subset M^4$ only a single velocity component in $X^2 \subset M^4$ is well-defined and can correspond to a time-like or space-like direction.

   Harmonic oscillator with well-defined energy, momentum component in z-direction and angular momentum L_z would be a good analog for $(n-L, L)$ and $(L, n-L)$ situations. For L, n_L this would correspond to a helical hydrodynamic flow associated with the vortex core with non-vanishing v_z and v_ϕ. About the radial component v_ρ one cannot say anything.

2. The standard MHD picture is that the velocity for a vortex flow is proportional to the magnetic field due to the freezing of the charged particles to the magnetic field lines. This assumption is an idealization since already classically charged particles move along cyclotron orbits along flux lines. This conforms with the above result that the motion in the general case is helical. For cyclotron states this situation corresponds to non-vanishing momentum component p_z and non-vanishing angular momentum component J_z.

For the M^4 deformations of both Lagrangian and cosmic strings to M^4, one expects that the number of well-defined velocity components decreases to the minimal one 1+1=2 corresponding to energy and rotational velocity.

18.3 TGD view about the generation of turbulence

18.3.1 The TGD view about the flow near boundaries and the generation of turbulence and its decay

The proposal implies a new view about the hydrodynamical flow near boundaries and about the generation of turbulence and its decay.

The flow near boundaries

Consider first a TGD based model for the flow.

1. Outside the cores of vortices and in regions far away from boundaries, dissipation is absent and the flow is gradient flow. The TGD would be in terms of space-time surfaces with vanishing Kähler fields assignable to Lagrangian non-monopole flux tubes. At QFT limit electroweak fields would vanish if the above model is accepted.

2. The absence of dissipation suggests a macroscopic quantum coherence at Lagrangian space-time sheets so that one would have $h_{eff} > h$ at the MB of this region. Superfluid model suggests that the vector potential A is associated with the space-time sheet at which the dark variants of particles with $h_{eff} > h$ reside. Quantization of circulation would be in multiples of $\hbar_{eff} = n\hbar_0$.

This conforms with the TGD based model for the generation of galactic jets [L149] in which the magnetic fields around galactic blackhole like object are relatively weak but correspond to $h_{eff} = \hbar_{gr} = GMm/v_0$ so that one has quantum coherence in the scale given by gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_s/2\beta_0$, $\beta_0 = v_0/c$ which has no dependence on mass m and is in general larger than Scwartschild radius r_s. Λ_{gr} for Earth appears in the TGD based model for superconductivity [L131].

3. What about the monopole flux tube associated with the vortex core? In the model of galactic jets, it would have a considerably smaller value of h_{eff}, perhaps $h_{eff} = h$ [L149]. This assumption would conform with the fact that the flow would be ordinary dissipative flow in this region.

   Remark: One can also consider a fractal hierarchy in which one has at every level a non-dissipative flow apart from vortices. There would be vortices inside vortices inside..., and at the lowest level one would have monopole flux tubes.

4. Near the boundaries one must somehow describe the transversal gradient of the longitudinal velocity field. The natural idea is that small vortices below measurement resolution are present already below the critical value of the Reynolds number R ($R = ud/\nu$) so that the shear would be concentrated in vortex cores.

   Consider two nearby flow lines with slightly different velocities. One can go to a rest system so that the velocities are opposite and replace this pair with a long flattened velocity vortex analogous to a long dipole: A would have as its source B just like B has as its source current j. The vortex core would be now a thin line parallel to the flow. One can replace this structure with a sequence of small vortices just as one can replace a long dipole with a sequence of small dipoles and put them in motion. These vortices could be below the measurement resolution, say having radii in the micron range.

   The flow near boundaries would already contain vortices but they would in general be below the measurement resolution.

The generation of turbulence and its decay

The transition to turbulence would be essentially a self-organization process made possible by energy feed provided by the flow or by some other energy source.

1. In the transition to turbulence, a phase transition increasing h_{eff} for the non-mopole parts and possibly also for the monopole parts of MBs of already existing vortices would take place. It would increase the corresponding parts of flux tubes and make the vortices visible.

   The energy of the flow would not be dissipated but would be used as "metabolic energy" for self-organization. The critical Reynolds number could be due to the condition that circulation is quantized for the vortices as multiples of h_{eff}/m, m the mass of the particle of the flow. Also the formation of bound states of particles by Galois confinement at flux tubes could liberate energy. This would directly relate to the formation of quasiparticles in condensed matter systems.

   Reconnection and braiding would generate complex vortex structures and for high Reynolds numbers the situation would approach chaos.

2. In the hydrodynamic flow in the presence of boundaries the flow would provide the metabolic energy feed whereas in the head-on collision of circular vortices the energy would come from the kinetic energy of the jets. In the burst of a bubble, which scomplex circular vortex ring structures, the metabolic energy would come from the pressure difference between the interior and exterior of the bubble before the creation of the film rupture and from the energy associated with the string tension. In the case of BECs, laser light can serve as the metabolic energy feed.

3. $h_{eff} > h$ phases at the Lagrangian flux tubes would be generated and this increases the size of the flux tubes. h_{eff} could increase also for the monopole flux tubes implying a larger vortex core. The value of h_{eff} could be however considerably smaller for these flux tubes.

Also the reconnection of smaller flux tubes (not plausible with a standard arrow of time) would give rise to larger flux tubes.

Turbulence decays as the metabolic energy feed ceases. How does this take place? The decay of a single linear vortex to parallel vortices has not been observed, which strongly suggests that the dynamics is based on braiding and reconnections leading to the emission of smaller vortices from larger vortices. The eventual outcome would be vortices which are so small that they are below measurement resolution present always near boundaries.

Who is the boss?

Who is the master and who is the slave in the self-organized system?

1. The MB of the entire flow would act as a master controlling the dynamics of the ordinary fluid flow.

2. What about the monopole and non- monopole parts of MB? Who is the master and who is the slave?

   The Lagrangian part of MB as an analog of supra flow could have considerably larger h_{eff}. Could it serve as the master and also control the monopole part of MB?

   However, monopole flux tubes would effectively act as a source of Kähler gauge potential A defining the gradient flow. The dynamics of MB would be essentially topological and involve phenomena like knotting, linking, braiding and reconnection. Could the dynamics of the monopole flux tubes dictate the dynamics of the non-monopole parts just like the moving sources define the non-radiative parts of fields in electrodynamics? Could the monopole part of MB serve as the master for the topological aspects of the flow as the analogy of monopole flux tubes with external field H suggests?

What about the role of time reversals?

What about the role of time reversals? ZEO [K125] [L105] together with the h_{eff} hierarchy predicts that both "small" and "big" (ordinary) SFRs (SSFRs and BSFRs) can occur in all scales.

1. BSFR changes the arrow of time and the outsider with an opposite arrow of time sees BSFR as a classical deterministic evolution leading to the final state of BSFR as the experimental findings of Minev *et al* suggest [L90]. The proposal is that BSFRs appear in all scales and allow us to understand why the world looks classical despite being genuinely quantal.

2. The generation of turbulence looks like self-organization whereas the decay of the turbulent patterns looks like dissipation. The self-organization aspect is usually explained in terms of non-equilibrium thermodynamics and the necessary energy feed is indeed present. In the TGD picture, the energy feed would make possible an increase of h_{eff} at the MB of the system and since MB controls the system, this would lead to the increase of vortex size and reconnection of microscopic vortices could be involved.

3. One can however ask whether time reversals could play a role in the process and even make spontaneous self-organization without energy feed possible. Could the transition to quantum turbulence in some situations involve a BSFR changing the arrow of time at MB, and lead to maximally self-organized configuration? This would be followed by a second BSFR leading to the decay of the turbulence. In this kind of situation, the self-organization would be essentially decay of large vortices to smaller vortices by reconnections but with a reversed arrow of time occurring after the first BSFR.

Inverse cascade, which is described in [D69], is observed in 2-D hydrodynamic systems with energy feed and looks essentially like the inverse process for the decay of vortices. Large scale vortices and steady states of them are generated. Jupiter and soap films represent examples of systems of this kind. Lars Onsager proposed a model based on statistical mechanics of quantized vortices to explain such behavior. The energy feed would lead to a state with a negative temperature. Nuclear spin systems and condensed matter systems can be forced to states with population reversal by manipulating spins or signs of the interparticle interactions. Authors report the first experimental confirmation of Onsager's model of turbulence in 2-D atomic BEC, in which vortex radius is of ofer micrometer to be compared with 1 Angstrom size in Helium superfluid.

To sum up, although the picture described in this section is is applied to hydrodynamics, it is universal. What is assumed is that current defines integrable flow so that one can assign to it an order parameter defined in terms of space-time geometry. Gradient flow is obtained if the current is conserved and in this case Kähler vacuums provide a model for the complement of vortex cores with a vanishing vorticity. In hydrodynamics and superfluidity the flow corresponds to conserved mass current and in super-conductivity em current but can be something else. The flow of matter would be controlled by the monopole part of MB carrying dark matter and the dynamics would be basically topological as far as turbulence is considered.

Also the vortex core flow is non-dissipative classically if both the CP_2 projection and M^4 projection are at most 2-D. One would have string like objects and dissipation could be understood as a deviation from being a string like object. The very early TGD inspired cosmology [K31, K99, K63, L91] could correspond to this phase.

18.3.2 Some examples of universality

In the following some applications of the universality of the generation of turbulence are proposed.

The reconnection problem of magnetohydrodynamics

As already mentioned magnetohydrodynamics (MHD) and hydrodynamics (MHD) could have very similar structure. The basic difference could be that in HD Z^0 magnetic fields dominate whereas in MHD magnetic fields dominate. If Weinberg angle vanishes in HD, only $\sum Z^0$ would be non-vanishing, and the difference could relate to Weinberg angle suggesting that in MHD the value of h_{eff} for Lagrangian regions of the vortices is considerably smaller.

Reconnection of magnetic field lines is believed to be the main mechanism for the generation of turbulence in MHD. The problem is that the reconnection rate is systematically predicted to be too low by many orders of magnitudes (`https://cutt.ly/GEq5zDD`). For instance, for solar flares the discrepancy is 13-14 orders of magnitude! One proposed cure is the increase of the local resistivity and therefore the emergence of a new much smaller scale.

The dimensional estimate for the dimensionless reconnection rate R_{SW} in 2-D Sweet-Parker model relies on the observation that in the connection of field lines the frozen charge carrier are transferred from portions of initial flux lines to the portions of re-connected flux lines so that one can speak of incoming and outgoing velocities for charges.

The condition in 2-D case is that the component of electric field normal to the plane of reconnection is conserved: $E_y \sim v_{in}B_{in}v_{out}B_{out}$. E_y defines what is called non-normalized reconnection rate. $v_{out} \simeq v_A = B/\sqrt{\rho}$ follows from the condition that upstream kinetic pressure equals the downstream magnetic pressure. The mass conservation gives $vinL = v_{out}\delta$. The ratio $R_{SP} = v_{in}/v_{out} = B_{out}/B_{in}$ is called normalized or dimensionals reconnection rate. The prediction for the non-normalized reconnection rate is

$$R_{SP} \sim \frac{1}{Re_m^{1/2}} \ ,$$

where the magnetic Reynolds number is given by $Re_m = v_A L/\eta$. $eta = 1/\sigma_0$ is magnetic diffusivity analogous to viscosity, $v_A = B\sqrt{\rho}$ is the Alfven velocity, and L is the scale of the system. What looks strange to me is that the reconnection rate is dimensionless. Is it impossible to deduce a genuine rate if the reconnection takes place for field lines?

R increases as the effective value of L decreases or the conductivity σ_0 decreases, and it has been proposed that the local increase of resistivity could save the situation but it is difficult to imagine this kind of mechanism in standard MHD.

What is the situation in the TGD framework?

1. The hierarchical structure of many-sheeted space-time brings in an entire hierarchy of scales (dark and p-adic ones). This makes possible the transfer of energy from long to short scales before it is dissipated at short scales. This is the intuitive vision originated by Kolmogorov.

2. The reconnection of magnetic field lines is replaced with that for monopole flux tubes (see 18.8.2 and **Fig. ??**) at the vortex cores. In the simplest model, Lagrangian flux tubes associated with the exteriors of the vortex core would have the generalized Beltrami property and have large h_{eff} - perhaps even $h_{eff} = h_{gr}$ - and be therefore quantum coherent and therefore non-dissipative ($\sigma = \infty$ is the approximation often made in MHD). Lagrangian property would imply vanishing induced Kähler field but non-vanishing em field $\sum\gamma = p\sum 4e^1 \wedge e^2$. Kähler gauge potential would be proportional to velocity field.

3. The monopole flux tubes at vortex cores would have h_{eff} not much larger than h and the vortex core would be therefore dissipative, meaning a large resistivity. The scale L for the entire system appearing in Re_m would be replaced with the size scale of the flux tube, say its length or transversal dimension so that the estimate for the reconnection rate R would increase dramatically if one believes in the naive dimensional analysis based estimate of MHD. Clearly, monopole flux tubes represent symmetry breaking: if the Lagrangian phase has $p = 0$, electroweak symmetry breaking would be in question.

4. The Alfven velocity v_A appearing in R is associated with Alfven waves (`https://cutt.ly/fEq5onl`) plays a key role in the energy transfer in MHD. In the TGD framework, Alfven waves would correspond to two kinds of waves for flux tubes. Either the thickness of the flux tube oscillates but preserves the monopole flux or the shape of flux the tube oscillates but preserves its thickness.

   The estimate $\beta = v/c$ for the phase velocity of the Alfven wave using units with $c = 1$ $\mu_0 = \epsilon_0 = 1$ can be expressed in terms of the relative permittivity $\epsilon_r = \epsilon/\epsilon_0$

$$\begin{aligned} \beta &= \sqrt{1/\epsilon_r} = \frac{1}{\sqrt{1+\rho/B^2}} = \frac{\beta_A}{\sqrt{1+\beta_A^2}} \ , \\ \beta_A &= \sqrt{\frac{B}{\rho}} \ . \end{aligned} \quad (18.3.1)$$

   The density ρ could correspond to that at the monopole flux tube or with the space-time regions associated with it.

In the TGD framework it is possible to deduce an estimate for the reconnection rate with a correct dimension.

1. Consider monopole flux tubes that are long and restrict the consideration into plane. The flux tubes intersect this plane at points so that effectively one has point-like particles in 2-D space if one neglects the transversal dimension of the flux tubes. Flux tubes are effectively strings and their orbits are string world sheets.

   The moving flux tubes are bound to intersect sooner or later due to a simple topological fact that the dimension of the string world sheets exceeds the dimension of 3-space by one unit. This means that string world sheets have a discrete set of intersection points in the generic case.

2. The estimate for the rate is obtained from the average velocity v for the flux tube motion and from the average distance L between flux tubes.

$$R_{rec} \sim \frac{1}{\tau_{rec}} = \frac{v}{l} \ . \quad (18.3.2)$$

   The average distance l between flux tubes in plane can be obtained from the density n of the intersections of flux tubes with the plane:

$$l = \frac{1}{n^{1/2}} \ . \quad (18.3.3)$$

3. The magnetic flux for monopole flux tubes is conserved and quantized as

$$\Phi_{tube} = \oint_{tube} q_K B_K dS = nm\hbar \ , \quad \frac{\hbar_{eff}}{\hbar} = m \ . \tag{18.3.4}$$

   Note that the cross section of the flux tube is a closed surface!

4. The density of the intersections with the plane with area L^2 the estimate

$$n = \frac{N_{tube}}{L^2} \ . \tag{18.3.5}$$

5. The number N_{tube} of flux tubes intersecting the plane can be estimated in terms of total magnetic flux as

$$N_{tube} \sim \frac{\Phi_{tot}}{\langle \Phi_{tube} \rangle} \ . \tag{18.3.6}$$

6. This would give for R_{rec} the expression

$$lR_{rec} = \frac{1}{\tau_{rec}} = v \times n^{1/2} = v \times \frac{N_{tube}^{1/2}}{L} \sim v \times \sqrt{\frac{\Phi_{tot}}{\Phi_{tube}}} \frac{1}{L} \ . \tag{18.3.7}$$

7. One should estimate the value of v. v corresponds either to the center of mass motion of plasma or to the transverse oscillations of flux tubes which can lead to reconnection if the density of flux tubes is high enough.

   Alfwen waves propagate with the Alfven velocity

$$v = v_A = \frac{B_K}{\sqrt{\rho}} \ . \tag{18.3.8}$$

   That there would be no dependence on conductivity would conform with the idea that reconnection is a purely topological process of monopole flux tubes rather than that of plasma.

   An analogous result is expected if v corresponds to the cm velocity of the flux tube.

The generation of magnetic fields in cosmic length scales

The problem is discussed in the article [D123] of Alexander Schekochihin can be used to summarize basic differences between TGD and standard approach. The problem discussed is the presence of long range magnetic fields in cosmic scales. Maxwellian magnetic fields always require currents to generate them by dynamo effect. In cosmic scales the plasma is however almost collisionless and it is very difficult to understand how magnetic fields could be generated by dynamo mechanism applied in MHD and why they could have such a long range and be preserved. Currents in long ranges are simply missing and if they exist they decay.

The proposal of Schekochihin is that this is possible. The observation is that magnetization M of molecules can be induced already in very weak long range magnetic fields H if such exist. Assuming the existence of H in cosmic scales, a numerical model providing evidence for the claim is constructed.

What I see as the problem is that such fields H in long scales should not exist if standard cosmology is right! Currents would be random in cosmic scales and long range coherence is lacking.

In the TGD based cosmology the situation is different. Monopole flux tubes carrying magnetic fields analogous to external magnetizing fields H exist already in the primordial cosmology as cosmic strings. Cosmic string world sheets (actually 4-D surfaces) are space-time surfaces with 2-D M^4 projection unstable against thickening of this projection. The thickening of cosmic strings to monopole flux tubes would have produced monopole flux tubes, whose motion induces currents at flux tubes which carry Maxwellian non-monopole magnetic fields analogous to magnetization M requiring the presence of currents. This is a dynamo effect but monopole flux tubes are necessary to generate it by taking the role of H missing from the model of Schekochihin. [This process would have liberated energy transforming to ordinary matter very much like inflaton fields are assumed decay to ordinary matter. The outcome is a solution to the galactic dark matter problem.]

Schekochihin discussed in his lecture (`https://cutt.ly/RW24bTN`) the conjecture that hydrodynamic turbulence in dense plasma could lead to an exponential amplification of magnetic fields (analogous to M) near to the equipartition of energy between kinetic and magnetic degrees of freedom: this equipartition has been observed but is not understood.

In the TGD framework the transfer of energy in plasma turbulence would be due to the generation of vortices, whose cores are accompanied by monopole magnetic flux tubes (H), vortex exteriors can carry ordinary magnetic fields (M) although Kähler gauge field vanishes. They can decay by reconnections to smaller vortices but it would seem that there is lower bound for the vortex size due to the conservation of monopole flux and this would correspond to equipartition of magnetic and kinetic energies in thermal equilibrium [Even nuclei, hadrons and elementary particles would correspond to this kind of flux tubes: flux tubes inside flux tubes inside...].

Bursting bubbles associated with optical cavities in photonic crystals generating jet vortex rings

One can take as an example the bursting bubbles associated with optical cavities in photonic crystals generating jet vortex rings. I am not a specialist so the first challenge is to to understand the above sentence.

1. Photonic crystal (PC) means a periodic structure with a lattice constant, which is half of the wavelength of light in micrometers scale. Photons in this crystal behave like electrons in a lattice. The lattice constant is roughly 10^4 larger than for atomic lattices.

2. Optical cavities (OP) are of size of order 100-1500 nm. Standing waves coupling to plasmons are formed inside the cavity, which leads to amplification of a laser beam. One can speak of a laser without population inversion. The modes inside the cavity are polaritons, which are mixtures of photons and plasmons. They form polariton BEC which can be described by an analog of hydrodynamics.

3. BEC can be regarded as an analog of liquid, it can contain bubbles presumably plasma ions. These bubbles can end up to the boundary of the optical cavity as analogs of soap bubbles and burst. The polariton BEC would form the analog of liquid film bounding a bubble containing plasma.

4. The burst of a bubble would mean generation of a hole at the bubble boundary so that the plasma would burst out. A vortex ring of BEC would be formed around the hole as it is thrown out as a jet. Pressure difference and surface tension for ordinary bubbles would have counterparts. Jet vortex ring would consist of a polariton BEC as an analog of liquid.

If the general vision is correct, an analog of MHD would describe the dynamics of the vortex ring jet. The monopole flux tubes carrying ordinary magnetic fields would define the cores of the BEC vortices.

Generation of vortices in the collision of two circular vortices

It is interesting to see whether the proposed picture allows us to understand a head-one collision of two circular vortices. The article of Chen *et al* [D105] discusses numerical simulations of the head-on collisions of circular vortex rings of opposite circulations. The article contains illustrations giving a good idea about the time evolution in the collision creating extremely beautiful flow patterns (see **Figs. 18.5**) and **18.6**).

In the head-on collision the circular vortex rings with opposite circulations separate from the rest of the fluid, which remains on the collision site, and their radii start to increase. The flux tubes almost reconnect and eventually reconnection inducing splitting to small vortex rings takes place.

In the TGD based model the vortex cores would accompany Kähler magnetic monopole fluxe tubes, which start to increase in size. Liquid flows fuse but flux tubes would stay separate. Eventually they annihilate to smaller monopole flux rings by reconnection. This gives rise to vortex ringlets. **Fig. 18.5**) illustrates the complexity of the resulting patterns. **Fig. 18.6**) illustrates a real collision of flux tubes.

The challenge is to see whether the formation of local flux loop extrusions associated with wavy motions of flux tubes preserving topology, and braiding and reconnections of the monopole flux tubes could explain the patterns. Reconnection for a single flux tube can produce a closed flux tube and emission of a closed vortex ringlet. Reconnection between *antiparallel* flux tubes produces two U-shaped flux tubes. Reconnection between *parallel* flux tubes 1 and 2 can produce elementary braiding AC +BD $\rightarrow$ AD +BC. Two reconnections produce a braiding consisting of two subsequent elementary permutations. After thar a reconnection for flux tube 1 (2) can yield a vortex ring around V2 (V1). This is possible also for opposite flux directions if the second flux tube develops a local fold.

The pairs of spikes or "teeth" (Λ vortices) (see sub-figures b) and c) of **Fig. 18.5**) look strange and it is not obvious how to understand them in the TGD framework. If there is a circular flow around the tooth axis with a non-vanishing circulation and if it corresponds to a monopole flux tube, the monopole flux tube must continue beyond the tip of the tooth. The vortex could disappear because there is no liquid, or could become invisible because the amount of liquid is too small. The members of the tooth pair would be naturally associated with the same flux loop and have opposite circulations and their behaviors should be strongly correlated. This interpretation is supported by the fact that when the Reynolds number is increased, tooth pairs are replaced by vortex loops (sub-figure d) of **Fig. 18.5**).

18.3.3 Breaking of the circulation theorem of Kelvin

This section was motivated by the article of Tobias *et al* [D32] about non-conservation of hydrodynamics circulation for 2-D flows caused by the presence of even weak magnetic fields. The following is just an attempt to interpret the findings described in the article.

Background

It is good to start with the abstract of [D32].

> *In this paper we examine the role of weak magnetic fields in breaking Kelvin's circulation theorem and in vortex breakup in two-dimensional magnetohydrodynamics for the physically important case of a low magnetic Prandtl number (low Pr_m) fluid. We consider three canonical inviscid solutions for the purely hydrodynamical problem, namely a Gaussian vortex, a circular vortex patch and an elliptical vortex patch.*
>
> *We examine how magnetic fields lead to an initial loss of circulation and attempt to derive scaling laws for the loss of circulation as a function of field strength and diffusion as measured by two non-dimensional parameters.*
>
> *We show that for all cases the loss of circulation depends on the integrated effects of the Lorentz force, with the patch cases leading to significantly greater circulation loss. For the case of the elliptical vortex the loss of circulation depends on the total area swept out by the rotating vortex and so this leads to more efficient circulation loss than for a circular vortex.*

For a 2-D incompressible flow, the velocity can be expressed either as a gradient of a scalar function or a rotor of a vector potential in z-direction and thus determined by a scalar function known as stream function. The two scalar functions correspond to real and imaginary parts of an analytic function. The presence of the Lorentz force destroys incompressibility and one loses the conservation of circulation since the velocity field for the vortices is not a gradient anymore. Symmetry breaking as loss of conformal invariance is in question.

The article describes situations in which a stably stratified and hence effectively 2-D flow can lead to a generation of long range correlation and large scale flows. Conservation laws and so called inversion procedure, which I interpret as a generation of large scale vortices from smaller ones than vice versa, is believed to be the reason for this.

Small magnetic field can however inhibit the generation of large scale flows. Magnetic fields can also inhibit shear flow instabilities and lead to a disruption of coherent structures such as vortices. Magnetic fields can also turn the direction of spectral transfer of 2-D turbulence: inverse cascades turn to forward cascades. Magnetic fields seem to be an enemy of the HD turbulence. Why?

TGD view about dissipation and loss of circulation

In the TGD framework, dissipation would mean the reduction of the values of h_{eff} for MBs of vortices: $h_{eff} = nh_0$ as a unit for the quantization of monopole flux is effectively reduced. This could mean several things.

Before continuing one must make clear that one must distinguish between the space-time sheet and the "fundamental region" of the Galois group. There are m sheets corresponding to the "roots" of an irreducible polynomial of order m. The Galois group with $n = h_{eff}/h_0$ elements gives rise to n fundamental regions and their number equals to m for cyclic extensions only. If the Galois group is a permutation group of m objects, its order $m!$ and much larger than the order m of the polynomial.

n is in general not equal to m and corresponds to the order of the Galois group and the order of extension of rationals is expected to decrease. This changes the dimension of algebraic extension of rationals and is expected to lead to both dissipation, the reduction of quantum coherence length scale and of the size of the vortex, and a genuine loss of circulation.

1. Quantum jumps transforming an irreducible polynomial to a reducible polynomial

Irreducible polynomials define connected space-time surfaces formed by m "roots". As the polynomial becomes reducible, say a product of two polynomials, it defines 2 space-time regions with a discrete set of intersection points citebtartGaloisTGD. This is what typically happens in particle reactions and also in SFR so that the processes might relate to each other.

If the WCW quantum state is a superposition of space-time surfaces associated with polynomials of the same degree with rational parameters it can occur that for some parameter values the irreducibility is lost [L129]. An SFR performing localization to these values of parameters would correspond to the decay of the space-time surfaces.

This suggests the following scenario.

1. m as the degree of polynomial is identifiable as the number of space-time sheets and is different from $n = h_{eff}/h_0$. m can correspond to number sheets as a covering of M^4 and also as a covering of CP_2. The latter case corresponds to a bundle of flux tubes and the number of flux tubes can be very large. Both cases can appear simultaneously in which case m is expected to factorize as $m = m(M^4) \times m(CP_2)$.

2. For M^4 coverings, dissipation could correspond to a decay in which the polynomial for critical values of parameters decomposes to a product of polynomials of degrees m_1 and m_2 and vortex decays to vortices with m_1 and m_2 sheets. These structures then leave each other and form separate vortices.

3. In the M^8 picture, in which space-time region corresponds to a "root" of a polynomial, this could mean that the m_2 roots of the polynomial defining the vortex region coincide. The simplest case, perhaps the only realistic situation, corresponds to a co-incidence of $m_2 = 2$ roots so that the polynomial of order m reduces to a product of a second order polynomial and a polynomial of order $m - 2$. The second order polynomial with rational coefficients would correspond to a single root disjoint from $m - 2$ roots. The vortex with $m_2 = 2$ should be small. The interpretation as a reconnection is highly suggestive.

For CP_2 coverings the flux tube bundle decomposes to flux tube bundles consisting of m_1 and m_2 flux tubes.

4. The orders n_1 and n_2 of Galois groups are expected to be smaller than n so that the vortex sizes would be scaled down. Circulation as magnetic flux proportional to $n\bar{h}_0$ is not expected to be conserved.

2. Cognitive measurement cascade

One can consider the situation also from the point of view of the Galois group with order $n = h_{eff}/h_0$. Dissipation would correspond to the reduction of n.

1. What I call cognitive measurement cascades [L125, L129] occur for extensions of extensions... of rationals Q reprentable as $Q \rightarrow E_1.... \rightarrow E_n$ would mean a stepwise sequence of symmetry breakings in which the representation of Galois group G_n of E_n would first reduce to the product of Galois groups G_n/G_{n-1} for E_n as extension of E_{n-1} and G_{n-1} of E_{n-1} as extension of Q, and the process continues in the similar manner downwards [L129].

2. A given step process would have as a space-time counterpart decay of flux tube to two flux tubes. Various factor groups G_k/G_{k-1} could act in extension of rationals. Only simple Galois groups such as alternating groups A_n would be stable against this process.

   One cannot exclude the possibility that the polynomial decomposes into a product of polynomials and the outcome is two separate space-time surfaces. Also the interpretation in terms of reconnection might make sense.

3. The dimensions n_i of factor groups would be factors of n and one would have $n = \prod n_i$. In the final state the total flux would be equal to $n = \sum n_i$ if the number of flux units is 1 is the initial and final states. Hence the magnetic flux would not be conserved and this could correspond to the non-conservation of circulation. Dissipation would be in question as is clear also from the fact that state function reductions occur. These reductions could be SSFRs.

4. The dissipative period following the generation of turbulence could correspond to this phase and involve genuine loss of information and complexity at the level of a single flux tube. The decay by reconnections could correspond to this process. If BSFR corresponds to an intuitive heureka moment, the sequence of SSFRs would correspond to an analysis period realized quite literally as a decay of vortices.

5. During the generation of turbulence the complexity would increase and time reversal of this process seems to be in question. TGD suggests a genuine time reversal.

A concrete model in terms of flux tubes

Suppose that one takes seriously the model for the flux tubes assigned to the vortices.

1. The Lagrangian non-monopole flux tube associated with the exterior of vortex core would have vanishing Kähler field J. By a generalization of the basic quantization conditions for superfluidity one would have a gradient flow with velocity $v = A/m$, where $A = d\Phi$ is the Kähler gauge potential (note that one does not have genuine gauge invariance). The value of h_{eff} would be large and there would be no dissipation. There would be a macroscopic quantum coherence at the magnetic flux tube in the exterior of the vortex and Beltrami flow or even gradient flow would serve as its space-time correlate.

2. The earlier considerations suggest that electroweak symmetry breaking is absent inside the Lagrangian region in the case of HD vortices and possibly also MHD vortices.

   The reason is that in the Lagrangian region weak bosons or at least Z^0 should behave like a massless boson since the Z^0 field at QFT limit defined as $\sum_{sheets} Z^0$ is non-vanishing and proportional to the sum of $\sum J_{CP_2}$, which is symplectic invariant. The absence of electroweak symmetry breaking below the size scale of the vortex suggests that the Weinberg angle vanishes: $p = sin^2(\theta_W) = 0$. If so, the electromagnetic field is proportional to $J = J_{M^4} + J_{CP_2} = J_{M^4}$ and vanishes if also the M^4 projection of the flux tube is Lagrangian.

3. What about the vortices of MHD? According to [D32], the size of vortices in astrophysical scales is typically considerably larger than that of HD vortices. The same would hold true also for h_{eff}. $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ is suggestive and mass M would be much larger in astrophysical scales: note that gravitational Compton length for particle with mass m is $\Lambda_{gr} = GM/v_0$ [L153, L152].

   Also now $p = 0$ would hold true in the Lagrangian region whereas $p > 0$ would be satisfied inside the vortex core in both cases. In MHD, the classical em field $\sum gamma$ would be non-vanishing both inside and outside the vortex core. This is the case if the M^4 projection of flux tubes is *not* a Lagrangian manifold anymore. Could the distinction between MHD and HD vortices be this?

4. The dissipation for $Re = UD/\nu \leq Re_{cr}$ would occur in HD in smaller scales than in MHD if $\nu/\eta \leq\leq 1$ is true. This suggests that kinematic viscosity ν and magnetic diffusivity $\eta \propto 1/\sigma$ are proportional to h_{eff} in the Lagrangian region.

   ν has dimensions of angular momentum divided by mass so that viscosity has dimensions of angular momentum density. How closely η could relate to the quantity $\hbar_{eff}/m$ serving as a unit of circulation? Could ν and η be proportional to minimal circulation?

5. One should also understand how the generation of the angular momentum of vortices can be consistent with the conservation of angular momentum. Could the angular momenta of dark matter at magnetic flux tube and the angular momentum of the ordinary matter at vortex sum up to zero? The generation of angular momentum of astrophysical objects is an unsolved problem and I have proposed this kind of mechanism as a possible solution to the problem [L132].

What could be the TGD interpretation of inversion

The inversion looks like dissipation meaning a decay of vortices but occurring in a reversed time direction. The most dramatic predictions of TGD based quantum theory is that the arrow of time changes in ordinary state function reductions (SFRs) (I call them "big" SFRs, briefly BSFRs) and that quantum coherence and therefore BSFRs are possible in arbitrary long scales [L105] [K125]. The physics would be apparently classical in long length scales: ZEO BSFRs imply that the physics looks classical for an observer with an arrow of time opposite to the system for which BSFR takes place [L90].

Could the inversion as a generation of larger vortices from smaller vortices, which in the TGD framework should occur in the first stage in the generation of turbulence, be associated with a BSFR in macroscopic scale?

If this interpretation is correct, the introduction of magnetic fields in the hydrodynamic system would induce BSFR and transform inversion back to dissipation. Why should this occur?

Energy feed is needed to increase h_{eff} assignable to vortex MBs. Could it be that electromagnetic and Z^0-magnetic vortices compete over metabolic energy. Could the generation of electro-magnetic flux tubes steal the metabolic energy from Z^0-magnetic hydrodynamical flux tubes? If $\nu < \eta$ holds true the formation of magnetic vortices would become possible at smaller length scales and could steal the energy feed.

18.3.4 Kelvin-Helholtz and Rayleigh-Taylor instabilities

Kelvin-Helmholz instability (K-H) Rayleigh–Taylor instability (R-T) are instabilities of fluid flow.

1. Kelvin-Helmholz instability (K-H) (`https://cutt.ly/TENyKZ0`) is caused by shear at boundary of the fluid flow or inside the flow and leads to a generation of vortices. Surface waves in water represent a basic example of K-H. In this case, the perturbation theory fails because the water surface does not anymore allow a description as a graph of a single valued function.

2. Rayleigh–Taylor instability (R-T) (`https://cutt.ly/6ENyXzQ`) involves two immiscible fluids with different densities. When lighter fluid is pushed against the heavier one, the boundary layer becomes unstable. This pushing can be caused by the gravitational field. This raises

the question whether the gravitational Compton length Λ_{gr} could play an essential role in the description of R-T.

Oil suspended above water in the gravitational field of Earth is one example. The mushroom shaped cloud formed by volcanic eruptions and atmospheric nuclear explosions represents a second example. During the first stage the dynamics is lianer. The second stage of R-T involves a generation of mushroom shaped spikes as heavier fluid forms intrusions inside the lighter one and bubbles as the lighter fluid penetrates inside the heavier fluid. In the third stage, the mushroom shapes interact with each other. Merging of bubbles and spikes to large ones takes place. Also competition takes place as the saturated spikes and bubbles of smaller wavelength are enveloped by larger ones not yet saturated. The dynamics is thus fractal and the process repeats in shorter length scales. The fourth stage corresponds to turbulence and fractality provided that the Reynolds number is large enough.

It has been recently discovered that the fluid equations governing the linear dynamics of the system admit a parity-time symmetry (PT). According to Wikipedia article, K-H occurs when and only when the parity-time symmetry (PT) breaks spontaneously. However, the article about R-T however claims that simultaneous K-H and R-T occur only when PT is spontaneously broken. The intuitive guess is that the failure of PT symmetry must be a general feature for the transition to turbulence. Reynolds number serves as a criterion for the emergence of turbulence caused by K-H.

Complex Hamiltonians with PT symmetry are hermitian

What makes K-H and R-T quantum mechanically so interesting is that the spontaneous breaking of PT symmetry at the level of flow is involved. On the other hand, if PT replaces complex conjugation, complex Hamiltonians can act as Hermitian Hamiltonians.

One can generalize the notion of Hamiltonian (or any Hermitian operator) to that of complex Hamiltonian provided the operator is invariant under PT [B7] (`https://cutt.ly/mENpOdq`). It turns out that in the TGD framework, one could actually replace PT with CPT transforming the positive and negative energy parts of zero energy states to each other in ZEO. This requires a modification of the inner product so that hermitian conjugation induced by T is replaced with PT involving spatial reflection. The eigenvalues of this operator are real, time evolution is unitary, and states have positive and real norms. A simple example involving addition of term -ix to harmonic oscillator Hamiltonian demonstrates that this is indeed the case.

The addition of the term -ix makes the space complex by the shift $x \to x - i/2$. This is of special interest in TGD, where one must complexify M^8 and therefore also $M^4 \subset M^8$: there the quark momenta in $X^4 \subset M^8$ correspond to algebraic integers, which can be complex [L147].

1. The restriction to imaginary shifts $x \to x + iy_0$ of real M^4 coordinates implied by the generalized hermiticity condition allows only imaginary shifts for space-like M^4 coordinates in M^8_c interpreted as momentum space. The reality of the number theoretic norm requires $\sum x\ cdoty_0 = 0$. This selects a 3-D surface of M^4 and reduces M^4 to M^3 for spacelike y_0. This would require an effectively 2-D system.

2. $M^8 - H$ duality would map the momenta to the intersections of geodesic lines with momentum $x + iy_0$ intersecting the opposite boundary of a complexified CD. Quark momenta are algebraic integers in an extension of rationals and can be complex: the real momenta for Galois confined states would belong to M^3.

Spontaneous breaking of PT symmetry in TGD framework

What could PT symmetry and its spontaneous breaking mean in classical TGD having the structure of hydrodynamics (field equations as conservation laws)?

1. Quite generally, CPT symmetry implies PT symmetry in systems in which matter dominates. The theory would be PT invariant and spontaneous PT violation would occur for the solutions of field equations. Spontaneous violation of PT and even CPT occur in all systems at elementary particle level and large values of h_{eff} could make this possible even in macroscopic scales.

2. If the generalized Beltrami hypothesis is satisfied, the classical dynamics is non-dissipative in each scale. The hypothesis does require PT and C as separate symmetries but in TGD one could loosen this condition by defining the generalized unitary by assuming that hermitian conjugation corresponds to CPT with C realized geometrically as a complex conjugation the level of CP_2.

   C transforms complex structure to its conjugate and changes the sign of the induced Kähler form. This does not seem possible for monopole flux tubes at a given boundary of CD in systems containing only matter. Lagrangian flux tubes do not correspond to complex manifolds and have a vanishing induced Kähler form so that non-trivial action of C could be allowed. The WCW spinor field could be C invariant in this case.

   If the spontaneous breaking of CPT at the level of space-time surface is possible, it would mean CPT non-invariance of individual space-time surfaces with P and T depending on the CD containing given space-time surfaces. T defined with respect to the center point of CD would permute the 3-surfaces at the opposite boundaries of CD.

   The WCW spinor fields as superpositions of pairs of 3-D quantum states at opposite boundaries of CD are not invariant under this transformation: T and therefore also CPT would permute the 3-D states at the opposite boundaries. Bras would be mapped to kets and vice versa.

   At space-time level CPT violation could make itself visible as the change of the sign of Kähler form of CP_2 or of M^4. CPT violation would occur at the Lagrangian regions of vortices with $h_{eff} > h$ and therefore could take place in long scales.

What does the generalized Beltrami hypothesis imply?

1. The spontaneous violation of PT in ordinary hydrodynamics would correspond in TGD to the breaking of unitary evolution by the occurrence of SSFRs and BSFRs. The sole source of dissipation in ZEO would be reduction of h_{eff}. The reduction of h_{eff} would lead to the reduction of quantum coherence scale and flow of energy to shorter scales. Self-organization as the reverse process in presence of energy feed or induced by time reversal at MB induced by BSFR is also possible and the formation of larger vortices could correspond to this process.

2. PT symmetry would mean absence of dissipation and its spontaneous violation as analog of breaking of unitary time evolution via the occurrence of SFRs.

According to the Wikipedia article, a spontaneous breaking of PT occurs in simultaneous K-H and R-T and possibly already in K-H. What would TGD predict?

1. Consider first the spontaneous violation of PT symmetry classically. The generation of Kähler magnetic fields in vortex cores in the presence of spinning particles would induce T violation. The large value of h_{eff} imply large electroweak violation of P in long (say biological) scales (classical Z^0 fields). The exteriors of vortices carrying Z^0 fields would correspond to regions, where h_{eff} is large, perhaps even equal to $\hbar_{gr}$.

   Do these violations of P and T compensate for each other or is a spontaneous violation of PT possible. Or is the PT violation produced in SFRs?

2. Could the interpretation spontaneous violation of PT in the case of simultaneous K-H and R-T be that the generation of vortices by K-H inside the intrusions (spikes and bubbles) formed by T-H as a flow of energy to shorter scales serves as the counterpart for the dissipation as a counterpart for the breaking of PT.

3. Can K-H alone be enough for the spontaneous violation of PT? This would correspond to reconnection of vortices producing smaller vortices. The boundary of vortex and exterior flow would define the boundary region with shear giving rise to a boundary layer and smaller vortices. This suggests that spontaneous PT violation in the TGD sense characterizes both K-H, R-T and their combination.

Remark: PT symmetry is in a key role in the TGD based model for the role of time reversal at the level of DNA [L190].

18.3.5 Some comments about quantum hydrodynamics

In this section some questions related to TGD inspired quantum hydrodynamics for various quasi-particle BECs are considered.

Could one assign quantum hydrodynamics to photonic quasi-crystalline structures?

Photons and polaritons are analogous to conduction electrons in metals. Again I can only ask questions.

1. Could they have as a classical correlate classical induced gauge fields such that the induced Kähler form defines a Beltrami flow with periodic properties? Flow lines are light-like locally but there would be a zitterbewegung involved.

2. What does the quasicrystal structure mean? Photonic quasicrystal should have a description as a quasiperiodic X^4. The identification of quasicrystals in terms of algebraic extensions of the ordinary lattices has been already considered. As a matter of fact, space-time surface X^4 defines a curved generalization of a quasicrystal obtained as points of X^4 belong to the set of points of $M^4 \subset M^8$ for which the M^4 coordinates are algebraic integers in the extension of rationals. In the "cut and project" construction (`https://cutt.ly/IWjxpLv`) one only replaces the low-dimensional plane in higher-D space containing ordinary crystal with the curved space-time surface. One can also define in M^8 crystal lattices tilted with respect to the chosen $M^4 \times E^4$ and obtain quasi-crystals and M^4 projections.

Bernard-von Karman (BvK) vortex streets in TGD framework?

Bernard von Karman (BvK) vortex streets are observed in an exciton-polariton superfluid [?]`https://cutt.ly/FWy3cNw`). The formation of BvK vortex streets (`https://cutt.ly/YWy3mjC` and `https://cutt.ly/JWy3WYP`) is a hydrodynamical phenomenon due to dissipation.

Some facts about classical BvK are in order.

1. The flow past obstacle is laminar or turbulent. Turbulence occurs above critical Reynolds number this corresponds to a critical velocity of supraflow. Turbulence gives rise to BvK vortex streets observed in various macroscopically coherent phases analogous to hydrodynamic flows.

2. BvK involves a periodic emission of vortices from opposite sides of the body, say cylinder, occurring alternately. This means long range coherence in the scale of the body. Vortices grow after leaving the body. Boundary layer is at rest.

3. The role of pressure increase caused by velocity decrease. Change of the direction of velocity gives rise to vortices. Separation and formation of vortices occurs at critical fluid velocity at the thickest part of the obstacle.

Is BvK for supra flows basically quantum phase transition increasing h_{eff}?

One can ask whether BvK for supra flows could be quantum phase transition creating MBs of vortices with $h_{eff} > h_{eff,flow}$.

1. TGD suggests that hydrodynamic vortices at the fundamental level correspond to Z^0 magnetic vortices. If the CP_2 projection of the X^4 is U(2) invariant sphere of S^3, both em and Z^0 field are proportional to Kähler form and long range weak interactions are possible.

2. The picture based on minimal surfaces would suggest that dissipation occurs at the frames and elsewhere there is no classical dissipation. Obstacles of the flow would serve as analogs of frames. Vortices have singular cores: do they correspond to frames?

3. Separation and formation of vortices is a critical phenomenon. In the TGD framework, it could relate to quantum criticality at some level of dark matter hierarchy and lead to the formation of phases with a large value of h_{eff}. The "metabolic energy" needed to increase h_{eff} would come from dissipation.

4. Even ordinary hydrodynamical vortices would be accompanied by quantum coherent structures at the level of their MBs.

What could happen in the process? One can only ask questions.

1. The velocity pattern of the vortex has radial velocity gradient zero and means absence of dissipation. The reason for the formation of vortices are the facts that near the obstacle velocity gradient becomes too large and dissipation starts and flow separation occurs.

2. Quantum criticality would appear when the flow velocity is above critical value so that dissipation near the obstacle begins. Could it give rise to a metabolic energy feed driving generation of $h_{eff} > h_{eff,flow}$ phases? Above this the dissipating flow would serve as an energy source making possible the increase of complexity and self-organization and generation of vortices with $h_{eff} > h_{eff,flow}$.

3. Could the formation of vortices correspond to a formation of new MBs with a different value of h_{eff} expected to occur at quantum criticality? Metabolic energy feed would generate the MBs of the vortices as additional layers in the hierarchy of dark matter. Although the values of h_{eff} could be even smaller than for the entire MB, the complexity would increase since the number of levels would increase.

4. Could the integer value quantized vortices correspond to the values of $h_{eff}/h = n$?

Quantum friction in the flow of water through nanotube

The popular article "Quantum friction slows water flow" (`https://cutt.ly/eORFiQp`) explains the work of Lyderic Bockquet related to quantum friction [D99] published in Nature.

In the experiments considered, water flows through very smooth carbon nanotubes. Water molecules have a diameter of .3 nm. The radius of the nanotube varies in the range [20,100] nm. A small friction has been measured. The surprising finding is that the resistance increases with the radius of the nanotube although large tubes are as smooth as small tubes.

In classical hydro-dynamics the wall is just a wall. Now one must define this notion more precisely. The wall is made of mono-atomic graphene layers. Layers are smooth, which reduces drag and water molecules are not adsorbed on the walls. Therefore the friction is very small but non-vanishing.

The reason is that the electrons of graphene interact with polar water molecules and form bound states and follow the flow. Catching the flow takes however some time which causes resistance. In Born-Oppenheimer approximation this is not taken into account and electrons are assumed to adapt to molecular configurations instantaneously. For thin nanotubes the graphene layers are not so well-ordered due to the geometric constraints and the number layers and therefore also of co-moving electrons is smaller. This reduces the friction effect.

Could TGD help to understand the findings?

1. The model for hydrodynamic turbulence involved the notion of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ even in macroscales. h_{eff} would characterize the "magnetic body" (MB) associated with the flow.

2. The quantum scale L associated with the flow is proportional to h_{eff} and could characterize the MB. L could be larger than the system size but would be determined by it. One could say that MB to some degree controls the ordinary matter and its quantum coherence induces ordinary coherence at the level of the ordinary matter. Quantum effects at the level of MB are suggested to be present even for the ordinary hydrodynamic flow. The detailed mechanism is however not considered.

3. The outcome is the prediction that kinematic viscosity is proportional to h_{eff}/m, where m is the mass of the unit of flow, now a water molecule.

4. What could be the quantum scale L now? The scale of classical forced coherence would be the radius R of the pipe or, as the study suggests, the size scale of the system formed by

water flow and the ordered graphene layers. The scale L of quantum coherence associated with MB could be larger. The larger the number of layers, the larger the size L of MB.

From $L \propto h_{eff}$, one has $\nu \propto hbar_{eff}/m \propto L$. In conflict with the classical intuitions, the friction would be proportional to L and decrease as the pipe radius decreases. This conforms with the proposal if the magnetic body associated with the electron system is the boss.

Mysterious lift of drill in downwards water flow

I learned of a very interesting and paradoxical looking phenomenon. Thanks for Shamoon Ahmed for the link. A drill with a helical geometry raises in a downwards fluid flow. This is in conflict with the naive expectations.

1. Suppose first that momentum is conserved. By momentum conservation water must get downwards directed momentum if the drill obtains upwards directed momentum. If there is no slipping, just the opposite should happen. Therefore the situation could be like in a turbulent flow: the water and the drill do not directly touch each other. There is indeed turbulence as one can see.

   But what makes possible the slipping? It has been quite recently learned that the surface of water in air has thin ice-like layer for which TGD suggests and explanation [L169, L146]. The surface between drill and water would be covered by a very thin ice layer so that slipping would take place naturally. Drill is like a skater. Also the boundary layer in the water (liquid) flow past a body could be a thin ice-sheet. Second analogy is as a screw penetrating upstream.

2. But is the momentum really conserved? Water is accelerated in the gravitational field: this gives it momentum. Water forms a vortex already before the drill is added. The downwards kinematic pressure, which increases downwards, pushes the drill having a helical geometry. If there is no friction fixing the drill to water flow, the drill has no other option than raise. The constraint due to helicality forces the drill to rotate.

   Water in the vortex and the drill would rotate in opposite directions and helicality constraint would transform the rotational motion of the drill to a translational motion and forces the rotation of drill to gain upwards directed momentum.

3. This raises some questions.

   (a) Could there be a connection with the fact that in the Northern/Southern hemisphere water flowing in a water tub rotates in a unique direction (kind of parity breaking)?

   (b) What is the role of the handedness of the drill? One would expect that the drill with an opposite handedness rotate in an opposite direction? What if the handedness of the drill does not favor the natural rotation direction for the vortex? Do these effects tend to cancel.

There might be a connection with the "ordinary" hydrodynamics. The drill raising in the fluid flow is analogous to a propeller. Could also ordinary propeller involve the same basic mechanism and act like a skater and in this way minimize dissipative energy losses? It is known that propellers induce cavitation as evaporation of water and there is anecdotal evidence from power plants that more energy is liberated in the process than one would expect. Recently it was found that the mere irradiation of water by light leads to its evaporation as a generation of droplets, which would have ice-like surface layer consisting of the fourth phase of water (this requires energy): Pollack effect again! Could dark photons with nonstandard value of Planck constant provide the energy needed for the cavitation creating a vapour phase with larger total area of fourth phase of water?

Runcel D. Arcaya informed me of the work of a brilliant experimentalist and inventor Victor Schauberger related to the strange properties of the flowing water. This work relates in an interesting manner to the effect discussed. I have written about Schauberger's findings about to the ability of fishes too swim "too" easily upstream. Gravitation and turbulence are involved also now. Could the bodily posture of the fish generate the counterpart of the helical geometry? Could the fish as a living organism help to generate the fourth phase of water in the water bounding their skin by Pollack effect, which requires the presence of a gel phase besides energy source (IR radiation for instance) to transform part of protons of water molecules to dark photons with a higher energy.

Schauberger also invented a method of water purification using vortex flow: the reason for why the method works remained unclear. In Pollack effect, the negatively charged exclusion zones (EZs) spontaneously purify themselves. This conflicts with the thermodynamical intuitions. The TGD explanation is in terms of reversed arrow of time which explains the purification process as normal diffusion leading to the decay of gradients but taking place with an opposite arrow of time. Could the purification of in vortex flow be caused by the Pollack effect creating the surface layers consisting of the fourth phase of water (EZs)?

Schauberger developed the notion of living water and believed that spring water is somehow very special in this respect. In TGD water is regarded as a multiphase system involving magnetic body with layers labelled by the values of effective Planck constant h_{eff}. The larger the value of the h_{eff}, the higher the (basically algebraic complexity) and "IQ" of the system. Gravitational magnetic body has the largest value of effective Planck constant. Spring water is pure and could be this kind of highly complex system. Also systems involving turbulence and vortices are very complex.

18.3.6 Why the water flowing out of bathtub rotates always in the same direction?

In FB Wes Johnson wondered whether Coriolis force could explain why the water flowing out of bathtub forms a vortex with direction which is opposite at Northern and Southern hemispheres.

Coriolis effect is a coordinate force proportional to $\omega \times v$, where ω is the angular velocity of Earth directed to Noth and v is the velocity of the object. For bathtub v would be downwards, that is in the direction of Earth radius. At the equator Coriolis force is along the equator and non-vanishing. On the other hand, the force causing rotation of water in the bathtub is of opposite sign below and above equator and therefore vanishes at equator. Therefore Coriolis force is excluded as an explanation.

My own view is that this is a hydrodynamical effect and new physics might be involved. Turbulence is involved and vortex is generated. The direction of the rotation of the vortex should be understood. The selection of a specific direction violates parity symmetry and this gives in the TGD framework strong guidelines.

1. The vortex is in the direction of the Earth's gravitational force. In the TGD framework, gravitational interaction is mediated by monopole flux tubes in the direction of the gravitational field. Quantum gravitation is involved and it is quite possible that the gravitational magnetic body (MB) induces the effect since quite generally MB plays a control role, in particular in living matter.

2. The induced Kähler field contributes to both electromagnetic and classical (weak) Z^0 fields: since the matter is em neutral but not Z^0 neutral, it seems that the Z^0 field must be in question. Could the gravitational MB of Earth consist of Z^0 monopole flux tubes?

   If this is the case, a macroscopic quantum effect involving a very large value $\hbar_{gr} = GMm/\beta_0$ of gravitational Planck constant of the pair formed by Earth mass and particle must be in question since ordinary Z^0 has extremely short range. The gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0 = r_S/2\beta_0$ does not depend on particle mass and is about .5 cm, one half of the Schwartschild radius of the Earth, for the favored $\beta_0 = v_0/c = 1$.

3. In the classical Z^0 field, particles with Z^0 charge rotate around the axis of the field and since magnetic flux is approximately dipole field, the flux lines are radial but are upwards/downwards above/below the equator. This would explain why the rotation directions of the vortex are opposite and Northern and Southern hemispheres. The presence of the classical Z^0 field, which violates parity symmetry, would also conform with the parity breaking and would be essential for the understanding of the mystery of chiral selection in biomatter.

18.3.7 Cymatics, ringing bells, water memory, homeopathy, Pollack, effect, turbulence

The following comments contain many words, which induce deep aggression in academic colleagues receiving a monthly salary: cymatics, the ringing bells of Buddhist monks, water memory, and homeopathy(!!). Pollack effect is perhaps not so aggression inducing and turbulence is quite neutral. All these words are linked. Cymatics is a very interesting phenomenon. Thanks to Jukka Sarno for a post inspiring this comment.

I came across a related phenomenon recently. The ringing of Buddhist monks' bells by running the bell along its edge has strange effects. The water started to boil so that a strong transfer of energy had to happen to the water by sound. Energy was supplied to the system by the ringer of the bells. This energy could play a role of metabolic energy and help in the problems resulting from its local deficiency in the patient's body.

Something analogous to turbulence also arises in cymatics. Turbulence and its generation are very interesting phenomena and poorly understood. Standard hydrodynamics, which was developed centuries ago, can't really cope with the challenges of the modern world: if only someone could tell this to the theoreticians working on it!

I myself have built a model for turbulence and related phenomena [L146, L169]. A core element of the model is the anomalous phenomenon observed by Pollack [I18, L24, I29, I26] related to water. When water is irradiated in the presence of a gel phase with, for example, infrared light, negatively charged gel-like volumes are created in the water: Pollack talks about the fourth phase of water. Living matter is full of them: for instance cell interior is negatively charged as also DNA.

Some of the water's protons disappear somewhere: in the TGD Universe they would go to the magnetic body of the water and form dark matter there precisely because we cannot detect them with standard methods. This dark matter would be a phase of ordinary matter with a nonstandard, and often very large value of effective Planck constant. This would make it quantum coherent in much longer scales than the ordinary matter.

Pollack's fourth phase resembles ice and very recently it has been discovered that there is a thin ice-like layer at the interface between water and air [L146, L169]. Could it be Pollack's fourth phase? The energy input is essential. In cymatics and in the case of bells the energy feeder would be sound rather than light. In homeopathy (one of the most hated phenomena of physics besides water memory; I have never understood why it generates so deep a hatred), the shaking of the homeopathic preparation would supply the energy. A fourth phase of water would be created and the water would become "living" as its magnetic body would "wake up" and start to control ordinary matter.

Homeopathy [K51] is one of the most hated phenomena of physics besides water memory (I have never understood why it generates so deep hatred), the shaking of the homeopathic preparation would supply the energy. A fourth phase of water would be created and the water would become "living" as its magnetic body would "wake up" and start to control ordinary matter.

In homeopathy, shaking would provide the metabolic energy making it possible to create magnetic organisms consisting of flux tubes associated with the water molecule clusters connected by hydrogen bonds. Their cyclotron frequency spectrum would mimic the corresponding spectrum of the molecules dissolved in water. Water would magnetically mimic the intruder molecule and from the perspective of biology this would be enough for water memory explaining homeopathic effects. This should be trivial for scientists living in the computer age but some kind of primitive regression makes it impossible for colleagues to stay calm and rational when they hear the word "homeopathy".

18.4 Are the hydrodynamic quantum analogs much more than analogs?

The hydrodynamic quantum analogs are highly interesting from TGD point of view and Wikipedia article gives a nice summary about them (`https://cutt.ly/xEk5Api`). The quantum-like aspects are associated with a hydrodynamical system consisting of a liquid layer and liquid drop. Liquid surface in a periodic accelerated motion due to shaking: this means energy feed. The fluid bath is just below the criticality for a generation of standing Faraday wave and the bouncind particle indeed generates this kind of wave.

Depending on the values of the parameters, the liquid drop is surfing, bouncing at a fixed position, or "walking" along the surface wave. The surface wave is created by the interaction of particle with the surface. These findings suggest that macrosopic quantum coherence could be involved and quantum phenomena have also classical description. There is energy feed to the systems.

The findings of the group led by Bush and describe in his Youtube lecture (`https://cutt.ly/xEk5Api`) give a nice overall view about the quantum analogs. Bush also suggests a generalization of theory of Vigier involving two pilot waves, which correspond to those associated with wave function and to classical system and theory of Bohm involving single pilot wave assigned to wave function.

The article of Bush *et al* [D40] describes the findings about the analog of quantum corral. The latter involves electrons inside a circular corral defined by negative ions.

> *Bouncing droplets can self-propel laterally along the surface of a vibrated fluid bath by virtue of a resonant interaction with their own wave field . The resulting walking droplets exhibit features reminiscent of microscopic quantum particles. Here we present the results of an experimental investigation of droplets walking in a circular corral. We demonstrate that a coherent wavelike statistical behavior emerges from the complex underlying dynamics and that the probability distribution is prescribed by the Faraday wave mode of the corral. The statistical behavior of the walking droplets is demonstrated to be analogous to that of electrons in quantum corrals.*

The key questions are following.

1. Could quantum classical correspondence (QCC) be more than an approximation (stationary phase approximation). Note that in TGD QCC is in a well-defined sense exact.

2. Can a macroscopic system can exhibit quantal looking behavior and is there a genuine quantum behavior behind it? In the TGD framework, the hierarchy of effective Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter located at magnetic body (MB). MB has a hierarchical structure and defines a master slave hierarchy.

   A given level of the hierarchy controls the physics at the lower levels. h_{eff} hierarchy makes quantum coherence possible in arbitrarily long scales at MB and this induces coherence at the level of ordinary matter and makes possible self-organization [L102] The increase of h_{eff} requires however the analogy of metabolic energy feed quite generally.

   There is indeed energy feed to the studied system at frequency of $f = 50$ Hz of the vibrating cylindrical shaker. The standing wave resonance occurs at Faraday frequency $f_F = f/2$. The Faraday frequency has slow time variation with the frequency f and slightly below f_F.

   The system system should be near criticality for the generation of h_{eff} phases. These phases at MB would induce long range correlations of ordinary matter near criticality. The system studied is indeed near criticality for the generation of standing Faraday waves.

3. What could the value of h_{eff} be? The Faraday wave length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ should be equal to the analog of Compton wavelength $\Lambda_c = \hbar_{eff}/m$, m the mass of the water droplet. λ_F does not however depend on the mass of the droplet and in the model of the Faraday waves hydrodynamical is determined in the model considered by the properties of the fluid that is friction and kinematic viscosity.

   The only possibility is that one has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where $\hbar_{gr}$ is the gravitational Planck constant introduced by Nottale [E9] [L141] and also appearing in the TGD based model of superconductivity [L131]. This would give $\lambda_F = \lambda gr = GM/v_0 = r_s(M)/2v_0$, where $r_s(M)$ is Schartschild radius. M is naturally the mass of Earth. The minimum value of λ_{gr} corresponds to $v_0/c = 1$ and is $\lambda_{gr} = r_s/2$. Earth's Scwartschild radius is 8.7 mm so that one would have $\lambda_F = 4.35$ mm.

   The value of Λ_F for the system studied in the analog of quantum corral by Bush *et al* is 4.75 mm [D40] and about 10 per cent larger than the minimal value suggesting that $\beta_0 = v_0/c \simeq .92$!

If this single testable prediction is not a nasty coincidence, it would mean an instantaneous breakthrough for the TGD view about quantum gravitation as macroscopic and even astrophysical phenomenon. The only parameter that can be varied in the prediction is β_0. One could measure $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ for different liquids to see whether v_0 codes for the properties of the liquid or whether λ_F is independent of the liquid so that the classical model for Faraday waves could be wrong.

4. The system has a memory in the sense that the induced Faraday wave interpreted as an analog of pilot wave is affected by the bouncing particle and in turns determines particle behavior but not quite completely: an analog of non-deterministic "zitterbewegung" seems to be present for strong enough acccelerations. The observations about the double slit experiment and also about approach to chaotic behavior indeed suggests that the system is not completely deterministic. The findings also suggest that the statistical description of this non-determinism is analogous that in quantum systems.

   In ZEO quantum state as time= constant snapshot is replaced with a space-time surface as preferred extremal (PE) analogous to Bohr orbit. What comes in mind, is that the bouncing corresponds to "small" SFRs (SSFRs). The determinism of PEs is not quite exact that it would serve as correlate for what I call cognitive measurements [L155] as SSFRs. In the TGD inspired theory of consciousness, the loci of non-determism for space-time surfaces as analogs of soap filmds would serve as the seats of mental images quite universally and also represent conscious memories.

5. In this talk Bush interprets the Faraday wave induced by the motion of the droplet along the surface as a kind of pilot wave. In the TGD framework the counterpart of the pilot wave would be the magnetic body (MB) carrying $h_{eff} = nh_0$ phases quantum controlling the behavior of ordinary matter. The magnetic flux tubes assignable to the exteriors of vortex cores are proposed to be present in microscopic scale also below turbulence and to serve as correlates for the vorticity caused by the boundary conditions at the boundary of flowing liquid. Now these boundaries correspond to the boundary between air and liquid bath and air and liquid droplet and could explain how the gravitational magnetic body characterized by $\hbar_{gr}$ enters into the physics of the moving water droplet.

The results discussed in the talk of Bush and the article provide a benchmark test for the general picture provided by TGD and allows to sharpen the TGD view about QCC in quantum hydrodynamics (QHD).

18.4.1 Summary of the experiments

Consider first a brief layman interpretation of the experiments based on the Youtube lecture of Bush (`https://cutt.ly/xEk5Api`). I must apologize for possible mistakes: I am just a layman as far as hydrodynamics is considered. The description of Faraday waves (`https://cutt.ly/vEk6cSi` should be helpful for the reader.

Faraday waves

One considers a cylinder containing fluid and driven by a shaker, which is a piston, whose position varies in an oscillatory manner with some amplitude A and frequency f. At a certain critical frequency known as Faraday frequency $f_F = f/2$ a standing wave is generated at the surface of the water. This phenomenon is known as Faraday instability.

The parametric oscillator for an infinitesimal fraction of liquid surface is given by

$$\begin{array}{l} \frac{d^2x}{dt^2} + 2\mu\frac{dz}{dt} + \Omega^2(t)z = 0 \ , \\ \Omega^2 = \omega_0^2(1+\alpha(t)) \ . \end{array} \tag{18.4.1}$$

Here z is the vertical position of the fluid element, μ is the damping rate determined by viscosity of liquid, ω_0 and of shaker is the frequency of oscillation of the fluid element in absence of gravitational acceleration and $\alpha(t)$ is dimensionless oscillating parameter function. One could say that a harmonic oscillator with time dependent frequency $\Omega(t)$ under the damping of a viscous force is in question. Shaking defines the driving force feeding energy to the system.

The time dependent gravitational acceleration $g(t)$ is given in the moving frame of the shaker by the expression

$$g(t) = g + A\omega_0^2 cos(\omega t) = g(1 + \Gamma cos(\omega t)) \ . \tag{18.4.2}$$

Here A is the amplitude of the vibrations of the and $\omega = 2\pi f$ is its angular frequency of the shaker. From this one has $\Gamma = A\omega_0^2/g$. Note that ω_0 is determined by the properties of the fluid such as density and surface tension. The parameters involved are g, fluid density ρ, surface tension σ, and Faraday frequency $f_F \simeq f_0/2$.

For certain combinations of Γ and ω_0 resonance occurs so that the situation is unstable. The parametric resonance occurs for subharmonics $\omega_0 = \omega \simeq 2/n$. The lowest sub-harmonic corresponds to $n = 2$ and is studied in the recent case. In the recenf case one has $f = 50$ Hz.

The instability occurs in the parameter range

At $\Gamma = \Gamma_F = 4g$, a resonance occurs in the driving frequency range

$$\omega_{min} < \omega < \omega_{max}, \quad \Omega_\pm = 2\omega_0 \pm \sqrt{\Gamma\omega_0^2 - 4\mu^2} \ , \tag{18.4.3}$$

A standing wave formed at the instability and the damping rate and wave number $k = 2\pi/\lambda_F$ are related by $\mu = 2\nu k^2$, here ν is kinematic viscosity. Faraday wave length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ depends on the viscosity and friction.

Besides the standing wave, also propagating waves are possible. The instability depends sensitively on parameters like the meniscus at the walls of the vessel and the instability of the fluid layer characteristics and of driving frequency and amplitude can lead to spatiotemporal chaos.

Couder walker

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Floating droplets on vibrating bath were first described by by Jearl Walker in Scientific American in 1978. In 2005, bouncing droplets on vibrain bath were studied by Yves Couder and his lab they discovered most quantum analogs (`https://cutt.ly/TEk5XyN`). John Bush and his lab expanded upon Couder's work and studied the system in more detail.

The droplet can float (also surf), bounce at a single position and walk by bouncing. The essential condition is that no coalescence occurs. The air layer between droplet and water surface is believed to prevent the coalescence. Coalescence does not occur if the droplet does not touch the fluid surface: the air layer prevents this. For a bouncing droplet the frequency of bouncing determined by surface acceleration must be high enough in order to prevent the draining of the air from the layer. Bouncing could be seen as a kind of trampoline effect. Essential is that there is an air layer between droplet and water preventing the direct touching leading to coalescence. Since both the fluid and the droplet move with respect to air, there are surface layers involved and if quantum phenomena are involved, they might relate to the surface layers and the interaction. In the TGD framework, this suggests a possible connection with the proposed model of turbulence. For floating without coalescence, the surface layers should fuse to a single connected structure. The existence of some kind of mattress is suggestive. Mini vortices having interpretation in terms of closed flux tubes is a possible TGD based explanation. Even a surface layer giving rise to a mattress can be imagined. Below a critical acceleration, the droplet makes only a few bounces. Above the criticality the bouncing continues. As the acceleration increases the trajectory transforms from a straight line to chaotic trajectory.

The bouncing of the droplet induces the possibly propagating Faraday wave implying that the system has a memory. For high enough surface acceleration but still below the threshold for the formation of standing waves, the span of the memory increases and chaos is approached.

The initiation of a walking motion requires that the droplet meets the surface in a position in which the surface wave has a large enough slope. The bouncing preserves the particle's momentum component parallel to the surface. If a vertically moving particle meets the surface in a position with non-vanishing slope, it preserves the momentum component parallel to the surface.

After that the particle makes an approximately parabolic orbit and if it meets the surface in a position of a slope of the correct sign, the reflection preserves the parallel momentum component.

From the TGD point of view it is important that there is energy feed and the system is near criticality defined by the Faraday threshold. Also walking is possible in a range of surface accelerations.

Since the bouncing affects the surface and the bouncing indeed creates the Faraday wave. The process is non-Markovian and hereditary since the recent state of the surface is determined by previous bounces. The memory traces about bounces decay exponentially but at critical surface acceleration the memory span becomes formally infinite.

In the lecture of Bush the trajectory equations for both bouncing and surfing are given explicitly. Newton's equation involves beside drag force what is called wave force, which is gravitational force proportional to the gradient of height of the surface which for the walking is asum over exponentially decaying heights changes induced by the previous collisions and for surfing an integral. The collisions serve as instantaneous point sources for a Faraday wave. The collisions approach at the surfing limit continual touching and sum is transformed to an integral. The naive expectation would be that the wave force is present only when the drop (or its air layer) touches the water surface but according to the formula it is present all the time. The equation of motion is however written in an inertial frame of accelerating surface which depends on the position at the surface so that the wave force term is analogous to inertial force like centrifugal force.

Hydrodynamic quantum analogs

There is a long list of hydrodynamics quantum analogs and many of them are discussed in the lecture of Bush (`https://cutt.ly/xEk5Api`). Also the Wikipedia article (`https://cutt.ly/TEk5XyN`) discusses them .

1. Single particle diffraction and interference were studied already by Couder and Fort. According to the Wikipedia article, Bohr and Andersen, and the groups led by Bush and Batelan did not see the interference patterns. Bush however mentions the effects and informs that the experiments have been carried out later and the claimed effects have been found.

   The diffraction was studied in both single slit and double slit experiments. In a single slit experiment a 3 peak structure was observed. This differs from Fraunhofer diffraction appearing in a quantum mechanical situation. If the motion of the droplet is deterministic with the measurement resolution for initial state, this pattern should not be observed and random fluctuations in the experimental conditions should not produce this kind of structure. The diffraction angle also tends to favor quantized values.

   In double slit experiment the diffraction pattern is modified due to the presence of the second slit. This can be understood at a qualitative level since the Faraday wave is affected by the presence of the second slit. Bush suggests that the differences from the quantum case are due to the fact that the droplet is not analogous to a plane wave as in the quantal case. Furthermore, the ratio of λ_F analogous to the de-Broglie wavelength $\lambda_{dB} = \hbar/p$- to the width of the slit is much larger than in quantum scale when it is of order 10^3.

2. Droplets for bound states analogous to molecules. Also walking droplets can form pairs. Bond lengths are quantized in terms of λ_F interpreted as analog of λ_{dB}.

3. The analog of quantum tunnelling through a barrier has been observed. The barrier is now a region of smaller depth. The droplet typically reflects from the barrier but sometimes also transmission takes place. There is an exponential decrease with the width of the barrier.

4. The analog of Zeeman splitting is observed for a bath rotating with a frequency Ω. $2m\Omega$ plays the role of a magnetic field. For a bound state of droplets, the distance between the droplets changes and the sign of the change depends on the relative sign, the direction of the rotation of the bath and of the droplet.

   Bush mentions also the notion of a hydrodynamical analog of spin realized in terms of the direction of the rotational motion of the droplet. The motivation is that there are only two directions of rotational motion and if one has angular momentum, there would be at least 3 different rotational states, with one state without splitting. If the rotational motion of the droplet were preserved at the limit of vanishing Ω, the interpretation as spin would become more convincing.

5. Walkers at circular orbits in a rotating frame are studied. For circular orbits in the rotating frame the centripetal and Coriolis accelerations cancel each other: this gives $\rho v^2/R = 2\rho\Omega v$ (here one must distinguish between rotation frequencies ω and Ω for particle *resp.* bath). This gives $v = 2\Omega R$.

   A quantization of R as in terms of λ_F is observed. According to the lecture, the orbital radii obey the analog of the formula for the cyclotron energies: $R = (n + 1/2)\lambda_F$. Note however that for Landau levels in a constant magnetic field, one has the formula is $R \propto \sqrt{n}$ as one finds from Bohr quantization of rom quantization of the magnetic flux for a constant magnetic field.

   One can however consider the possibility that Ω defines a magnetic field which depends on the distance from the rotation axes. One would actually expect that Ω for a liquid depends on this distance. Assuming that $qB_Z = 2m\Omega f(\rho/\rho_0)$, the quantization of magnetic flux would give $q2m\Omega \int_{\rho_0}^{\rho_n} f(\rho/\rho_0)\rho d\rho 2\pi = n\hbar eff$. This gives $f(\rho) = \rho_0/\rho$ and

$$\rho_n = n\frac{\hbar eff}{m2Q\Omega\rho_0^2} \quad . \tag{18.4.4}$$

   The vector potential qA_ϕ would be of form

$$qA_\phi = 2m\Omega log(\frac{\rho}{\rho_0}) \quad . \tag{18.4.5}$$

   In the TGD framework $v \propto A$, where A is Kähler potential is proposed and this would mean that the velocity of the liquid motion varies very slowly and gives rise to a spirals $\phi = (k/\rho)$.

   Given a quantized radius is observed for several values of Ω so that one has plateaus. Could the parameter $\frac{\hbar eff}{m\Omega\rho_0^2}$ be nearly independent of Ω? This would be the case for $\rho_0^2 \propto \hbar_{eff}/m\Omega$. Could this formula be interpreted in terms of Uncertainty Principle?

6. Also unstable rotational orbits with radii smaller than $\lambda_F/2$ are observed. The motions become chaotic for a large acceleration parameter and the jumps between orbits which tend to have a quantized radius of curvature have been observed so that statistical distribution for the radii becomes multimodal.

7. One can also mimic central force by using ferrofluids and magnetic fields to create central force. In this case one obtains analogs of orbitals labelled by integer value average angular momentum and radius R.

   The instantaneous pilot wave approaches the mean wave field at high Me.

8. Quantum corral is a system in which electrons are inside a circular corral formed by negatively charged ions. The hydrodynamical analog of the quantum corral is possible [D40]. In the corral the depth is smaller. Statistical description gives rise to a similar interference pattern as in the case of quantum corral with λ_{dB} replaced with λ_F. A correlation between position and fluctuation speed bringing in mind the Uncertainty Principle is found.

9. One can also study the analog of scattering. The first example is a walker interacting with a pillar which is represented by a water with smaller depth (surface Schlieren imaging). The surprising find was that the scattering orbit was a logarithmic spiral. It can be produced by an analog of either Coriolis force or Lorentz force $2\pi\gamma_B v \times \Omega$ if $2\pi\gamma_B\Omega$ serves as an analog of the magnetic field. Here Ω is the instantaneous angular velocity with respect to the pillar

What looks strange is that the walker would create this force associated with the pillar. In the TGD framework the magnetic field would be a Z^0 magnetic field at the MB of the system and would determine the motion of the particle and thus also the value of Ω. In the TGD framework the process would correspond to a phase transition generating dark matter at the Z^0 magnetic flux tubes.

The second analog is the analog of Friedel oscillations. Instead of a pillar, one studies scattering from a well realized as a region in which the depth of water is larger. In this case long range statistical signature is found to resemble the square of probability density for quantal Friedel oscillations. Also now the λ_F replaces λ_{dB}.

The summary of Bush about the findings is roughly as follows.

1. There are 3 time scales. The fast time scale of bouncing, the intermediate time scale of surfing and the long term time scale for the emergence of statistical behavior. Bush speaks of a mean pilot wave at this limit. There are even indications for the analog of mode superposition. In the TGD framework the counterpart of the pilot wave would be taken by the MB.

2. Resonant interaction between walker/surfer and quasi-chromatic Faraday wave created by droplet is essential.

3. Quantized states emerge from dynamical constraints.

4. Memory effects due the fact that the walker can be said to determine the Faraday wave are basically responsible for the quantum-like behavior.

Bush suggests the following three basic paradigms.

1. Chaotic pilot wave dynamics is proposed. It would involve intermediate switching and multimode quantum-like statistical behaviors.

2. In-line oscillations involve speed fluctuations leading to a correlation between position and speed bringing in mind the Uncertainty Principle. Faraday length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ analogous to λ_{dB} serves as a statistical signature and the challenge would be to understand its origin. The fact that it seems to be the same at least for a given fluid unlike in wave mechanism where it is proportional to the inverse $1/p$ of momentum, suggests that it is more like Compton wave-length depending on the droplet mass m only. In fact, it could be independent of even m.

   In TGD framework gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0$ where M is naturally the mass of Earth and $\beta_0 = v_0/c = 1/2$ seems like a good guess implying that Λ_{gr} is Schartschild radius of Earth about .9 cm might be a possible interpretation. If this is the case, β_0 could code for the variation of ν/μ. Λ_{gr} does not depend on the mass of the droplet, which might serve as a test.

3. Quantized random walks are also a central element. Random walks have steps equal to λ_F, which seems to be a universal feature. Diffusivity is equal to $U\lambda_F = U\hbar_{gr}/m$.

18.4.2 TGD based view

Quantum classical correspondence

Quantum classical correspondence (QCC) in the TGD framework is much stronger than in standard quantum theory, where it is only approximate (stationary phase approximation). In zero energy ontology (ZEO), the quantum state is a superposition of classical deterministic time evolutions - that is space-time surfaces that are minimal surfaces of very special kind being also extremals of Kähler action: I talk about preferred extremals.

QCC implies many things.

1. Space-time surface is like Bohr orbit, meaning quantization rules. The findings of Bush *et al* demonstrate these kinds of rules at the level of HD.

2. One can assign to each SFR a superposition of classical evolutions and in good approximation single time evolution, the "average" one. In particular, BSFR with the change of arrow of time, has as a correlate time reversed classical time evolutions which leads from the final state 3-surface to the past. For an observer with a standard arrow of time it looks like deterministic time evolution leading to the final state. This is what Minev *et al* observed in atomic physics.

3. This implies that SFRs look classical. The world looks classical in all scales although SFRs occur in all scales by h_{eff} hierarchy. Of course, also the basic paradox of quantum measurement theory disappears by ZEO.

h_{eff} hierarchy and gravitational Planck constant

h_{eff} hierarchy realized at the level of magnetic bodies (MBs) acting as controlling agents of lower levels, implies that BSFRs and SSFRs occur in all scales. In particular, hydrodynamics systems should show Bohr quantization and various other quantum effects.

What could these effects be?

1. The interpretation of ordinary quantum measurements relies on classical physics. Without QCC we could not test quantum theory, since everything is based on classical physics at the level of experiment. All the statistical aspects of quantum measurement should have classical correlates.

2. For instance, in double slit experiments you have incoming beam replaced with water droplets in the experiments of Bush *et al.* 3 peak interference pattern is observed and a possible explanation would be in terms of Bohm's pilot wave. One could even argue that non quantum theory is needed. To me this proposal is obviously wrong.

   The classical interference patterns could be the statistical representation for the outcomes of SFR - actually BSFR at some level of MB hierarchy - which indeed occurs. The only difference between the ordinary double slit experiment and that described by Bush *et al* is that their experiment the h_{eff} at MB is much larger since the scale is dramatically larger. The first guess is that $h_{eff}/\hbar$ is of order 10^{14} (roughly). An educated guess, to be discussed below, is that the scale would correspond to $hbar_{gr} = GMm/v_0$, where M is Earth's mass and $v_0/c = 1/2$. $v_0/c = .92$ turns out be a more realistic guess!

3. Viscosity and magnetic diffusivity could be proportional to $\hbar_{eff}/m$ as proposed inthe TGD based model for the generation of HD and MHD turbulence. Nelson has proposed in his model of stochastic quantum theory that $hbar_eff/m$ plays the role of diffusion constant.

4. Bush represents many examples how water drop experiments provide a statistical representation analogous to interference pattern represented in terms of wave function modulus squared. Double slit experiment is only one example.

What could the value of h_{eff} be?

1. The Faraday wave length

   $$\lambda_F = 2\pi\sqrt{2\nu/\mu}$$

   should be equal to either the analog of Compton wavelength $\Lambda_c = \hbar_{eff}/m$, m the mass of the water droplet or to de Broglie wavelength $\lambda_{dB} = \hbar/mv$. λ_F does not depend on the velocity of the droplet so that only Compton wavelength is a possible interpretation.

   The problem is that there is no dependence on the mass of the doplet either. A further problem is that in the hydrodynamical model of the Faraday waves λ_F is determined in the model considered by the properties of the fluid, that is friction and kinematic viscosity. This model could be of course wrong.

2. The only remaining possibility in the TGD framework is that one has

$$\hbar_{eff} = \hbar_{gr} = \frac{GMm}{v_0} \ , \tag{18.4.6}$$

where $\hbar_{gr}$ is the gravitational Planck constant introduced by Nottale [E9] [L141] and also appear in the TGD based model of superconductivity and superfluidity [L131]. This would give

$$\lambda_F = \lambda gr = \frac{GM}{v_0} = \frac{r_s(M)}{2v_0} \ , \tag{18.4.7}$$

where $r_s(M)$ is Schwartschild radius associated with mass M. M is naturally the mass of Earth. The minimum value of λ_{gr} corresponds to $\beta_0 = v_0/c = 1$ and is $\lambda_{gr} = r_s(M)/2$. Earth's Scwartschild radius is 8.7 mm so that one would have $\lambda_F = 4.35$ mm.

The value of Λ_F for the system studied in the analog of quantum corral by Bush *et al* is 4.75 mm [D40] and about 10 per cent larger than the minimal value suggesting that $\beta_0 = v_0/c \simeq .92$! The error is about 10 per cent.

3. One can argue that this is a mere coincidence. The usual reductionist thinking is that the ν and μ appear as dissipative parameters in hydrodynamics and their values emerge from quantum theory in atomic scales. One can of course ask, whether the relationship

$$\frac{2\nu}{\mu} = (\frac{GM}{v_0})^2 \ . \tag{18.4.8}$$

could emerge from a microscopic theory. The alternative option suggested by the numerous grave difficulties of the description of the hydrodynamic turbulence is the description of viscosity and friction require new quantum theory predicting quantum coherence in even astrophysical scales?

4. If this correct prediction is not a mere nasty coincidence, it would mean an instantaneous breakthrough for the TGD view about quantum gravitation as a macroscopic and even astrophysical phenomenon. The Equivalence Principle behind $\hbar_{gr}$ would become a cornerstone of models thought to have nothing to do with quantum gravitation.

The only parameter that can be varied in the prediction is β_0. One could measure λ_F for different liquids to see whether v_0 codes for the properties of the liquid or whether λ_F is independent of the liquid so that the classical model for Faraday waves could be wrong.

It might be also possible to measure λ_F in Mars for which mass is $.107 M_E$ so that λ_{gr} should be by a factor .107 smaller unless v_0 is scaled down by factor .107.

5. It is needless to emphasize how profound implications the inherent connection between dynamics of systems with a size Earth and of size of liquid drop would have. The dependence of the liquid properties determining λ_F on the mass of the planet is totally unexpected and it could be that the classical model is wrong (this is the case in the case of turbulence).

Does the turbulence of air at the surfaces of the droplet and water bath prevent the coalescence?

The mechanism preventing the coalescence of the water droplet with water bath is poorly understood and here macroscopic quantum gravitation could enter the picture.

1. The magnetic flux tubes assignable to the non-dissipating exteriors of vortex cores with gradient flow around the axis of the vortex and assumed to carry Z^0 magnetic fields at their MBs are proposed to be present in microscopic scales also below the criticality for the development of turbulence. They would serve as a microscopic representation for the vorticity caused by the boundary conditions at the boundary of flowing liquid. The cores of Z^0 vortices would be monopole flux tubes and the shear would be concentrated at them.

2. In the recent case the boundaries are between air and liquid bath and air and liquid droplet and the dark matter at the magnetic bodies of air vortices could explain how the gravitational magnetic body characterized by $\hbar_{gr}$ enters into the physics of the moving water droplet.

3. The air layer and perhaps its separation from the surfaces of the liquid drop and liquid bath is analogous to the separation occurring in the generation of turbulence in a liquid flow past a solid body. The TGD based proposal is that in this case the formation of microscopic vortices plays a key role in the separation. The separation of the air layer prevents the touching of the droplet and fluid surface and the coalescence. Circular vortices of air flow analogous to smoke rings would represent the shear due to the radial variation of the vertical velocity component of air flow at the surface of liquid. They would also provide a representation for the separation.

4. The diameter of the circular vortex tube would be naturally $\lambda_F = \lambda_{gr}$. Could the spherical Faraday wave correspond to expanding concentric air vortex rings with radii coming as multiples of Λ_{gr} as a representation of the shear of air. Could they form the mattress preventing direct touch and coalescence?

Should one replace pilot wave with magnetic body?

In his talk Bush interprets the Faraday wave induced by the motion of the droplet along the surface as a kind of pilot wave providing a stastistical description of the system in long time scales resembling the description provided by Schrödinger amplitude. In particular, λ_F appears as a statistical signature in this description.

In the TGD framework the role of the pilot wave would be taken by the magnetic body (MB) of the system carrying $h_{eff} = nh_0$ phases quantum controlling the behavior of ordinary matter. In hydrodynamics magnetic flux tubes assigned with vortices would carry in their cores Z^0 magnetic fields proportion to induced Kähler form whereas the ordinary magnetic field vanishes.The exterior of the core would have vanishing Z^0 magnetic field but Kähler gauge potential would be gradient only in the exterior regions (note that symplectic transformations leaving induced Kähler form invariant are not genuine gauge transformations since they change the induce metric). The simplest model assumes that the Weinberg angle $p = sin^2(\theta_W)$ vanishes in this phase. The interpretation is that below the dark weak scale the electroweak symmetry breaking is absent.

What is encouraging, that the analog of rotation frequency Ω appears in the role of the magnetic field in several quantum-like phenomena discussed by Bush. The prediction is indeed that MB controls the fluid flow and that Ω, that is circulation, is proportional to B_Z whereas velocity is proportional to the vector potential of Kähler form. In one experiment, the instantaneous rotation frequency Ω around a "pillar" causes an analog of Lorentz force. In a second experiment the rotation frequency of the liquid bath gives rise to the analog of Zeeman splitting and analogs of cyclotron orbits.

Classical determinism is not exact

The analog of double slit experiment suggests classical non-determinism. Water drops with the same initial state (modulo measurement resolution) do not behave always in the same manner. If classical non-determinism were exact, this should not be the case.

The work with minimal surfaces [L155] demonstrated that classical non-determinism is probably not quite exact.

1. Space-time surfaces are analogous to soap films spanned by frames (which correspond to initial and final 3-surfaces plus intermediate partonic 2-surfaces) and already for soap films

the same frame can allow several soap films. Same occurs now but because of boundary conditions at boundaries of CD (perceptive field) the non-determinism is extremely restricted.

2. There is a finite, discrete non-determinism associated with what I identified as the TGD counterparts of reaction vertices and "very special moments in the life of self". This finite determinism would be the counterpart for quantum non-determinism for space-time surfaces inside a single CD.

3. This non-determinism could have as an adelic counterpart the non-determinism of p-adic differential equations due to the fact that integration constants as functions with a vanishing derivative are not genuine constants as in real case but depend on finite number of the pinary digits. This non-determinism would correspond to cognitive non-determinism having a real counterpart. This non-determinism would correspond to what I call cognitive determinism occurring for the representations of Galois group [L125, L135]

Therefore, if one has a beam of identical droplets in the initial state, they behave differently and one could obtain in the long run a representation for quantum mechanical interference pattern as an analog of the modulus square for a wave function.

Does quantum entanglement have a classical representation?

Can quantum entanglement be represented as a property of the space-time surface?

1. In the TGD framework quantum entanglement has a classical correlate/prerequisite. The flux tube pairs connecting particles as 3-surfaces would serve as prerequisites for the entanglement. This is analog ro ER-EPR correspondence: I actually proposed flux tubes instead of wormholes in GRT sense much before ER-EPR correspondence.

2. The reduction of entanglement in quantum measurement/SFR could correspond to the splitting of a flux tube pair connecting two systems to two U-shaped flux tubes associated with particles or more generally decay of the space-time surface representing systems in measurement interaction to two disjoint space-time surfaces.

   Putting the interaction Hamiltonian on could correspond to the formation of flux tube pair by reconnection and after that the usual description by unitary evolution would be a reasonable model.

3. Entanglement has also a purely classical analog. For instance, superposition of spherical harmonics for a classical field can be seen as an entangled state. At the level of WCW this is also possible.

4. The crucial notion is however the tensor product of Hilbert spaces. I find it impossible to imagine any classical counterpart for it. An entangled two-particle state can have as a classical prerequisite two 3-surfaces connected by flux tube but I am unable to imagine how entanglement could be representable for *single* space-time surface. One must allow quantum superposition of these pairs of this kind of 3-surfaces connected by a flux tube. One has entanglement in WCW degrees of freedom. WCW is needed for entanglement. I see no way to avoid this.

   By the way, in TGD quarks are the only fundamental particles. One does not have fundamental bosons although one can assign to the deformations of 3-surfaces analog of Kac-Moody algebra involving bosonic oscillator operators.

   Quark entanglement due to Fermi statistics is always maximal and cannot be reduced in SFRs: something totally trivial but not realized by most colleagues. Only entanglement at the level of WCW can be reduced. This came as a surprise also to me!

   The natural entanglement associated with hierarchies of normal subgroups of Galois groups can be reduced and is reduced in cognitive measurements to which SSFRs can correspond. Cognitive measurement cascades become possible. SSFR is a counterpart for analysis. BSFR is the intuitive eureka moment from the point of view of cognition [L125, L147].

Does Fermi statistics have a classical correlate?

A fermion with momentum p corresponds to a point of $X^4 \subset M^8$ and $M^8 - H$ duality as the TGD counterpart of momentum-position duality maps this point to a point at the 3-surface at either light-like boundary of CD in H depending on sign of the energy. One can put to the same point p several quarks with different spin or electroweak spin. This is not what one would want , that is one fermion per point.

What about twistor lift which provides a geometric description of spin as analog of partial waves in the twistor sphere: twistor space is indeed locally a product of space-time and twistor sphere S^2. Quantization axis of spin means a choice of one direction that is a point of S^2. But both the point and its diametric opposite give the same quantization axis. The interpretation would be that the two choices correspond to two spin directions for fermion. This makes sense for both spin and electroweak spin. The Fermi statistics would mean geometrically that a single point of twistor space can contain only a single fermion.

Twistor lift has a counterpart at the level of M^8 as I realized quite recently. At the level of M^8 twistor lift Fermi statistics would have a classical correlate at the M^8 level and would mean that one cannot put two fermions at the same space-time point. One can say that wave function is involved but there is a localization to a single point representing momentum p and spin.

18.5 Trying to understand viscosity and critical Reynolds numbers

It is interesting to see whether the critical Reynolds number could be interpreted in terms of criticality for the phase transition generation of dark flux tubes with $h_{eff} > h$ assignable to the flux tubes controlling vortices associated with them. One can also consider the possibility that the angular momenta of dark flux tubes and vortex compensate for each other.

18.5.1 The notion of viscosity

Kinematic viscosity (`https://cutt.ly/iRuXTsH`) for liquid can be fitted by using the expression

$$\nu(\frac{h}{m}, \frac{T}{T_b}) = \frac{h}{m} \times f(\frac{T_b}{T}) \quad , \quad f(\frac{T_b}{T}) = exp(3.6\frac{T_b}{T}) \quad . \tag{18.5.1}$$

(note that one has $c = 1$). T_b is the boiling point for the liquid and m is the average mass of the liquid particle. The expression makes sense between freezing point and boiling point. The model is ad hoc and it is not especially good. The two essential features are proportionality to h suggesting quantum origin the rapid increase with temperature below the boiling point.

From the tables of viscosity (`https://www.engineersedge.com/fluid_flow/kinematic-viscosity-table.htm`), one finds that a natural unit for viscosity is CentiStokes = 10^{-6} m^2/s. CS/c corresponds to a size scale about 3×10^{-15} m/s, which is about $2.3\lambda_p$ where λ_p is proton Compton length. The factor having an exponential temperature dependence brings in mind the inverse of Boltzmann exponent with $3.6T_b$ having a possible interpretation as the energy for a transition of some kind. The formula explains qualitatively the variation of ν by roughly 4 orders of magnitude. This would correspond to a variation of T_b/T by factor 2.9.

18.5.2 Critical Reynolds numbers

The value Re_{cr} of the critical Reynolds number for the laminar-turbulent transition varies in a wide range (`https://www.ecourses.ou.edu/cgi-bin/ebook.cgi?topic=fl&chap_sec=09.3&page=theory`).

1. For a fully developed pipe flow turbulence with pipe diameter D the value is $Re_{cr} \sim 2300$.
2. For a flow over a flat plate the transition from laminar to turbulent flow occurs at critical distance $D = x_{cr}$ downstream from the leading edge for $Re_{cr} \sim 5 \times 10^5$.

A hydrodynamical model predicts for the laminar flow past plate for the thickness of the liquid layer thickness δ as function of the distances x from the leading edge

$$\frac{\delta}{x} = \frac{5}{\sqrt{Re_x}} \quad , \quad Re_x \leq Re_{x_{cr}} \simeq 5 \times 10^5 \quad . \tag{18.5.2}$$

For a turbulent flow past a flat plate of finite length L, the prediction is

$$\frac{\delta}{x} = \frac{.38}{Re_L^{1/5}} \quad , \quad 5 \times 10^5 \leq Re_L < 10^7 , \tag{18.5.3}$$

Above $Re_{cr} = 10^7$ only a thin boundary layer forms and the flow develops a thin wake.

Critical Reynolds number as a measure for the ratio of units of angular momentum for the final and initial state

The critical Reynolds number could be essentially a measure for the ratio of the units of dark and ordinary angular momentum. The following estimate suggests that this might make sense.

In the case of laminar flow and using the formulas above, one can estimate the angular momentum associated with a particle of flow as

$$L = m\delta \times U \quad , \quad \delta = 5\sqrt{\frac{\nu}{u}}\sqrt{x} \quad . \tag{18.5.4}$$

Here x is the length measured from the leading edge of the plate.

At the critical value of $\delta/x = 5/\sqrt{Re_{cr}}$ one cast this equation into the form

$$L = 5m \times Re_{cr}\nu \quad . \tag{18.5.5}$$

$L = \hbar_{eff}$ would give for the transition

$$Re_{cr} = \frac{\hbar_{eff,f}}{\hbar_{eff,i}} \quad \text{for} \quad \hbar_{eff,i} = 5m\nu \quad . \tag{18.5.6}$$

The estimate is of course very rough. What is however essential that the identification of kinematic viscosity in terms of h_{eff} could make sense.

Note that one can associated to the vortex a Reynolds number

$$Re_V = \frac{U\delta}{\nu} = \frac{\delta}{D} \times Re_{cr} = 5Re_{cr}^{1/2} \quad . \tag{18.5.7}$$

18.5.3 Laminar-turbulent transition as a quantum phase transition?

Could one understand the laminar-turbulent phase transition in terms of quantum hydrodynamics at the level of MB in terms of the formation of $h_{eff} > h$ flux tube structures accompanying the vortices?

1. Suppose that the kinematic viscosity related to angular momentum it makes to speak of "dark" viscosity ν_{dark} and that ν_{dark} decomposes to a product $\hbar_{eff}/m$ with the same temperature dependent factor $f(T/T_b)$ as the ordinary ν. Assume that the critical Reynolds number $Re = UD/\nu$ corresponds to a phase transition $h \rightarrow h_{eff}$ making possible a formation of vortices accompanied by pairs of monopole flux tube associated with the core of vortex and non-monopole Lagrangian flux tubes associated with the exterior of the vortex.

2. The transfer of angular momentum from the main flow to vortices is enough to take care of angular momentum conservation. Also the quantized dark angular momentum $m\hbar_{eff}$ at MB could compensate for the angular momentum of the vortex. In this case, the angular momentum of vortices could be considerably larger than one might estimate from the change of the angular momentum of the main flow. This option is of special interest in astrophysical systems.

3. Could the parameter UD at criticality have an interpretation as minimal angular momentum $\hbar_{eff}/m$ for the vortex? Could it be that the angular momentum of the fluid particle of the flow in the region $x \geq x_{cr}$ has angular momentum larger than $\hbar_{eff}$ so that dark magnetic flux tube so that the particle can transform to its dark variat at magnetic flux tube.

The basic question is what the fluid particle is. The intuitive picture is that the increase of viscosity means increase of the fluid particle mass and thus interia. The size of the fluid particle would be caused by the increase of h_{eff} at the MB controlling the ordinary matter in the flow.

If dark matter is formed it could emerge as fluid particles with mass larger than say proton mass which appears as factor h/m in the formula for ν involving also temperature dependent factor increasing at higher temperatures. The increase of the kinematical viscosity ν could mean that the mass m_f of a fluid particle increases with temperature. Suppose that one has $\nu(T/T_b) = \hbar_{eff}(T)/m_f(T)$. If ν would not depend on temperature one would have $\nu(T/T_b) = \nu(1)$, and $\hbar_{eff}(T)$ should be proportional to $m_f(T)$. This is of course not true since the $\nu(T)$ increases with the decreasing temperature. In the range between boiling point and freezing point the change is not however very large.

One should have

$$\frac{f(T/T_b)}{f(1)} = \frac{\hbar_{eff}(T)}{\hbar(T_b)} \times \frac{m(T)}{m_f(T_b)} \geq 1 \ . \tag{18.5.8}$$

The increase of the viscosity would be indeed due to the formation of larger mass units due to long range correlations induced by MB with larger value of h_{eff}.

18.5.4 Nottale hypothesis and turbulence

Nottale hypothesis states that it makes sense to talk about gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where M can be the Earth's mass M_E. The gravitational Compton length is given by $\Lambda_{gr} = \hbar_{gr}/m = GMm/v_0 = r_s/2\beta_0$. The "gravitational" kinematic viscosity would be given by $\nu_{gr} = \Lambda_{gr}c$ and independent of the mass m of the fluid particle unless β_0 does not depend on it.

Λ_{gr} does at all on the particle mass. This looks strange. The ratio $m_p/m_e = 1880$ is near to $2^{11} = 2048$ appearing defined by $v_0 = simeq 2^{-11}$ in the Nottale's model for the 4 inner planets. This inspires the question whether the proportionality $\beta_0 = m/m_p$ might hold true approximately and realize approximately the expectation that gravitational Compton length is proportional to $1/m$. For instance, could β_0 correspond to the ratio of the p-adic length scales $L(k) \propto 2^{k/2}$ for proton and for the particle with mass m. For the electron one has $k = 127$ and for proton $k = 107$ so that the prediction would be $\beta_0 = 2^{-10}$ and by factor 2 too large.

Interestingly, for a neutrino mass about .1 eV this hypothesis would give $\Lambda_{gr} \sim 200$ AU which is the length of the heliospheric magnetotail at the side of the downwind.

Encouraging observations

There are several encouraging observations.

1. Λ_{gr} for Earth appears both the TGD based model of superconductivity [L131] and in the model for the hydromic quantum analogues as a correct prediction for the Faraday wavelength.

   Λ_{gr} could relate to the length or radius of the vortex. Since the MB of the system is responsible for the generation of coherence as induced quantum coherence, the simplest interpretation would be in terms of the length of the dark magnetic flux associated with the vortex.

2. The Nottale model for the inner planetary orbits assumes $\beta_0 \simeq 2^{-11}$. From Schwartscild radius of Sun one has for the gravitational Compton length of Sun $\Lambda_{gr}(Sun) = GM_{Sun}/v_0 = 6$ Mm to be compared with the radius $R_E = 6.4$ Mm of Earth. This would suggest a dark graviton BEC in the scale of Earth and a deep connection between the gravitational physics of Earth and Sun.

In MHD, magnetotail is analogous to a wake of hydrodynamic flow past a body. The length of the magnetotail is about $D_R \simeq 10^3 R_E$: "10^3" suggests that $\beta_0 = 2^{-11}$ appearing in $\hbar_{gr}$ for the inner planets is involved.

If the parameter UD appearing in Re corresponds $\nu_{gr} = \hbar_{gr} c/m\Lambda_{gr} c$, one has $D = \Lambda_{gr} c/U$. The velocity U of the solar wind varies in the range 300-800 km/s, that is $U/c \in \{2 - 5.4\} \times \beta_0$, where $\beta_0 = 2^{-11}$, which is perhaps not an accident. $U = 4 \times 10^2$ km/s serves as a nominal value. $\Lambda_{gr}(Sun) = 6 \times 10^3$ km for $\beta_0 = 2^{-11}$ and for the nominal value of U gives the estimate $D = 700 R_E$ to be compared with $D_R \sim 10^3 R_E$.

One can look at the situation also in the case of solar magnetotail. The solar magnetotail has length about $D_R = 200$ AU ($AU \simeq 2.3 \times 10^4 R_E$) at the downside of the flow. The center of the Milky Way could contain the source of the galactic wind defining the mass M appearing in $\hbar_{gr}$. One can imagine two options.

1. The mass appearing in $\hbar_{gr}$ for the galaxy could be the total mass M_{MW} of the Milky Way. The estimates forM_{MW} vary in the range $M_{MW}/M_{Sun} \in [10^{11} - 10^{12}]$ and are based on the halo model of dark matter. Dark energy and matter are estimated to contribute about 95 per cent to the mass of the Universe.

   In the TGD framework, the flat velocity spectrum for stars rotating around galaxies is explained in terms of dark cosmic strings predicting automatically flat velocity spectrum. Since the galactic wind from the galactic jet emerging from the galactic blackhole-like entity should not affect to the gravitational field associated with solar magnetotail, the estimate for the visible mass of the galaxy reduces by a factor $\sim .05$ to $M(M_{MW}/MSun = 5.0 \times 10^{10}$ giving for the Schwarschild radius the estimate $r_S(MW) = 15 \times 10^{10}$ km. The estimate for the ratio $r_{S,MW}/D_R$ is $r_{S,MW}/D_R = 5.0$.

   The estimate of the ratio D_{pr}/D_R for the predicted value D_{pr} of D is

$$\frac{D_{pr}}{D_R} = \frac{r_{S,MW}}{D_R} \times \frac{c}{U\beta_0} \simeq 5 \times \frac{c}{U\beta_0} \quad .$$

   By $c/U\beta_0 \geq 1$, $D_{pr}/D_R \geq 5$ is true even for ($\beta_0 = 1, U = c$). Of course, the idea that the galactic wind would blow with the speed of light, does not seem plausible.

2. The galactic wind could correspond to a galactic jet emerging from the blackhole-like entity in the center of the Milky Way having mass about $4 \times 10^6 M_{Sun}$. In this case, r_S is reduced by a factor 10^{-6} and one obtains $D_{pr}/D_R = (r_{S,MW}/D_R) \times (c/U\beta_0) \simeq 10^{-6} \times (c/U\beta_0)$. If $\beta_0 = 2^{-11} \simeq m_e/m_p$ appears as a universal parameter then a good guess is ($\beta_0 = 2^{-11}, U/c = \beta_0$). For this guess, the ratio equals unity.

Remark: The mass of the Moon is $.012 M_E$. For $\beta_0 = 1$, this would correspond to $\Lambda_{gr} \simeq 10^{-4}$ m, which could be some biological length scale.

Does the transition to turbulence correspond to a large change of h_{eff}?

The simplest option is that the variation of β_0 explains the temperature variation of kinematic viscosity in terms of a slow variation of $\hbar_{eff} \leq\leq \hbar_{gr}$. h_{gr} is not a plausible candidate for understanding the kinematic viscosity but can be replaced with its electromagnetic analog $\hbar_{em}$ or Z^0 analog $\hbar_Z$. Z^0 option is attractive in hydrodynamics whereas the electromagnetic analog might have a role in MHD.

In the transition to turbulence, a dramatic change of h_{eff} seems to take place.

1. Are both $\hbar_{eff}$ and the mass m_f of the fluid particle scaled up by Re_{cr} so that ν would remain invariant? In the case of $\hbar_{gr}$ this would be naturally the case.

2. Is only $\hbar_{eff} = \hbar_{gr}$ scaled up by Re_{cr} so that $\nu = \hbar_{eff}/m_f$ would be scaled up by Re_{cr}? If one accepts the notion of gravitational quantum coherence, one can consider the change of M and Earth mass M_E and solar mass M_{Sun} appear as natural candidates.

Could critical Reynolds numbers be understood in terms of the Nottale's hypothesis and its generalization?

One can try to understand the two critical Reynolds numbers in terms of $\Lambda_{gr} = GM/v_0$. Assuming Nottale's formula and the proposed connection between $\hbar_{eff}$ and ν, the ratio M/β_0 would change at criticality by factor Re_{cr}. The masses of Earth and Sun are natural candidates to consider. The critical quantum numbers depend on the geometry of the flow but this could be explained by the change of β_0.

1. For the pipe flow, one has $Re_{cr} = 2300$. Perhaps it is not a mere accident that $Re_{cr} = 2300$ is not too far from $1/\beta_0 = 2^{11} = 2048 \sim m_p/m_e$ associated with the inner planets of the Solar system. If the initial state corresponds to $\beta_0 \simeq .92$ for the initial state as suggested by the model for the quantum-like aspects of hydrodynamics, one has $Re_{cr} = 2226$ and the error .5 per cent.

   Could the transition to a turbulent pipe flow correspond for the final state to $\beta_0 \simeq 1 \to 2^{-11}$ for $\Lambda_{gr} = GM_{Sun}/\beta_0 \simeq 3.2km$, $\beta_0 \simeq .9$ so that one would have $\Lambda_{gr} \simeq R_E$ after the transition. The Earth's crust has thickness between 5-70 km: could this variation relate to the variation of β_0 in range $(.64, .045)$?

2. Consider next the flow past a planar object with $Re_{cr} = 5 \times 10^5$. The ratio of the masses of Sun and Earth is $M_{Sun}/M_E \simeq 3 \times 10^5$, which is not far from $Re_{cr} \sim 5 \times 10^5$. Could $Re_{cr} \sim 5 \times 10^5$ correspond to a phase transition $M_E \to M_{Sun}$ and $\beta_0 \simeq 1 \to 3\beta_0/5$?

M_E, M_{Sun}, and the values $\beta_0 \simeq 1$ and $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ could appear in the model for the transition to turbulence. The dependence of the Re_{cr} for the pipe flow on the mass of the planet is a rather dramatic prediction, and could kill the proposal.

The natural assumption is that the gravitational flux tubes have length Λ_{gr} so that the phase transition would mean emergence of longer flux tubes corresponding to the gravitational Compton length hierarchy $\Lambda_{gr} \in \{.1 \ \ m, 3.2 \ \ km, 644 \ \ Mm\}$.

Needless to emphasize, these proposals are only a light-hearted thought game taking seriously the notion of macroscopic quantum gravitational coherence.

18.5.5 Trying to understand kinematic viscosity

The model for the hydrodynamical quantum analogs leads to a proposal, which is completely crazy from the reductionistic point of view and looks like a return to astrology. The motivation is that the Faraday wave length λ_F appearing as analog of Compton length equals the gravitational Compton length associated with the gravitational Compton length associated with the gravitational Planck constant proposed by Nottale [E9].

Kinematic viscosity cannot be described in terms of $\hbar_{gr}$ for the masses of Earth and Sun

The first thing to notice is that ν_{gr} is several orders of magnitude larger than kinematic viscosity.

One obtains for ν_{gr}

$$\nu_{gr} = \Lambda_{gr} c = \frac{GMc}{\beta_0} = \frac{r_s c}{2\beta_0} \ . \tag{18.5.9}$$

This corresponds for Earth's mass $M = M_E$ and $\beta_0 = 1$ to the Schwarshild radius 0.87 cm of Earth. This scale is by a factor roughly 10^{13} times longer than the Compton length of proton assignable to CentiStoke 10^{-6} m^2/s as a unit of kinematic viscosity.

Therefore the value of ν_{gr} is however very large as compared to the values of ν for ordinary liquids and the reduction of β_0 would make the value of ν_{gr} even larger. Therefore ordinary viscosity cannot correspond to $\hbar_{gr}$ for any astrophysical mass.

One can of course ask, whether h_{eff} could correspond to $\hbar_{gr}$ but for a smaller non-astrophysical - say mass M of some geological unit or of a unit assignable to atmosphere. Note that the variationof β_0 could allow us to understand the dependence on temperature.

Could one understand kinematic viscosity in terms of masses of geological or atmosperic objects?

Could one understand kinematic viscosity in terms of masses of geological or atmosperic objects?

1. As already noticed, the decrease of the velocity parameter β_0 with temperature perhaps related to the decrease of thermal velocity could be enough to explain the temperature dependence of ν. This raises the question whether the basic scale for ν could be set by some natural astrophysical or geological mass.

2. For M_E, one has $\Lambda_{gr} \simeq 10^6$ m^2/s whereas centiStoke as natural unit of η is 10^{-6} m^2/s and defines lower bound for it (the range of variation is 4 orders of magnitude) so that the mass M for ν should be smaller than M_E by 8-12 orders of magnitude. Therefore only geological objects appearing as basic building bricks of Earth's crust can be considered. Note that also β_0 appears as a parameter.

   The size scale L of an object of density $\rho_{ave} \sim 5.5 \times 10^3$ kg/m^3 with mass $M \sim 3 \times 10^{-13} M_E$ corresponding to $\nu = 1$ centiStoke would be about $L = 640$ m. There is no obvious identification.

   Could the object in question correspond to an atmospheric basic unit? The density of air is 1.2 kg/m^3 so that the size scale of the object would be 32 km. Note that the eye of the hurricane has a radius 16-32 km.

The basic objection is that the value of the kinematic viscosity would depend on local physics at Earth and this seems highly implausible.

It seems that one must distinguish between classical hydrodynamics assignable with ordinary matter with $h_{eff} = h$ and quantum hydrodynamics assignable to dark matter with $h_{eff} > h$. In particular, one must distinguish between quantum gravitational aspects of hydrodynamics assignable to $\hbar_{gr}$ involving mass of Earth or Sun.

18.5.6 Also the notions of $\hbar_{em}$ and $\hbar_Z$ make sense

It is of course not necessary to assume $\hbar_{eff} = \hbar_{gr}$. One can also consider the electromagnetic and weak variants of $\hbar_{gr}$.

1. For hydrodynamics, dark Z^0 interaction looks natural and one would have $\hbar_Z/\hbar = Q_Z 4\pi\alpha_Z/\beta_0$, where $Q_Z = N$ is the total Z^0 charge the number of elementary particles with Z^0 charge giving rise to the particle. Z^0 would be effectively massless below dark weak length scale.

   In the electromagnetic case, one has $\hbar_{em}/\hbar = Q_{em} 4\pi\alpha/\beta_0$. A highly interesting possibility suggested by the model of the vortices is that electroweak symmetry breaking is absent for the Lagrangian MB controlling the region of vortex exterior to the core (one would have $p = sin^2(\theta_W) = 0$). This raises the question whether electromagnetic and Z^0 situations are equivalent in this case.

2. These formulas make sense only for $\hbar_{em}/\bar{>}1$ and $\hbar_{em}/\bar{>}1$ and this gives the following criterion for darkness

$$\begin{array}{l} Q_Z \geq \frac{\beta_0}{4\pi\alpha_Z} \ , \\ Q_{em} \geq \frac{\beta_0}{4\pi\alpha_{em}} \ , \end{array} \tag{18.5.10}$$

   In the electromagnetic case and for $\beta_0 = 1$, the transition would take place for completely ionized atoms with charge $Q_{em} > 10$. Natrium with $Z = 11$ would be the first dark completely ionized atom (ionization energy for the ground state electron is about 1.645 keV). Dark proton sequences at flux tubes consisting of dark proton triplets realizing genetic code would be the basic example from TGD inspired quantum biology [L194, L137, L135].

   The interpretation would be that when a perturbation series fails to converge, a phase transition takes place. The new coupling strength is $Q_{em}e^2/\hbar_{em}$ resp. $Q_Z g_Z^2/\hbar_Z$ and is equal to

$v_0/4\pi$ so that the perturbative expansion is universal and has the same coupling strength for all interactions. This conforms with the assumption that all classical fields are induced from the geometry of the embedding space.

Also now one can define dark Compton lengths for electromagnetic and Z^0 ions as

$$\Lambda_{em} = \frac{\hbar_{em}}{m} \ , \tag{18.5.11}$$

$$\Lambda_Z = \frac{\hbar_Z}{m} \ , \tag{18.5.12}$$

$$\tag{18.5.13}$$

where m is the mass of the em or Z^0 charged particle at the flux tube. One can of course ask whether the notion of Z^0 makes sense.

The em charged particles at flux tubes could be protons or biologically important dark ions as proposed in the TGD based model for quantum biology. There would be $N = Q_{em}$ dark protons associated with or at the flux tube so that their density is $\Lambda_{eff}/\lambda_c(m)$. Similar interpretation applies in the Z^0 case.

If em and weak interactions are dark at gravitational flux tubes, the weak scale is scaled up by $h_{gr}/\hbar$ to $10^{-4}\ m, 3\ m, 6\ km\}$ corresponding to various dark gravitational Compton lengths. Therefore one could regard neutrons and protons as having weak Z^0 charge since the weak charge of neutrons is 50 times larger than that of protons. Dark neutrinos would be responsible for the screening of weak charge of dark nuclei.

Could one understand hydrodynamical viscosity and magnetohydrodynamical diffusivity in terms of $\hbar_{em}$ and $\hbar_Z$?

The variation of hydrodynamical kinematic viscosity could have explanation in terms of the variation of β_0. The basic units with Z^0 charge $Q_Z = Nq_z$ could correspond to vortex like entities. For gases one would have $\hbar_{em} = \hbar$ and dark matter would have no role in the dynamics.

For MHD plama the the picture would be similar and one can consider vortex like units and plasmoids as basic units with charge Q_{em}. TGD counterparts would be magnetic and Z^0 magnetic flux tubes: here one can consider the core of the vortex as a monopole flux tube or its exterior and Lagrangian flux tube.

Consider the kinematic viscosities.

1. Consider first the Z^0 case. The Z^0 charges of proton and neutrino are by a factor about 1/50 smaller than those of proton and electron. Stability requires that the weak charges of neutrinos and dark nuclear neutrons sum up to zero. It is convenient to talk about the length scale

$$L_\nu = \frac{\nu}{c} = \frac{\hbar_Z}{m} = \frac{4\pi\alpha_Z q_z^2 N}{\beta_0}\frac{\hbar}{m} \ . \tag{18.5.14}$$

   Here N is the number of dark Z^0 charge carriers at magnetic flux tube.

   The already described formula for the kinematic viscosity reads as $L_\nu = \lambda_c(n) \times f(T/T_b)$. This suggest the identification as $\hbar_{eff}/\hbar = f(T/T_b)/f(1)$, $f(1) = exp(3.6) \simeq 16.3$. At boiling point and above it one would have $\hbar_{eff}/\hbar = 1$.

   This would give for $m = m_n$ the following formula

$$N = \frac{1}{4\pi\alpha_Z q_Z^2} \times \beta_0 \frac{f(T/T_b)}{f(1)} \ . \tag{18.5.15}$$

N would be the total number of neutrons with Z^0 charge q_Z within volume defined by the scale L_ν. If one has $\beta_0 = k\frac{f(T/T_b)}{f(1)}$, N is constant and L_ν scales like $1/\beta_0$. Could N correspond to the number of neutrons for a dark atomic nucleus with $\hbar_{eff}/\hbar = \frac{4\pi\alpha_Z q_z^2 N}{\beta_0}$? The decrease of β_0 would increase quantum correlation length and viscosity.

2. Electromagnetic case can be treated in similar way.

Could dark quantum coherence scales for dark gravitation, dark Z^0 and dark em interaction be identical?

Could dark em, and Z^0, and gravitational quantum coherence scales be identical in some situation? Could this condition make possible astrophysical quantum coherence and symmetry restoration of electroweak interactions at the level of MB?

The general conditions for the equality of the quantum coherence scales are as follows.

$$\begin{aligned}
\Lambda_{em} &= \Lambda_Z = \lambda_{gr} \ , \\
\Lambda_{em} = \frac{\hbar_{em}}{m_e} &= \frac{e^2q^2N_p}{\beta_0}L_{c,e} \sim \frac{10^{-2}N_p}{\beta_0} \times 2\times 10^{-12} \ \ m \ , \\
\Lambda_Z = \frac{\hbar_{em}}{m_\nu} &= \frac{e^2q^2N_n}{\beta_0}L_{c,\nu} \sim \frac{10^{-2}N_n}{\beta_0} \times 10^{-6} \ \ m \sim \Lambda_{gr} \ , \\
\Lambda_{gr} &= \frac{GM}{\beta_0} \ , \\
(M,\beta_0) &\in \{(M_E,\beta\simeq 1),(M_{Sun},\beta_0\simeq 1),(M_{Sun},\beta_0\simeq 2^{-11})\} \ .
\end{aligned} \tag{18.5.16}$$

This gives the conditions

$$\begin{aligned}
N_p &= \frac{\beta_0}{e^2q^2}\frac{\Lambda_{gr}}{L_{c,e}} \ , \\
N_n &= \frac{\beta_0}{g_Z^2q_Z^2}\frac{\Lambda_{gr}}{L_{c,\nu}} \ .
\end{aligned} \tag{18.5.17}$$

This gives for $\Lambda_{gr} \in \{1.0 \ \ cm, 3.2 \ \ km, 6.4 \ \ Mm\}$.

$$\begin{aligned}
N_p &= \frac{4\pi\beta_0}{\alpha e^2}\frac{\Lambda_{gr}}{L_{c,e}} \in \frac{4\pi\beta_0}{\alpha e^2} \times \{.5\times 10^{10}, 1.6\times 10^{15}, \\
N_n &= \frac{4\pi\beta_0}{\alpha_Z q_Z^2}\frac{\Lambda_{gr}}{L_{c,\nu}} \in \frac{4\pi\beta_0}{\alpha_Z q_Z^2} \times \{2.5\times 10^{16}, 8.0\times 10^{21}, 1.8\times 10^{25}\} \ .
\end{aligned}$$

The only natural interpretation is that these scales correspond to flux tube lengths. Assume that one has $\beta_0 = 1$.

1. For $\beta_0 = 1$, the density of protons would be in all three cases about 5×10^{12} per meter: of order 2 protons per electron Compton length. This is of the same order of magnitude as deduced for the density of dark protons in magnetic flux in the model of "cold fusion". For $\beta_0 = 2^{-11}$, where would be roughly one proton per 10^{-8} m, this is the p-adic length scale $L(151)$ and thickness of neuronal membrane.

2. For the Z^0 case with $\beta_0 = 1$ the density of neutrons would be roughly 2.5×10^{15} per meter for all options so that there would be one neutron per length 4×10^{-16} m. The Compton

length of the neutron is $\lambda_n = 3.8 \times 10^{-16}$ m so that there would be roughly 1 neutron per neutron Compton length. This suggests that nuclear flux tubes are in question for $\beta_0 = 1$.

If one assumes that $\beta_0 = 2^{-11} \simeq m_p/m_e$, the density would be roughly 1 neutron per electron Compton length. The TGD based proposal for solar cores is that they correspond to this kind of nuclear flux tubes.

Both dark neutrinos and neutrons and dark electrons and protons would neutralize each other. This suggests a connection with Pollack effect [L24] in which part protons of water molecules form sequences at dark flux tubes in the presence of a metabolic energy feed. Every fourth water molecule would give one proton which would be transformed to dark proton. Pollack effect is the cornerstone of the TGD inspired model of quantum biology [L194]. In the recent case, the flow would provide the energy needed to transform the protons to dark protons.

Gravitational de-Broglie wavelength and hydrodynamic length scale hierarchies

It is possible to define quantum gravitational de-Broglie wavelength as

$$\Lambda_{gr,dB} = \frac{\hbar_{gr}}{m(v/c)} = \frac{GM}{\beta_0\beta} = \frac{r_s}{2\beta_0\beta} \quad . \tag{18.5.19}$$

The length scale $UD/c = \Lambda_{gr}$ suggests $D = \Lambda_{gr}c/U)$ giving $D = \Lambda_{gr,dB}$ for $v = U$ proposed to correspond to the length of magnetopause as an analog of wake in MHD.

In TGD, the p-adic length scale hierarchies $L_p \propto p^{1/2}$ assignable to $p \simeq 2^k$ for some integers k, play a central role [K70]. $p = 2$ defines length scale hierarchy in powers of $\sqrt{2}$ giving as a sub-hierarchy in powers of 2, which could correspond to a hierarchy of period doublings in approach to chaos.

This raises interesting questions.

1. Could this kind of hierarchy correspond to a hierarchy $\beta_{0,n} = p^{-n}\beta_{0,1}$ giving a period doubling hierarchy for $p = 2$? The velocity hierarchy and the associated length scale hierarchy would respect UP. Could the vortex lengths or radii for vortex hierarchies in hydrodynamic turbulence be described in this manner?

2. Could $\beta_0(Sun) \simeq 2^{-11}$ correspond to $\beta_{0,11}$ level for $\beta_{0,1} \simeq 1$. As found, $\beta_{0,1} \simeq .92$ predicts correctly the Faraday wavelength for hydrodynamic quantum analogs. For $\beta_{0,1} = .94$, $R_E = \Lambda_{gr,Sun}$ holds true exactly. For $\beta_{0,1} = .89$ $Re_{cr} = 2300$ for critical Reynolds number in pipe flow is predicted.

The original motivation for the Nottale hypothesis comes from the Bohr orbit model of the planetary system. This model involves an ad hoc feature. For the outer planets of the solar system, one must assume $\beta_0(out) = \beta_0(in)/5$. $p = 5 = 2^2 + 1$ is prime but not near a power of 2. Another interpretation is that β_0 is not changed but the principal quantum numbers come as $n = 2, 4, 5, 6$ for the 4 inner planets and as $n = 5k$ for $k = 2, ..., 6$, for the outer planets. Earth could be interpreted as an inner or outer planet.

This would suggest a secondary hierarchy in powers of 5 and $\beta_{0,1} = \beta_0(Sun)$.

Could 2-adic fractality conform with this rule? Could the rule be that the allowed 2-adic length scales proportional to $2^{k/2}$ must be as near as possible to the radius of an elliptic Bohr orbit for the principal quantum number n satisfying the Bohr conditions. For an elliptic orbit, the radius of the orbit could be defined as the geometric mean $\sqrt{ab}$. This condition also predicts the ellipticity of the orbit.

The fractal orbits with radii $r \propto 2^k$, $k = 3, 4$ have radii proportional to $2^3 = 8, 2^4 = 16$ and fit rather satisfactorily with the circular Bohr orbits with $n = 3, 4$ and radii proportional to $3^2 = 9, 4^2 = 16$ (Mercury and Venus). Earth and the outer planets would correspond to $2^{k+4+1/2}$ $k = 0, 1, ..6$ with $2^{4+1/2} \simeq 22.6$ as an approximation of $n^2 = 25$ for $n = 5$ orbit (Earth) in the Bohr model: the 2-adic length scale is 10 per cent smaller than the prediction of Bohr model for a circular orbit.

Since the inner and outer planets seem to be separate systems, one can consider the possibility that $\beta_{0,1}(out)$ for solar-planet gravitational flux tubes satisfies $\beta_{0,1}(out) = 1.1\beta_{0,1}(in)$. This requires $\beta_{0,1} \leq .9$. The values $k/2 \in \{2, 3, 4, 4 + 1/2, 5, 6\}$ would provide a reasonable fit for the outer planets and would correspond to $n \in \{1, 2, 3, 4, 5, 6\}$.

Remark: The Bohr orbits are assumed to correspond to magnetic flux tubes carrying dark matter delocalized along the orbit. The wave function for the dark matter BEC along the orbit could be a restriction of the 3-D hydrogen wave function at the orbit. For a circular orbit the angular dependence would be trivial in accordance with the interpretation that the angular momentum vanishes for these orbits in a quantum sense. Ordinary matter would be localized at the orbit and perform classical motion.

18.6 Why don't airplanes fall down?

Why do airplanes not fall down? Surprisingly, the physics of this phenomenon still remains poorly understood. In the sequel, a quantum hydrodynamics based proposal for the solution of the problem is discussed.

18.6.1 Some Background

I learned of an interesting step of progress in the description of the fluid flow over a lifting airfoil (`https://cutt.ly/mLHg3bh`) from a popular article "Pursuit of useless knowledge leads to a new theory of lift" (`https://cutt.ly/mLHg7gh`). The theory of Haithem Taha and his student Cody Gonzales is described in the article "A Variational Theory of Lift" [D82] (`https://cutt.ly/nLHheYH`).

What causes the lift on flying object?

The challenge is to explain the lift in terms of hydrodynamics. Surprisingly, this problem is still poorly understood mathematically and perhaps also physically. We do not understand why airplanes do not fall down! Partial progress in the understanding of the problem has however occurred.

1. Lord Rayleigh found the exact solution for a 2-D potential flow around an open disk. The incompressibility condition implies that the potential for the flow satisfies Laplace equation. The boundary condition is that the flow is tangential and the fluid and body move with the same velocity at the surface.

   By the conformal invariance of the Laplace equation, the problem can be solved for a general cross section of the object by mapping the geometry to that of the cylinder. The solution is however not unique: one can add to the flow vortices, which are irrotational except at the core of the vortex. The vortices appear in the real flow above the critical value of the Reynolds number and are essential for the occurrence of lift. The problem is to understand the generation of the distribution of the vortices. As a matter of fact, the generation and decay of turbulence as the generation and decay of vortices is an unsolved problem of hydrodynamics [L146].

2. Kutta's formula meant a progress in the understanding of the lift force. Kutta-Joukowski theorem assumes that the lift is caused by a single vortex surrounding an airfoil (`https://en.wikipedia.org/wiki/Airfoil`) and gives an explicit formula for the lift force. The lift force is identified as Magnus force (`https://cutt.ly/ALHhy1H`) L per span l on a fixed airfoil or any infinite 2-D shape with a rear becoming infinitely think at large distance is given by $\rho_\infty v_\infty \Gamma$. ρ denotes the density of the fluid. Γ is the velocity circulation around the object outside the viscous region (`https://cutt.ly/LLHg1Zy`). The interpretation is that the lift force is due to the viscosity.

   The formula of the lift force given by Kutta-Joukowski theorem holds true for a general geometry but conforms with empirical findings only in very special geometries in which the trailing edge of the wing is very sharp.

A variational principle for lift

Instead of Euler equations, which are essentially Newton's equations, Taha and Gonzales [D82] (https://cutt.ly/nLHheYH) propose a variational principle. One assumes a single vortex also now and the variational principle involves the circulation Γ as a single variational parameter, whose value is fixed by the minimization of the analog of action. There is no attempt to describe the generation of the vortex or its generation.

1. The variational principle at single particle level is Hertz's principle of least curvature (or acceleration). The analog of action, known as Appellian, is a 3-D integral of a quantity obtained from kinetic density by replacing velocity with acceleration: $\rho v^2/2 \rightarrow \rho a^2/2$. More generally, the deviation from the extremal of an action principle would be minimized instead of the action itself. This would allow non-extremals near to extremals.

   This gives as a special case solutions of Euler equations. Energy conservation must be assumed separately.

2. In the particle description there are two kinds of forces: external forces F_i and constraint forces R_i. In this situation, Gauss's Principle states that the quantity to be minimized is $\sum_i (m_i/2)(a_i - F_i)^2$. The constraint forces are eliminated by allowing a more general variational principle. At the continuum limit one obtains instead of sum a volume integral.

3. Hertz's principle is obtained by putting $F_i = 0$. Equivalently, force density f vanishes. For a steady state hydrodynamical flow the acceleration can be expressed as $a = v\cdot\nabla v + \nabla p + g$. In the approximation $f = (\rho(\nabla p + g) = 0$, one indeed obtains Hertz's principle.

4. One can start from an incompressible potential flow and add vortices to it. The simplest example is a single vortex rotating around a planar object, which is conformally related to a cylinder. In this case one has $u(\Gamma) = u_0 + \Gamma u_1$, where u_0 is a solution of the Laplace equation in absence of vortices representing potential flow and u_1 is a vortex solution with unit vorticity.

   The vorticity is given as $\Gamma = \oint u \cdot dl =$ (only u_1 contributes and gives $\oint u_1 \cdot dl = 1$). The integral is taken over a flow line around the object but staying outside the surface layer where the flow is not gradient flow fails. Note that one stays away from the region where the viscosity matters.

5. The varied quantity is known as Appellian

   $$S(\Gamma) = \frac{\rho}{2}\int a^2 dV = \frac{\rho}{2}\int [u(\Gamma)\cdot\nabla u(\Gamma)]^2 dV \quad ,$$

   where one has $a = v\cdot\nabla v$. One takes vorticity Γ as the basic variable and minimizes Appellian S with respect to the value of Γ.

6. This approach works in the general case and predicts the value of the vorticity and therefore also the lift force by Kutta-Joukowksi formula (https://cutt.ly/LLHg1Zy).

In the following I will consider a TGD based microscopic model for lift assuming that the generation of the vortex is involved. The TGD based model involves new physics but is consistent with the model of Taha and also fixes the circulation of the vortex.

18.6.2 Some TGD inspired quantum hydrodynamics

The TGD inspired model for the lift involves the basic ideas of quantum hydrodynamics and these are discussed first.

h_{eff} hierarchy and the analogy with super-conductivity and super-fluidity

If the velocity field v is proportional to a gauge potential as in super-conductivity, the quantization of the circulation as quantization of angular momentum fixes the value of the parameter Γ and Kutta-Joukowski formula gives the value of the lift force.

1. The TGD based view of hydrodynamics involves macroscopic quantum coherence in an essential manner. Magnetic body consisting of magnetic flux tubes carrying ordinary particles as $h_{eff} = nh_0$ phases of ordinary particles is the role of controller of ordinary matter. In particular, gravitational Planck constant $\hbar_{gr} = GM_E m/v_0$ defining gravitational Compton length $\Lambda_{gr} = GM/v_0$ corresponds to the largest dark scale and would be important at quantum criticality accompanying ordinary thermodynamic criticality.

   The induced Kähler form decomposes to electromagnetic and Z^0 parts and both can be important. Z^0 vortices could accompany hydrodynamic vortices, which would imply a very close analogy between the descriptions of superconductivity and superfluidity. For instance, the very large value of $h_{eff} = h_{gr}$ can explain the fountain effect of super-fluidity as delocalization in scales, which are larger than gravitational Compton length $\Lambda_{gr} = GM_E/v_0$.

2. Also zero energy ontology (ZEO) is involved. ZEO predicts the possibility of ordinary ("big") state function reductions (BSFRs) in macroscopic scale. Generation of hydrodynamical turbulence and its decay are not understood in the standard framework based on Navier-Stokes equations.

   Quantum criticality associated with the flow near the boundary and BSFRs could play a central role in the generation of turbulence and its decay. The arrow of time changes in BSFR and this could explain hydrodynamic self-organization as dissipation with a reversed arrow of time.

Generation and decay of turbulence as quantum processes

The TGD inspired view of hydrodynamics [L146] leads to a proposal that the notion of viscosity is length scale dependent.

1. Kinematical viscosity ν has dimensions of L^2/T and ν/c has dimensions of length. This suggests for the ordinary kinematic viscosity a parameterization $\nu/c = L = f(T)\hbar/m$, which is indeed used.

2. The hierarchy of Planck constants $h_{eff} = nh_0$ suggests a hierarchy of length scales $L(n)$ and an associated hierarchy of viscosities defined as $L(n) = \nu(\hbar_{eff}/\hbar)/c = k\hbar_{eff}/m = kn\hbar/m$, $n = \hbar_{eff}/m$ and k a numerical constant possibly depending on temperature.

   Here the counterpart of Compton length is used. One can also consider the counterpart of de-Broglie wavelength and start from the length scales $L = UD/c = \beta D$, $\beta = U/c$ appearing in the definition of Reynolds number as $R = UD/\nu$. This would give a hierarchy of length scales $D_{dB}(n) = L(n)/\beta$.

Gravitational Planck constant $h_{gr} = GM/m$ defines a good candidate for the largest length scale in the hierarchy. The natural candidates for the large mass M are masses of Earth and Sun and the considerations of [L163, L170, L161] combined with earlier considers in [L146] suggest that both are important in both ordinary hydrodynamics and in quantum biology.

1. The original definition of gravitational Compton length as $\Lambda_{gr} = GM/\beta_0$. The gravitational de-Broglie length define as $\Lambda_{gr,dB} = GM/\beta_0\beta$, where β is a typical velocity, say in a hydrodynamical system was also considered in [L146].

   The physical interpretation of β_0 has remained somewhat unclear: in any case, for (quantum) hydrodynamics at the surface of Earth $\beta_0 = 1$ seems to be an excellent approximation [L146, L161].

2. One can ask why the velocity parameter β_0 appearing in the formula could not actually correspond to β so that $\Lambda_{gr} = GM/\beta_0$ for $\beta_0 < 1$ would correspond to $\Lambda_{gr,dB}$ for β_0. The

problem is that it is difficult to physically interpred the $\beta_0 = 1$ case applying at the surface of Earth. What could be the hydrodynamical entities flowing with light velocity? The rather science fictive candidate that comes into mind are dark N-photons forming Galois confined bound states of photons. For these states there exists quite recent experimental evidence [L145]. The fluid would consist of dark photons!

3. A natural guess would be that at the critical values of Reynolds number $R = UD/\nu$, the scale $L = UD/c$ coincides with a dark Compton or de-Broglie length for a particle of the fluid flow.

   This hierarchy of viscosities would apply to the description of the hydrodynamic turbulence as a generation of vortices in long scales characterized by a large value of h_{eff} quantum coherent in the scale.

   At quantum criticality new longer quantum coherence length would appear and lead to generation of larger vortices giving rise to turbulence. The decay of turbulence would be a reverse process. Vortices would decay in a cascade-like matter to smaller vortices characterized by smaller values of h_{eff}. Decay cascade would lead to the atomic level, where ordinary kinematic viscosity associated with $h_{eff} = h$ is a useful concept.

18.6.3 What prevents airplanes from falling down?

Could this conceptual framework provide insights to the question of what prevents airplanes from falling? Could the new physics predicted by TGD explain what happens in the generation of the vortex (or vortices). Could the variational principle introduced by Taha be interpreted in terms of this new physics?

1. It is known that vortices are essential for the generation of the lift force. They are generated above critical Reynolds number at the surface of the flying objects where the separation of the flow takes place. I have proposed that quantum criticality is associated with the critical Reynolds number: whereas superconductivity emerges below critical temperature, vortices emerge above critical Reynolds number. This is called flow separation.

   Flow separation is thought to occur in the following way (`https://cutt.ly/xLHhf3C`). The velocity of the fluid in the surface layer approaches zero at the surface. This increases the pressure near the surface and the average pressure in the layer. What happens is that the flow detaches from the surface via the formation of vortices and the pressure becomes constant.

2. One can express this more quantitatively. The conservation of energy along a flow line, expressed as $\rho v^2/2 + p = constant$, would imply that v decreases. Instead of this, a separation of flow occurs and vortices are generated and the average value of v inside the surface layer stays constant. For vortices the pressure increases near the core of the vortex so that the increase of pressure at the surface layer is replaced by its increase near the surfaces of vortices.

   Separation occurs above critical value R_{cr} of Reynolds number $R = UD/\nu$, where U is the velocity of flow above the surface layer, D is an appropriate length scale, say the distance from the tip of the airfoil, and ν is kinematic viscosity.

3. Separation generates vortices and in TGD they would correspond to quantum objects, perhaps Z^0 magnetic vortices inducing hydrodynamic flow. The simplest situation is that a single vortex for which fluid rotates around the object around axes orthogonal to the flow, is generated. This situation is assumed in the model of Taha. It is highly plausible that this vortex is unstable against decay to smaller vortices occurring also in standard hydrodynamics.

4. The conclusion of Taha and Gonzales [D82] is that momentum conservation is what matters rather than viscosity. If the fluid sticks at the surface of the moving body at the boundary layer, fluid flow loses momentum and could be transformed to the momentum of the vortices with respect to the rest system of fluid at larger distances.

Viscosity usually associated with the loss of momentum and energy in microscopic scales would be replaced with a transfer of momentum and energy to the vortices. The vortices would decay in a cascade-like manner to smaller ones and eventually the momentum and energy would be transformed to microscopic degrees of freedom. In a stationary situation there would be distribution of vortices of various sizes.

In the ZEO based picture, the occurrence of BSFR would change the arrow of time and the dissipation with a reversed arrow of time would in standard time direction look like self-organization based on the extraction of energy and momentum from the main flow to that of vortices.

5. The big vortex is analogous to a spinning object moving in fluid and would experience Magnus effect as a lift: Magnus force is proportional to the cross product of mass current and the angular velocity Ω of vortex defining vorticity and would cause the lift of the vortex. Since the object is inside the vortex, also the object would be lifted. This mechanism does not depend in an essential manner on the shape of the wing except it should be such that separation and generation of vortices is possible.

The strength of the lift force from the quantization of magnetic flux

TGD leads to a view about hydrodynamics [L146] involving a new view about classical fields and quantum coherence possible even in macroscopic scales. Actually, quantum hydrodynamics would be a more appropriate term.

It has been already found that the quantization of the Z^0 magnetic magnetic flux for the vortex fixes the possible values of Γ. Therefore variational principle is not needed for this purpose.

1. This gives a connection with the breaking of super-conductivity by a generation of vortices. In the TGD view about superfluidity, velocity vortices would correspond to Z^0 magnetic vortices carrying quantized monopole flux, whose existence distinguishes between TGD and standard model.

2. The unit of quantization would be $h_{eff} = nh_0$ and there would be a hierarchy of values of h_{eff} assignable to the hierarchy of vortices. The decay of vortices would decrease the scale of quantum coherences. The largest value of h_{eff} could correspond to h_{gr} with $\Lambda_{gr} = GM_E/v_0$ defining a lower bound for vortex scale.

   For $v_0 = c$, the scale would be above $\Lambda_{gr} = .45$ cm. Intriguingly, this scale occurs as a scale of snowflakes which are associated with the criticality of water against freezing: the TGD interpretation is in terms of quantum fluctuations associated with the quantum criticality of water generating a hierarchy of quantum phases with $h_{eff} \leq h_{gr}$ [L161].

3. This interpretation predicts a quantization of vorticity due to the quantization of $q \oint A \cdot dl$ as magnetic flux, completely analogous to that in super-fluidity. The quantization corresponds to a quantization of angular momentum for a particle of flow, such as proton. The quantization requires a non-standard value $h_{eff} = nh_0 > h$ of Planck constant or a very large value m of flux quanta for a small value of h_{eff}. The values of h_{eff} in the hydrodynamic situation are considered in [L146].

   Conservation of angular momentum requires that the vortex characterized by integer $n = h_{eff}/h_0$ decays to vortices characterized by integers n_i satisfying $n = \sum n_i$. If the vortices are identical ($n_i = n_1$) one has $m = n/n_1$ vortices and n_1 must divide n. If this condition holds true, the decay process corresponds to a division of n to its factors.

4. This quantization would take place even in ordinary hydrodynamics and would imply superfluidity-like phenomenon at the level of the magnetic body. The quantization of the magnetic flux as a multiple of h_{eff} fixes the value of the vorticity parameter Γ, which is also fixed by the minimization of Appellian so that it is not quite obvious whether the minimization of the counterpart of Appellian is needed.

   The quantization corresponds to that for the Kähler magnetic monopole flux of the flux tube. It would be interesting to test whether the quantization giving rise to a quantization of the lift force takes place. Outside the core at least, velocity vortices would naturally correspond to Z^0 vortices with vanishing electromagnetic B.

Bohr quantization for angular momentum as quantization of Kähler magnetic monopole flux

The Bohr quantization condition for angular momentum or equivalently quantization of Kähler magnetic flux having purely topological origin implies the quantization of circulation $\Gamma = \oint v \cdot dl$ as multiples of $\hbar_{eff}/M$, where M is the mass of the basic hydrodynamic unit.

1. The most plausible interpretation for velocity v would be as being proportional to a vector potential A for an analog of magnetic field, in a neutral fluid most naturally the induced Z^0 gauge potential A_Z, which would be proportional to Kähler gauge potential in the situation considered:

$$A_Z = q_Z A_K \quad .$$

 Flow lines would be along those of A_K.

2. The covariant constancy $(p_t - qA_t)\Psi = 0$ satisfied along the flow lines has the condition $\oint (p - qA) \cdot dl = 0$ and stronger condition $p = Mv = q_Z A$ as classical counterparts. This gives the condition $v = A/M$ for the flow lines in the case of vortices.

3. The Bohr quantization of angular momentum for particle with mass M gives

$$M \oint v \cdot dl = m\hbar_{eff} = N\hbar \qquad N = mm \quad .$$

 The mass M can correspond to a mass of dark particle and proton is the most plausible candidate. In superfluidity it would be ^3He or ^4He atom which suggests that also atomic mass, which in a reasonable aprroximation is multiple of proton mass, is possible.

4. It is not completely clear whether the quantization for the gauge flux should be posed for Kähler flux associated with A_K or for Z^0 gauge potential. The quantization of Kähler flux follows from topology and is automatically satisfied. In fact, the quantization gives the same results under the conditions poses also in the model discussed in [L146].

 One would $p - A_K = mv - q_Z A_K = 0$ along the flow line. q_Z would correspond to the Z^0 charge of proton, or atomic nucleus which in good approximation is proportional to the neutron number (protonic Z^0 charges is roughly 2 percent of that for the neutron).

 The interpretation of A as Z_0 gauge potential proportional to Kähler gauge potential conforms with the model developed in [L146]. Depending on the situation, A can be reduced to electromagnetic or Z^0 gauge potential as in hydrodynamics.

5. If one has $A_Z = q_Z A_K$, the two quantization conditions are indeed equivalent. If one has $h_{eff} = nh$ (this is a special case of the most general condition $h_{eff} = nh_0$ satisfied if rationals are replaced with ground state extension of rationals with $h_{eff} = h = n_0 h_0$), one has

$$q_Z \oint A_Z \cdot dl = q_Z \int B_K \cdot dA = q_Z m\hbar_{eff} = q_Z mn\hbar = q_Z N\hbar \quad .$$

 The Bohr quantization condition for angular momentum would be therefore equivalent with the quantization of Kähler magnetic monopole flux.

The situation is quantum critical.

1. Since the several values of $h_{eff} = nh_0$ correspond to the same value of total flux $N = mn$ for single flux quantum. There would also be a large degeneracy corresponding to various decompositions $N = mn$ to a product of integers. This degeneracy can be interpreted in terms of quantum criticality involving fluctuations in the value of h_{eff}.

2. One can also have a decomposition to several flux quanta analogous to a decomposition of a vortex to a set of vortices. The interpretation would be as a decomposition of the big vortex to smaller ones.

Appellian or a magnetic part of gauge action for a massive gauge boson?

One can consider two basic options for the choice of the magnetic action based on hydrodynamic and gauge theoretic intuition respectively.

1. For the model of vortex associated with the lift forces, the vector potential $a_0 \propto v_0$ would define a vanishing Z_0 magnetic field and satisfy the analog of gauge condition $\nabla \cdot A_0 = 0$. The vector potential assignable to v_1 would give a magnetic field, which is non-vanishing along a line singularity that is a thin Kähler magnetic monopole flux tube.

2. The counterpart of Appellian follows from hydrodynamic intuition and would be proportional to $S = \int (A \cdot \nabla A)^2 dV$ and would be varied with respect to Γ, which is however fixed to an integer N by flux quantization.

   Without the core contribution the minimization would reduce to minimization with respect to $N = mn$. The core with a finite size would give a finite contribution proportional to N^2. Appellian contribution from the exterior of the core would give terms coming as powers of $(n/A)^k$, $0, 1, 2, 4$, where A is the transverse area of the core tube.

   Therefore the minimization is with respect to the value of n and the parameter characterizing core size, say the area A. For $h_{eff} = h$ the value of m is very large so that one has a quasi-continuum for the values of N. For large values of h_{eff} only few values of m are possible. Flux quantization would fix the value spectrum of N and minimization with respect to $1/A$ would fix the value of A for a given value of N as a root of a third order polynomial in (N/A). A further minimization with respect to $m = N/n$ would fix the value of m.

3. Gauge theoretic intuition motivates the consideration of the analog of magnetic energy density for a massive gauge field. The Maxwellian contribution would be proportional to $\int B^2 dV$ and concentrate to the vortex core. By flux quantization, one would have $\int B^2 dV \propto m^2 \Phi_n^2 L/A = m^2 n^2 \Phi_0^2 L/A$, where $\Phi_n = (h_{eff}/h)\Phi_0 = n/n_0$ is flux quantum, m is the number of flux quanta, A is the transverse area of the flux tube and L its length. Minimization with respect to A would allow only $n = 0$.

   By adding the analog of mass term $m^2 \int A^2$ would give rise to terms proportional to powers $(n/A)^k$, $k = 0, 1, 2$. Outside the vortex core this option corresponds to Eulerian $\rho v^2/2$ option and apart from flux quantization to standard hydrodynamics.

   The minimization for a given value of N would fix the value of A as a root of a first order polynomial. A further minimization with respect to m, would fix the value of m for a given value of n.

Electromagnetic gauge invariance is not a strict gauge invariance

For both options, the action fails to be gauge invariant. For the second option the presence of the A^2 term could be interpreted as reflecting the massivation of the Z^0 magnetic field. This also takes place for electromagnetic fields in superconductivity, where the cores of flux quanta correspond to regions, where super-conductivity is broken.

In TGD the breaking of gauge invariance is only apparent since gauge invariance is broken by classical gravitation from the beginning and the breaking becomes large in presence of monopole flux tubes not possible in the standard model and in general relativity.

1. The gauge transformations for the induced Kähler form correspond to symplectic transformations of CP_2 and affect the induced metric and therefore also Kähler action unlike genuine gauge transformations would do: the effect is small for Einstein space-time regions with large 4-D M^4 projection since it is gravitational. In long scales, where Einsteinian space-regions with 4-D M^4 projection dominate, this leads to huge spin glass degeneracy and approximate gauge invariance.

   As a matter of fact, the sub-algebra SSA_n of super-symplectic algebra SSA with conformal weights coming as n-ples of those of SSA annihilate the physical states as also does the commutator $[SSA_n, SSA]$. SSA_n acts effectively as gauge transformations and gauge symmetry for conformal weights smaller than n is replaced with isometries of the "world of classical worlds" (WCW): they correspond to long length scales. One can assign to these generators charges of dynamical symmetries emerging in long scales.

2. For the magnetic flux tubes, which are deformations of string-like entities with 2-D M^4 projection, the effect of gauge symmetry breaking can be large. One indeed assigns the breaking of gauge invariance to the cores of the flux quanta in superconductivity.

   Electromagnetic gauge invariance is believed to break down in superconductivity. This is in conflict with the expectation from the standard model. This conforms with the TGD view of electromagnetic gauge invariance as an approximate gauge invariance. Symplectic transformations of CP_2 are however identified as isometries of WCW and one can say that the in symmetry breaking only those symplectic transformations corresponding to SSA_n remain gauge transformation and the rest become genuine symmetries generating dynamical symmetry group.

   It should be also noticed that in the general case classical em and Z^0 gauge potentials contain besides the Kähler part also an $SU(2)$ part.

18.7 QHD in nuclear physics and hadron physics

Also nuclear and hadron physics suggests applications for QHD. The basic vision about what happens in high energy nuclear and hadron collisions is that two BSFRs take place. The first BSFR creates the intermediate state with $h_{eff} > h$: the entire system formed by colliding systems need not be in this state. In nuclear physics this state corresponds to a dark nucleus which decays in the next BSFR to ordinary nuclei.

The basic notions are the notion of dark matter at MB and ZEO, in particular the change of the arrow of time in BSFR.

18.7.1 Cold fusion, nuclear tunnelling, $\hbar_{eff}$, and BSFRs

This model allows us to understand "cold fusion" in an elegant manner [L54, L117, L27]. The dark protons at flux tubes associated with water and created by the Pollack effect have much smaller nuclear binding energy than ordinary nucleons. This energy is compensated to a high degree by the positive Coulomb binding energy which corresponds roughly to distance given by electron Compton length.

Dark nuclear reactions between these kinds of objects do not require large collision energy to increase the value of h_{eff} and can take place at room temperature. After the reaction the dark nuclei can transform to ordinary nuclei and liberate the ordinary nuclear binding energy. One can say that in ordinary nuclear reactions one must get to the top of the energy hill and in "cold fusion" one already is at the top of the hill.

Quite generally, the mechanism creating intermediate dark regions in the system of colliding nuclei in BSFR, would be the TGD counterpart of quantum tunnelling in the description of nuclear reactions based on Schrödinger equation. This mechanism could be involved with all tunnelling phenomena.

Where does the heat energy go in Tokamak?

Magnetic body is an essential element of quantum hydrodynamics irrespective of the scale considered. Flux tubes are systems with infinite number of degrees of freedom and this implies the phenomenon of Hagedorn temperature which could serve as an empirical signature of the magnetic body.

Quite recently, I learned about a 12 year old puzzle related to fusion reactors discovered at the U.S Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) (`https://cutt.ly/bZteLdB`).

The heat energy feed to the reactor should increase the temperature of the reactor to make reaction possible but the temperature raise slows down. Now Stephen Jardin has proposed a solution of the problem [C73]. The heating energy would go to the plasma degrees of freedom and increase plasma pressure. At some point the pressure would start to destroy magnetic surfaces near the center of the Tokamak and the temperature would stop growing up. Skeptic can can argue that that there is a limiting temperature and that standard physics does not allow this.

TGD suggests a solution involving new physics. The heat heat energy could go to new degrees of freedom which open up as the temperature slowly decreases. The notion of Hagedorn temperature T_H as a limiting temperature was originally introduced in string theory. In this case, the feeded energy would go to opening up degrees of freedom of a vibrating string. The heat capacity of the combined system increases and temperature rise slows down and one approaches T_H. The threshold temperature for nuclear fusion is around 10^4 eV, which corresponds to an atomic length scale about 1 Angstrom and T_H should be below and near this temperature.

This happens always in the presence of extended objects with an infinite number of degrees of freedom. In TGD the strings are replaced by monopole flux tubes representing new physics and there is an entire hierarchy of Hagedorn temperatures corresponding to the spectrum of string tensions predicted by p-adic length scale hypothesis - new physics again. In cosmology the hierarchy of Hagedorn temperature plays an important role in the TGD inspired cosmology [L83, L149] and also in the model of stars and blackhole-like objects [L91].

Also in the living matter, the physiological temperature could be Hagedorn temperature [L191, L195]. The idea is that the temperature at the magnetic body containing quantum coherent dark matter as phases of the ordinary matter with large value of Planck constant, which controls the biological body, slowly approaches T_H, the entropy increases and the biocontrol by MB starts to fai. This would give rise to aging.

In nuclear fusion reactors, magnetic monopole flux tube structures carrying dark particles could be formed and they would "eat" the feeded energy.

18.7.2 QHD and hadron physics

Hadron physics suggests applications of QHD.

Quark gluon plasma and QHD

In hadron physics quark gluon plasma (`https://cutt.ly/xEDQNZA`) has turned out to be what it was thought to be originally. Instead of being like a gas of quarks and gluons with a relatively large dissipation, it has turned out to behave like almost perfect fluid. This means that the ratio η/s of viscosity and entropy is near to its minimal value proposed by string model based arguments to be $\eta/s = \hbar/m$.

To be a fluid means that the system has long range correlations whereas in gas the particles move randomly and one cannot assign to the system any velocity field or more general currents. In the TGD framework, the existence of a velocity field means at the level of the space-time geometry generalized Beltrami flow allowing to define a global coordinate varying along the flow lines [L131, L147]. This would be a geometric property of space-time surfaces and the finite size of the space-time surface would serve as a limitation.

In the TGD framework the replacement $\hbar \rightarrow \hbar_{eff}$ requires that s increases in the same proportion. If the fluid flow is realized in terms of vortices controlled by pairs of monopole flux tubes defining their cores and Lagrangian flux tubes with gradient flow defining the exteriors of the cores, this situation is achieved.

In this picture entropy could but need not be associated with the monopole flux tubes with non-Beltrami flow and with non-vanishing entropy since the number of the geometric degrees of freedom is infinite which implies limiting temperature known has Hagedorn temperature T_H which is about 175 MeV for hadrons, and slightly higher than pion mass. In fact, the Beltrami property holds for the flux tubes with 2-D CP_2 projection, which is a complex manifold for monopole flux tubes. The fluid flow associated with (controlled by) the monopole flux tubes would have non-vanishing vorticity for monopole fluxes and could dissipate.

The monopole flux tube at the core of the vortex could therefore serve as the source of entropy. One expects that η/s as minimal value is not affected by $h \rightarrow h_{eff}$. One expects that $s \rightarrow (\hbar_{eff}/\hbar)s = ns$ since the dimension of the extension of rationals multiplies the Galois degrees of freedom by n.

Almost perfect fluids are known to allow almost non-interacting vortices. For a perfect fluid, the creation of vortices is impossible due to the absence of friction at the walls. This suggests that the ordinary viscosity is not the reason for the creation of vortices, and in the TGD picture the situation is indeed this. The striking prediction is that the masses of Sun and Earth appear as basic parameters in the gravitational Compton lengths Λ_{gr} determining $\nu_{gr} = \Lambda_{gr}c$.

The phase transition creating quark gluon plasma

The phase transition creating what has been called quark gluon plasma is now what it was expected to be. That the outcome behaves like almost perfect fluid was the first example. TGD leads however to a proposal that since quantum criticality is involved, phases with $\hbar_{eff} > h$ must be present.

p-Adic length scale hypothesis led to the proposal [K66, K67] that this transition could allow production of so called M_{89} hadrons characterized by Mersenne prime $M_{89} = 2^{89} - 1$ whereas ordinary hadrons would correspond to M_{107}. The mass scale of M^{89} hadrons would be by a factor 512 higher than that of ordinary hadrons and there are indications for the existence of scaled versions of mesons.

How M_{89} hadrons could be created. The temperature $T_H = 175$ MeV is by a factor 1/512 lower than the mass scale of M_{89} pion. Somehow the colliding nuclei or hadrons must provide the needed energy from their kinetic energy. What certainly happens is that this energy is materialized in the ordinary nuclear reaction to ordinary pions and other mesons. The mesons should correspond to closed flux tubes assignable to circular vortices of the highly turbulent hydrodynamics flow created in the collision.

Could roughly 512 mesonic flux tubes reconnect to circular but flattened long flux tubes having length of M_{89} meson, which is 512 times that of ordinary pions? I have proposed this kind of process, analogous to BEC, to be fundamental in both biology [L194, L121, L137] and also to explain the strange findings of Eric Reiter challenging some basic assumptions of nuclear physics if taken at face value [L148].

The process generating an analog of BEC would create in the first BSFR M_{89} mesons having $\hbar_{eff}/\hbar = 512$. In the second BSFR the transition $\hbar_{eff} \to \hbar$ would take place and yield M^{89} mesons. It would seem that part of the matter of the composite system ends up to n M_{89} hadronic phase with 512 times higher T_H. In the number theoretic picture, these BEC like states would be Galois confined states [L129, L135].

Can the size of a quark be larger than the size of a hadron?

The Compton wavelength $\lambda_c = \hbar/m$ is inversely proportional to mass. This implies that the Compton length of the quark as part of the hadron is longer than the Compton length of the hadron. If one assigns to Compton length a geometric interpretation as one does in $M^8 - H$ duality mapping mass shell to CD with radius given by Compton length, this sounds paradoxical. How can a part be larger than the whole? One can think of many approaches to what might look like a paradox.

One could of course argue that being a part in the sense of tensor product has nothing to with being a part in geometric sense. However, if one requires quantum classical correspondence (QCC), one could argue that a hadron is a small region to which much larger quark 3-surfaces are attached.

One could also say that Compton length characterizes the size of the MB assignable to a particle which itself has size of order CP_2 length scale. In this case the strange looking situation would appear only at the level of MBs and the magnetic bodies could have sizes which increase when the particle mass decreases.

What if one takes QCC completely seriously? One can look at the situation in ZEO.

1. The size of the CD corresponds to Compton length and CDs for different particle masses have a common center and form a Russian doll-like hierarchy. One can continue the geodesic line defining point of CD associated with the hadron mass so that it intersects the CDs associated with quarks, in particular that for the lightest quark.

2. The distances between the quarks would define the size scale of the system in this largest CD and in the case of light hadrons containing U and D quarks it would be of the order of the Compton length of the lightest quark involved having mass about 5 MeV: this makes about $.2 \times 10^{-13}$ m. There are indeed indications that the MB of proton has this size scale.

One could also require that there must be a common CD based on such an identification of h_{eff} for each particle that its size does not depend on the mass of the particles.

1. Here $\hbar_{gr} = GMm/\beta_0$ provides a possible solution. The size of the CD would correspond to $\Lambda_{gr} = GM/v_0$ for all particles involved. One could call this size the quantum gravitational size of the particle.

2. There is an intriguing observation related to this. To be in gravitational interaction could mean $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ so that the size of the common CD would be given by $\Lambda_{gr} = GMm/v_0$. The minimum mass M given $\hbar_{gr} > \hbar$ would be $M = \beta_0 M_{Pl}^2/m$. For protons this gives $M \geq 1.5 \times 10^{38} m_p$. Assuming density $\rho \sim 10^{30} A/m^3$, A the atomic number, the length L for the side cube with minimal mass M is $L \sim \beta_0 \times 10^2/A^{1/3}$. For $\beta_0 = 2^{-11}$ assignable to the Sun-Earth system, this gives $L \simeq 5/A^{1/3}$ mm. The value of Λ_{gr} for Earth is 4.35 mm for $\beta_0 = 1$. The orders of magnitude are the same. Is this a mere accident?

One solution to the problem is that the ratio $\hbar_{eff}(H)/\hbar_{eff}(q)$ is so large that the problem disappears.

1. If $\hbar eff(1) = \hbar$, the value of $\hbar_{eff}$ for hadron should be so large that the geometric intuitions are respected: this would require $h_{eff}/\hbar \geq m_H/m_q$. The hadrons containing u, d, and c quarks are very special.

2. Second option is that the value of h_{eff} for quarks is smaller than h to guarantee that the Compton length is not larger than $\hbar$. The perturbation theory for states consisting of free quarks would not converge since Kähler coupling strength $\alpha_K \propto 1/\hbar_{eff}$ would be too large. This would conform with the QCD view and provide a reason for color confinement. Quarks would be dark matter in a well-defined sense.

3. The condition would be $\hbar_{eff}(H)/\hbar_{eff}(q) \geq m(H)/m_q$, where q is the lightest quark in the hadron. For heavy hadrons containing heavy quarks this condition would be rather mild. For light hadrons containing u,d, and c quarks it would be non-trivial. Ξ gives the condition $\hbar/\hbar_{eff} \geq 262$. The condition could not be satisfied for too small masses of the value of $\hbar = 7!\hbar_0 = 5040\hbar_0$ identifiable as the ratio of dark CP_2 deduced from p-adic mass calculations and Planck length.

18.8 Appendix

18.8.1 Comparison of TGD with other theories

Table 18.1 compares GRT and TGD and **Table 18.2** compares standard model and TGD.

18.8.2 Brief glossary of the basic concepts of TGD

The following glossary explains some basic concepts of TGD and TGD inspired biology.

- ***Space-time as surface***. Space-times can be regarded as 4-D surfaces in an 8-D space $M^4 \times CP_2$ obtained from empty Minkowski space (M^4) by adding four small dimensions (CP_2). The study of field equations characterizing space-time surfaces as "orbits" of 3-surfaces (3-D generalization of strings) forces the conclusion that the topology of space-time is non-trivial in all length scales.

- ***Geometrization of classical fields***. Both weak, electromagnetic, gluonic, and gravitational fields are known once the space-time surface in H as a solution of field equations is known.

  Many-sheeted space-time (see **Fig. 18.1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by ***wormhole contacts*** (see **Fig. 18.3**) identified as the building bricks of elementary particles. The sizes of wormhole contacts vary but are at least of CP_2 size (about 10^4 Planck lengths) and thus extremely small.

	GRT	**TGD**
Scope of geometrization	classical gravitation	all interactions and quantum theory
Spacetime		
Geometry	abstract 4-geometry	sub-manifold geometry
Topology	trivial in long length scales	many-sheeted space-time
Signature	Minkowskian everywhere	also Euclidian
Fields		
classical	primary dynamical variables	induced from the geometry of H
Quantum fields	primary dynamical variables	modes of WCW spinor fields
Particles	point-like	3-surfaces
Symmetries		
Poincare symmetry	lost	Exact
GCI	true	true - leads to SH and ZEO
	Problem in the identication of coordinates	$H = M^4 \times CP_2$ provides preferred coordinates
Super-symmetry	super-gravitation	super variant of H: super-surfaces
Dynamics		
Equivalence Principle	true	true
Newton's laws and		
notion of force	lost	generalized
Einstein's equations	from GCI and EP	remnant of Poincare invariance at QFT limit of TGD
Bosonic action	EYM action	Kähler action + volume term
Cosmological constant	suggested by dark energy	length scale dependent coefficient of volume term
Fermionic action	Dirac action	Modified Dirac action for induced spinors
Newton's constant	given	predicted
Quantization	fails	Quantum states as modes of WCW spinor field

Table 18.1: Differences and similarities between GRT and TGD

	SM	TGD
Symmetries		
Origin	from empiria	reduction to CP_2 geometry
Color symmetry	gauge symmetry	isometries of CP_2
Color	analogous to spin	analogous to angular momentum
Ew symmetry	gauge symmery	holonomies of CP_2
Symmetry breaking	Higgs mechanism	CP_2 geometry
Spectrum		
Elementary particles	fundamental	consist of fundamental fermions
Bosons	gauge bosons, Higgs	gauge bosons, Higgs, pseudo-scalar
Fundamental fermions	quarks and leptons	quarks: leptons as local 3-quark composites
Dynamics		
Degrees of freedom	gauge fields, Higgs, and fermions	3-D surface geometry and spinors
Classical fields	gauge fields, Higgs	induced spinor connection
	SU(3) Killing vectors of CP_2	
Quantal degrees of freedom	gauge bosons,Higgs,	quantized induced spinor fields
Massivation	Higgs mechanism	p-adic thermodynamics with superconformal symmetry

Table 18.2: Differences and similarities between standard model and TGD

Many-sheeted space-time replaces reductionism with ***fractality***. The existence of scaled variants of physics of strong and weak interactions in various length scales is implied, and biology is especially interesting in this respect.

- ***Topological field quantization (TFQ)*** . TFQ replaces classical fields with space-time quanta. For instance, magnetic fields decompose into space-time surfaces of finite size representing flux tubes or -sheets. Field configurations are like Bohr orbits carrying "archetypal" classical field patterns. Radiation fields correspond to topological light rays or massless extremals (MEs), magnetic fields to magnetic flux quanta (flux tubes and sheets) having as primordial representatives "cosmic strings", electric fields correspond to electric flux quanta (e.g. cell membrane), and fundamental particles to CP_2 type vacuum extremals.
- ***Field body*** (FB) and ***magnetic body*** (MB). Any physical system has field identity - FB or MB - in the sense that a given topological field quantum corresponds to a particular source (or several of them - e.g. in the case of the flux tube connecting two systems).

  Maxwellian electrodynamics cannot have this kind of identification since the fields created by different sources superpose. Superposition is replaced with a set theoretic union: only the *effects* of the fields assignable to different sources on test particle superpose. This makes it possible to define the QFT limit of TGD.
- ***p-Adic physics*** [K70] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- ***Adelic physics*** [L64, L69] is a fusion of real physics of sensory experience and various p-adic physics of cognition.
- ***p-Adic length scale hypothesis*** states that preferred p-adic length scales correspond to primes p near powers of two: $p \simeq 2^k$, k positive integer.
- A ***Dark matter hierarchy*** realized in terms of a hierarchy of values of effective Planck constant $h_{eff} = nh_0$ as integers using $h_0 = h/6$ as a unit. Large value of h_{eff} makes possible macroscopic quantum coherence which is crucial in living matter.

- ***MB as an intentional agent using biological body (BB) as a sensory receptor and motor instrument*** . The personal MB associated with the living body - as opposed to larger MBs assignable with collective levels of consciousness - has a hierarchical onion-like layered structure and several MBs can use the same BB making possible remote mental interactions such as hypnosis [L20].

- ***Cosmic strings Magnetic flux tubes*** belong to the basic extremals of practically any general coordinate invariant action principle. Cosmic strings are surfaces of form $X^2 \times Y^2 \subset M^4 \times CP_2$. X^2 is analogous to string world sheet. Cosmic strings come in two varieties and both seem to have a deep role in TGD.

  Y^2 is either a complex or Lagrangian 2-manifold of CP_2. Complex 2-manifold carries monopole flux. For Lagrangian sub-manifold the Kähler form and magnetic flux and Kähler action vanishes. Both types of cosmic strings are are simultaneous extremals of both Kähler action and volume action: this holds true quite generally for preferred extremals.

  Cosmic strings are unstable against perturbations thickening the 2-D M^4 projection to 3-D or 4-D: this gives rise to monopole (see **Fig. ??**) and non-monopole magnetic flux tubes. Using $M^2 \times Y^2$ coordinates, the thickening corresponds to the deformation for which $E^2 \subset M^4$ coordinates are not constant anymore but depend on Y^2 coordinates.

- ***Magnetic flux tubes and sheets*** serve as "body parts" of MB (analogous to body parts of BB), and one can speak about magnetic motor actions. Besides concrete motion of flux quanta/tubes analogous to ordinary motor activity, basic motor actions include the contraction of magnetic flux tubes by a phase transition possibly reducing Planck constant, and the change in thickness of the magnetic flux tube, thus changing the value of the magnetic field, and in turn the cyclotron frequency. Transversal oscillatory motions of flux tubes and oscillatory variations of the thickness of the flux tubes serve as counterparts for Alfwen waves.

  Reconnections of the U-shaped flux tubes allow two MBs to get in contact based on a pair of flux tubes connecting the systems and temporal variations of magnetic fields inducing motor actions of MBs favor the formation of reconnections.

  In hydrodynamics and magnetohydrodynamics reconnections would be essential for the generation of turbulence by the generation of vortices having monopole flux tube at core and Lagrangian flux tube as its exterior.

  Flux tube connections at the molecular level bring a new element to biochemistry making it possible to understand bio-catalysis. Flux tube connections serve as a space-time correlates for attention in the TGD inspired theory of consciousness.

- ***Cyclotron Bose-Einstein condensates (BECs)*** of various charged particles can accompany MBs. Cyclotron energy $E_c = hZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $h \rightarrow h_{eff}$ E_c is scaled up by a fractor $h_{eff}/h = n$. For sufficiently high value of h_{eff} cyclotron energy is above thermal energy $E = h_{eff}\ ZeB/m$. Cyclotron Bose-Einstein condensates at MBs of basic biomolecules and of cell membrane proteins - play a key role in TGD based biology.

- ***Josephson junctions*** exist between two superconductors. In TGD framework, ***generalized Josephson junctions*** accompany membrane proteins such as ion channels and pumps. A voltage between the two super-conductors implies a ***Josephson current***. For a constant voltage the current is oscillating with the ***Josephson frequency*** . The Josephson current emits ***Josephson radiation***. The energies come as multiples of ***Josephson energy***.

  In TGD generalized Josephson radiation consisting of dark photons makes communication of sensory input to MB possible. The signal is coded to the modulation of Josephson frequency depending on the membrane voltage. The cyclotron BEC at MB receives the radiation producing a sequence of resonance peaks.

- ***Negentropy Maximization Principle*** (NMP). NMP [K65] [L139] is the variational principle of consciousness and generalizes SL. NMP states that the negentropy gain in SFR is non-negative and maximal. NMP implies SL for ordinary matter.

- ***Negentropic entanglement*** (NE). NE is possible in adelic physics and NMP does not allow its reduction. NMP implies a connection between NE, the dark matter hierarchy, p-adic physics, and quantum criticality. NE is a prerequisite for an experience defining abstraction as a rule having as instances the state pairs appearing in the entangled state.

- ***Zero energy ontology (ZEO)*** In ZEO physical states are pairs of positive and negative energy parts having opposite net quantum numbers and identifiable as counterparts of initial and final states of a physical event in the ordinary ontology. Positive and negative energy parts of the zero energy state are at the opposite boundaries of a ***causal diamond*** (CD, see **Fig. 18.2**)) defined as a double-pyramid-like intersection of future and past directed light-cones of Minkowski space.

  CD defines the "spot-light of consciousness": the contents of conscious experience associated with a given CD is determined by the space-time sheets in the embedding space region spanned by CD.

- ***SFR*** is an acronym for state function reduction. The measurement interaction is universal and defined by the entanglement of the subsystem considered with the external world [L105] [K125]. What is measured is the density matrix characterizing entanglement and the outcome is an eigenstate of the density matrix with eigenvalue giving the probability of this particular outcome. SFR can in principle occur for any pair of systems.

  SFR in ZEO solves the basic problem of quantum measurement theory since the zero energy state as a superposition of classical deterministic time evolutions (preferred extremals) is replaced with a new one. Individual time evolutions are not made non-deterministic.

  One must however notice that the reduction of entanglement between fermions (quarks in TGD) is not possible since Fermi- and als Bose statistics predicts a maximal entanglement. Entanglement reduction must occur in WCW degrees of freedom and they are present because point-like particles are replaced with 3-surfaces. They can correspond to the number theoretical degrees of freedom assignable to the Galois group - actually its decomposition in terms of its normal subgroups - and to topological degrees of freedom.

- ***SSFR*** is an acronym for "small" SFR as the TGD counterpart of weak measurement of quantum optics and resembles classical measurement since the change of the state is small [L105] [K125]. SSFR is preceded by the TGD counterpart of unitary time evolution replacing the state associated with CD with a quantum superposition of CDs and zero energy states associated with them. SSFR performs a localization of CD and corresponds to time measurement with time identifiable as the temporal distance between the tips of CD. CD is scaled up in size - at least in statistical sense and this gives rise to the arrow of time.

  The unitary process and SSFR represent also the counterpart for Zeno effect in the sense that the passive boundary of CD as also CD is only scaled up but is not shifted. The states remain unchanged apart from the addition of new fermions contained by the added part of the passive boundary. One can say that the size of the CD as analogous to the perceptive field means that more and more of the zero energy state at the passive boundary becomes visible. The active boundary is however both scaled and shifted in SSFR and states at it change. This gives rise to the experience of time flow and SSFRs as moments of subjective time correspond to geometric time as a distance between the tips of CD. The analog of unitary time evolution corresponds to "time" evolution induced by the exponential of the scaling generator L_0. Time translation is thus replaced by scaling. This is the case also in p-adic thermodynamics. The idea of time evolution by scalings has emerged also in condensed matter physics.

- ***BSFR*** is an acronym for "big" SFR, which is the TGD counterpart of ordinary state function reduction with the standard probabilistic rules [L105] [K125]. What is new is that the arrow of time changes since the roles of passive and active boundaries change and CD starts to increase in an opposite time direction.

  This has profound thermodynamic implications. Second law must be generalized and the time corresponds to dissipation with a reversed arrow of time looking like self-organization for an observed with opposite arrow of time [L102]. The interpretation of BSFR is as analog of biological death and the time reversed period is analogous to re-incarnation but with non-standard arrow of time. The findings of Minev *et al* [L90] give support for BSFR at atomic level. Together with h_{eff} hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

18.8.3 Figures

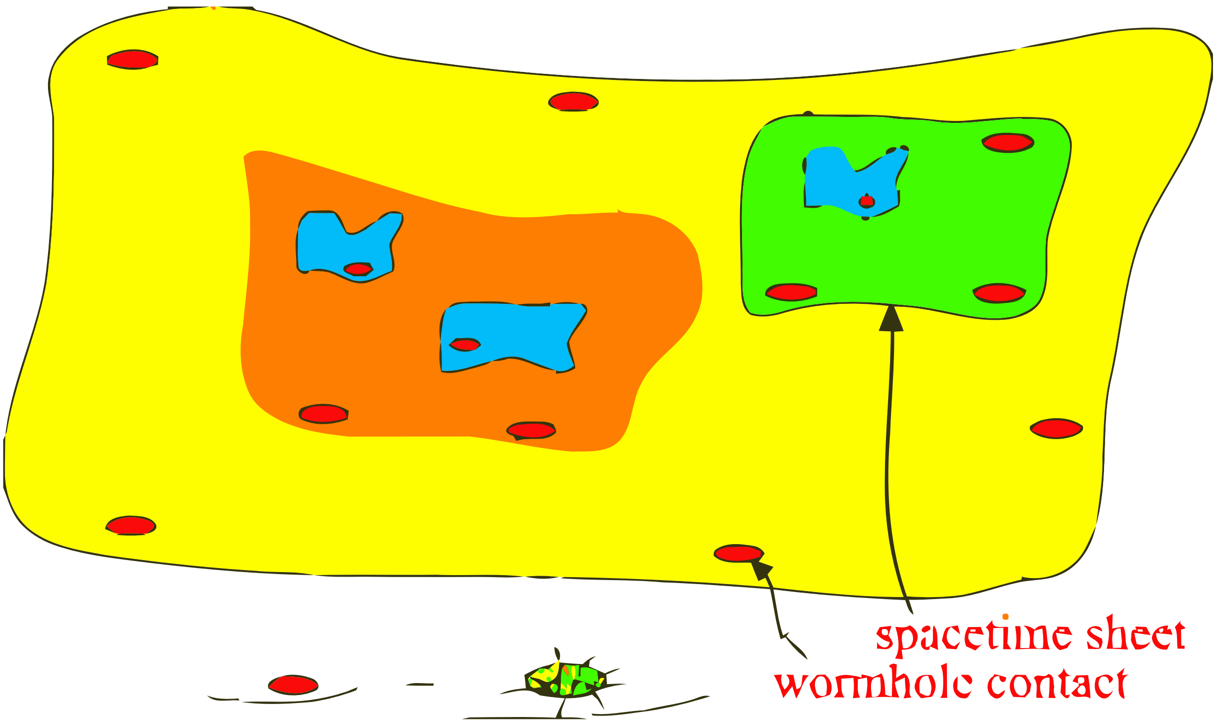

Figure 18.1: Many-sheeted space-time.

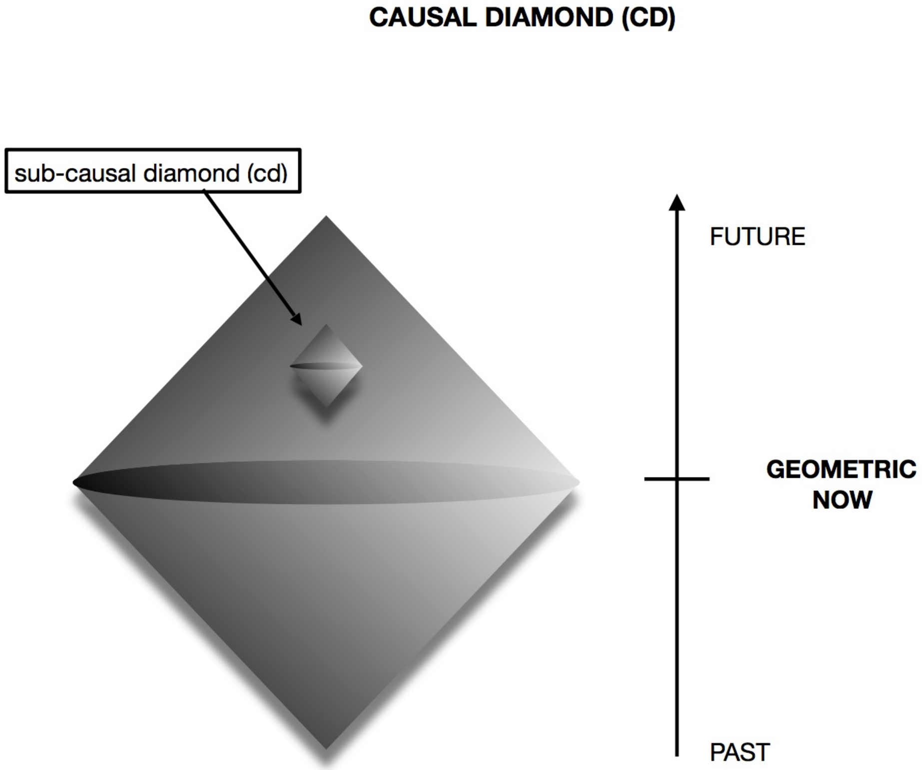

Figure 18.2: Causal diamond

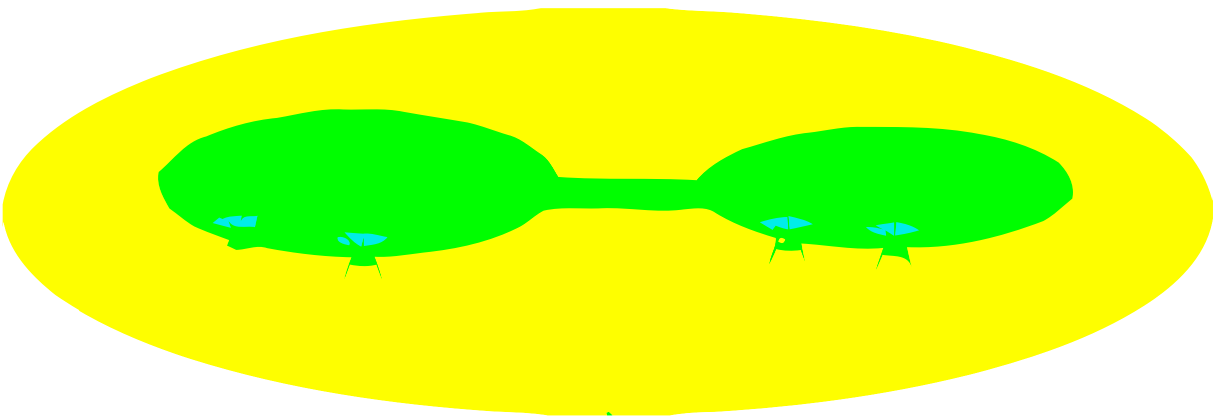

Figure 18.3: Wormhole contacts.

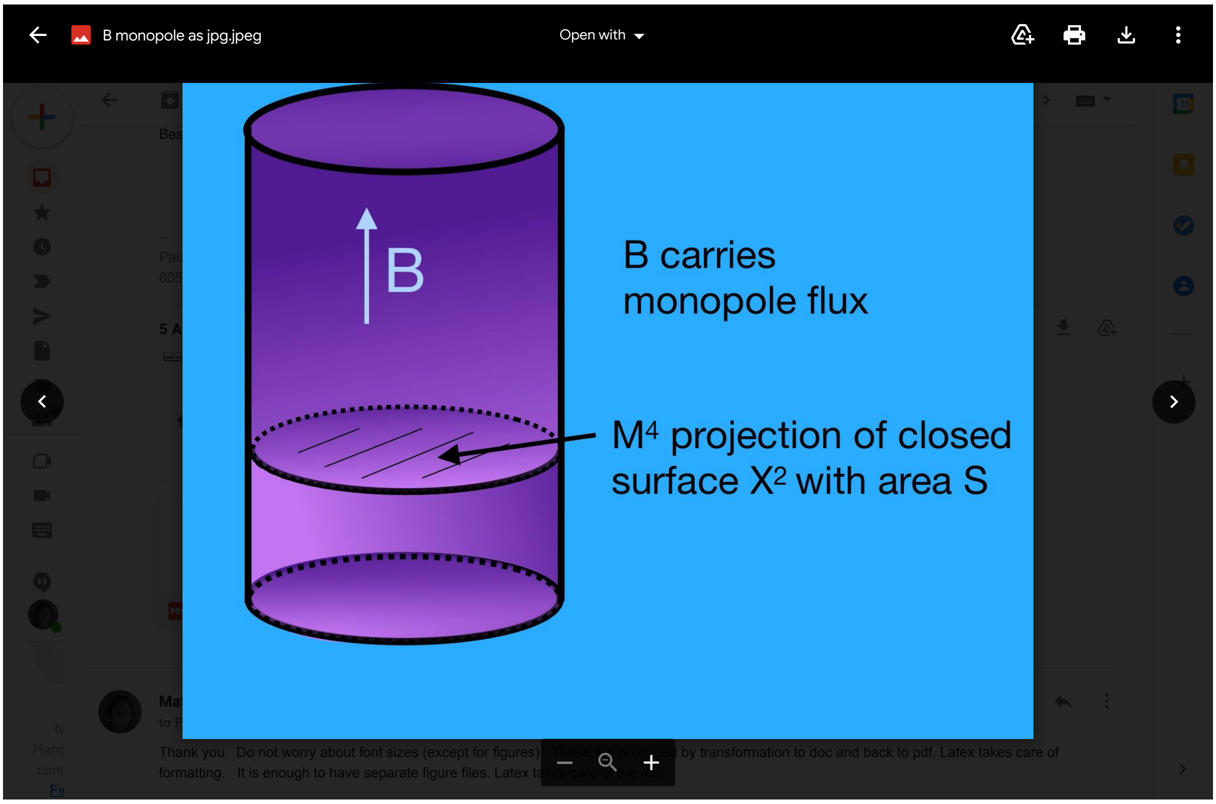

Figure 18.4: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e\oint B\cdot dS = eBS = kh$ at single sheet of n-sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

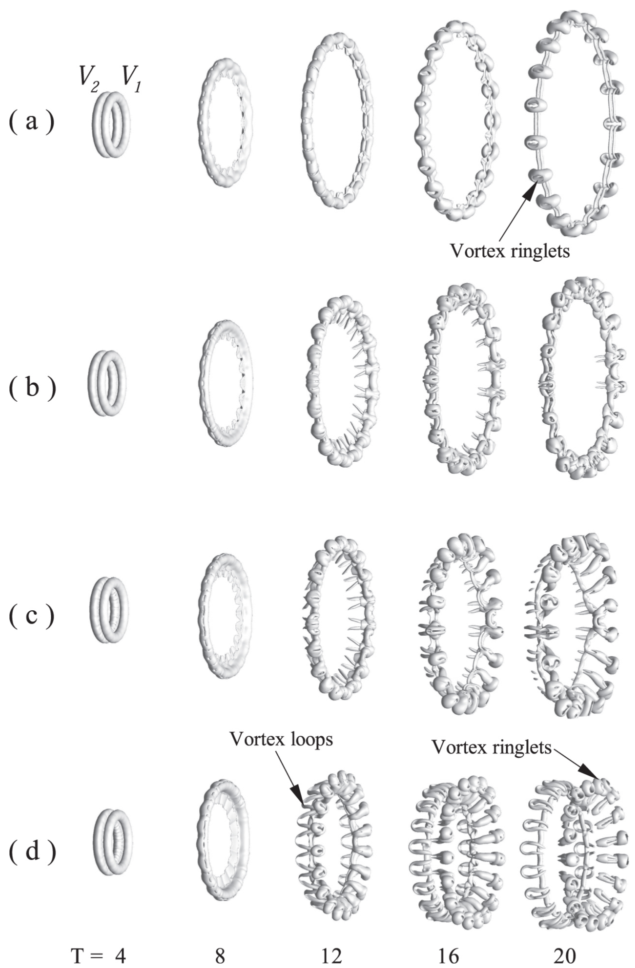

Figure 18.5: Illustrations of flow patterns resulting in a numerical simulation of a head-on collision of vortex rings with opposite circulations.

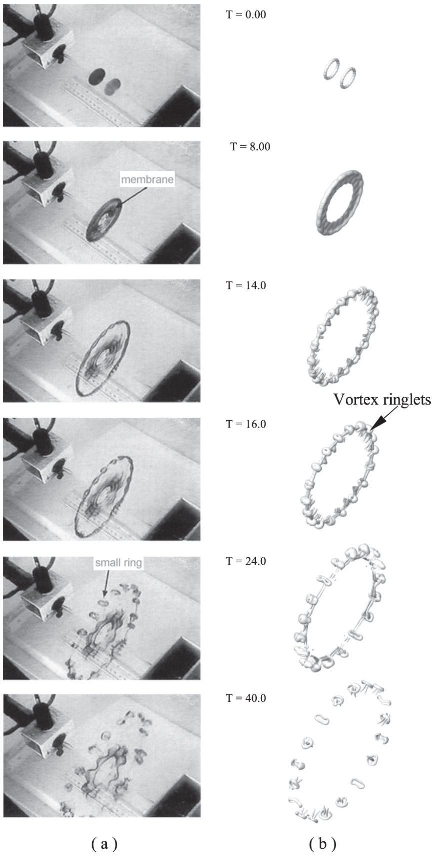

Figure 18.6: Illustrations of flow patterns resulting in a real head-on collision of vortex rings with opposite circulations.

Chapter 19

TGD inspired model for freezing in nano scales

19.1 Introduction

Freezing is a phase transition, which challenges the existing view of condensed matter in nanoscales. For this reason it is interesting to look whether TGD could say something interesting about this phenomenon.

In the TGD framework, quantum coherence is possible in all scales and gravitational quantum coherence should characterize hydrodynamics in astrophysical and even in small scales [L146, L163, L161]. The hydrodynamics at the surface of planet such as Earth should have mass of planet and even that of Sun should characterize gravitational Planck constant h_{gr} [E9] [K96, K78, K80] [L72] assignable to gravitational flux tubes mediating gravitational interactions. In this framework, quantum criticality involving $h_{eff} = nh_0 > h$ phases of ordinary matter located at the MB and possibly controlling ordinary matter, could be behind the criticality of also ordinary phase transitions.

19.1.1 Freezing inside porous structures

The stimulus for considering freezing phenomenon came from a discussion of what happens in the freezing of water inside porous structure such as concrete. The freezing of conrete is of high interest for practical reasons. The ordinary freezing involves a reduction of temperature, which is above the criticality to the critical value T_{cr}. In the case of water, the temperatures slightly above T_{cr} lead to an increase of the volume that can can destructive effects on a porous material.

The porous structures like concrete have sizes in the size range of nanoparticles between 1 t 100 nm. The freezing is known to occur at considerably lower critical temperature which can be as low as -70 °C than ordinary freezing and to be a very slow process. Somehow this should relate to surface tension which carries a lot energy and to the small volume of pore implying that the large volume limit of thermodynamics does not apply as such.

Are the pores filled with water completely or only partially? From [D139, D137] (`https://cutt.ly/cCVWKXx` and `https://cutt.ly/2C1GZHR`) one learns that the pores are partially filled with water so that there is also a gas phase present.

What motivates the interest on the physics of porous materials, is that the hydrodynamic phenomena in nano scales are hot topics of the recent condensed matter physics. Since TGD predicts all kinds of new quantum phenomena in these scales, it is interesting to see whether the TGD view could provide some new insights on the phenomenon of freezing.

19.1.2 The surface of water contains an ice-like layer

There is quite recent evidence that the surface of water bounded by air contains an ice-like layer consisting of 2-3 molecular layers [D115] (`https://cutt.ly/DCVWM6C`). Second popular article telling that the boundary layer is neither water of ice and is conducting [D96] (`https://cutt.ly/KC9Q2EA`).

Could the water at the surface freeze and liberate free energy as essentially thermal energy of motion, which is transformed to the energy of surface tension associated with the ice layer? This would explain what surface tension is at the fundamental level.

The ice layer at the surface would be analogous to a metal foil. Metal foils are unstable against warping, which means stretching without bending so that the induce metric remains flat ($z = z(x)$,$g_{xx} = 1 + (dz/dx)^2, g_{yy} = 1$ $\sqrt{g_2} = \sqrt{1 + (dz/dx)^2}$. Could the simplest surface waves of water be essentially warping waves in which the area increases and involves therefore phase transition creating more ice at the surface layer.

This would require that the surface of water is at criticality. In the TGD framework, this would correspond to quantum criticality and I have indeed proposed that at least some boundary layers involve membrane like structures at quantum criticality at the level of the MB of the system [L155, L160]. Light-like boundaries of space-time surface define an analogous but not equivalent proposal to be discussed in this article. The quantum criticality would be essential for the ability of the water volume to change its shape while preserving its volume (volume preserving flow combined with a phase transitions occurring at the boundary layers.)

The temperature at the surface layer would be considerably higher than freezing temperature. Can one regard this phase as super-heated ice or some kind of quantum ice with long range correlations? Could one think that hydrogen bonds create long range order, which solidifies the boundary layer above the normal freezing temperatures. Here the notion of ordered water proposed to be associated with living systems such as DNA strand is suggestive.

The fourth phase of water, proposed by Pollack [I18, L24, **?**, I26], is a good candidate for this phase. This phase is formed in the presence of a gel phase and consists of hexagonal layers with an effective $H_{1.5}O$ stoichiometry.

TGD leads to a model of this phase in terms of the MB carrying dark protons transferred from so called exclusion zones (EZs), which are negatively charged [L24] and have properties suggesting time reversal at the level of the MB of the system. For instance, EZs seem to dissipate in the reverse time direction [L105, L142].

The fourth phase of water would differ from the ordinary water inside the nanopores. For instance, the freezing temperature would be much lower than for the ordinary water.

19.1.3 Mysterious lift of drill in downwards water flow

I learned of a very interesting and paradoxical looking phenomenon. Thanks for Shamoon Ahmed for the link. A drill with a helical geometry raises in a downwards fluid flow. This is in conflict with the naive expectations.

1. Suppose first that momentum is conserved. By momentum conservation water must get downwards directed momentum if the drill obtains upwards directed momentum. If there is no slipping, just the opposite should happen. Therefore the situation could be like in a turbulent flow: the water and the drill do not directly touch each other. There is indeed turbulence as one can see.

   But what makes possible the slipping? It has been quite recently learned that the surface of water in air has thin ice-like layer for which TGD suggests and explanation [L169, L146]. The surface between drill and water would be covered by a very thin ice layer so that slipping would take place naturally. Drill is like a skater. Also the boundary layer in the water (liquid) flow past a body could be a thin ice-sheet. Second analogy is as a screw penetrating upstream.

2. But is the momentum really conserved? Water is accelerated in the gravitational field: this gives it momentum. Water forms a vortex already before the drill is added. The downwards kinematic pressure, which increases downwards, pushes the drill having a helical geometry. If there is no friction fixing the drill to water flow, the drill has no other option than raise. The constraint due to helicality forces the drill to rotate.

   Water in the vortex and the drill would rotate in opposite directions and helicality constraint would transform the rotational motion of the drill to a translational motion and forces the rotation of drill to gain upwards directed momentum.

3. This raises some questions.

   (a) Could there be a connection with the fact that in the Northern/Southern hemisphere water flowing in a water tub rotates in a unique direction (kind of parity breaking)?

   (b) What is the role of the handedness of the drill? One would expect that the drill with an opposite handedness rotate in an opposite direction? What if the handedness of the drill does not favor the natural rotation direction for the vortex? Do these effects tend to cancel.

There might be a connection with the "ordinary" hydrodynamics. The drill raising in the fluid flow is analogous to a propeller. Could also ordinary propeller involve the same basic mechanism and act like a skater and in this way minimize dissipative energy losses? It is known that propellers induce cavitation as evaporation of water and there is anecdotal evidence from power plants that more energy is liberated in the process than one would expect. Recently it was found that the mere irradiation of water by light leads to its evaporation as a generation of droplets, which would have ice-like surface layer consisting of the fourth phase of water (this requires energy): Pollack effect again! Could dark photons with nonstandard value of Planck constant provide the energy needed for the cavitation creating a vapour phase with larger total area of fourth phase of water?

Runcel D. Arcaya informed me of the work of a brilliant experimentalist and inventor Victor Schauberger related to the strange properties of the flowing water. This work relates in an interesting manner to the effect discussed. I have written about Schauberger's findings about to the ability of fishes too swim "too" easily upstream. Gravitation and turbulence are involved also now. Could the bodily posture of the fish generate the counterpart of the helical geometry? Could the fish as a living organism help to generate the fourth phase of water in the water bounding their skin by Pollack effect, which requires the presence of a gel phase besides energy source (IR radiation for instance) to transform part of protons of water molecules to dark photons with a higher energy.

Schauberger also invented a method of water purification using vortex flow: the reason for why the method works remained unclear. In Pollack effect, the negatively charged exclusion zones (EZs) spontaneously purify themselves. This conflicts with the thermodynamical intuitions. The TGD explanation is in terms of reversed arrow of time which explains the purification process as normal diffusion leading to the decay of gradients but taking place with an opposite arrow of time. Could the purification of in vortex flow be caused by the Pollack effect creating the surface layers consisting of the fourth phase of water (EZs)?

Schauberger developed the notion of living water and believed that spring water is somehow very special in this respect. In TGD water is regarded as a multiphase system involving magnetic body with layers labelled by the values of effective Planck constant h_{eff}. The larger the value of the h_{eff}, the higher the (basically algebraic complexity) and "IQ" of the system. Gravitational magnetic body has the largest value of effective Planck constant. Spring water is pure and could be this kind of highly complex system. Also systems involving turbulence and vortices are very complex.

19.1.4 Evaporation without heating

It has been found that light can evaporate water without any heat, this is called photomolecular effect (`rebrand.ly/l019pll`). What comes first in mind for a habitant of the TGD Universe is that the photomolecular effect reduces to Pollack effect in which light in visible and infrared wavelength range induces a formation of negatively charged regions, exclusion zones (EZs) containing fourth phase of water, as Pollack calls them. These regions have very strange properties suggesting time reversal: for instance, they clean themselves from impurities which suggests diffusion with a reversed arrow of time at the magnetic body of EZ. EZs are layered structures with effective stoichiometry $H_{1.5}O$. Pollack talks of EZs fourth phase of water and the ordered water at the surfaces of say biomolecules like DNA and folded proteins could consist of this kind of phase.

TGD proposes a model of Pollack effect based on the TGD view of dark matter. Part of protons would go to the magnetic body of water and form dark proton sequences. Pollack effect has become one of the key mechanisms of the TGD inspired quantum biology and would appear in metabolism (ATP), biocatalysis, and nerve pulse generation [L185].

Quite recently it has been learned that the water-air boundary has a thin cover, which consists of a phase analogous to ice (`https://cutt.ly/DCVWM6C`). A reasonable hypothesis is that this phase consists of the fourth phase of water and is responsible for the surface tension of the bulk water. I have developed a TGD based model for the anomalies related to freezing in nanoscales explaining also this phenomenon to be discussed in this article.

How could the Pollack effect induce evaporation without heat? Evaporation occurs at criticality. In TGD it could be accompanied by quantum criticality meaning the presence of dark matter at the magnetic body of the water, in particular dark protons generated in the Pollack effect. At quantum criticality the bulk water is unstable against the formation of water droplets surrounded by layers of fourth phase. The surface area of droplets plus bulk water is larger than that of bulk. More of the fourth phase of water must be created and this requires energy. The irradiation would provide this energy by the Pollack effect.

19.1.5 Immersed freezing and contact freezing

Freezing can occur as immersion freezing or contact freezing. In immersion freezing [D135] (`https://cutt.ly/bCVEPqT`), which is the dominating mode for freezing, the growing region of ice is inside a possibly supercooled water volume. In the contact freezing [D100] (`https://cutt.ly/BCVEHZj`), the collision of a volume of possibly supercooled water with another object initiates the freezing. That is occurs could be understood from criticality.

Why contact freezing occurs much faster than immersion freezing is not well-understood [D125] (`https://cutt.ly/6CVEM9Q`). Could the contact freezing start at the entire area of the outer surface of water blob and proceed to the interior and transform the liberated thermal kinetic energy to the energy of surface tension of the boundary layer between liquid and solid. If the boundary layer is and ice-like quantum coherent structure, the coherent freezing would be natural and occur coherently for the entire boundary layer. In the case of immersion freezing, temperature fluctuations imply that the ice nuclei can increase or decrease so that the process is less coherent and therefore slower.

Note that the freezing inside pores should be immersion freezing since collisions or other perturbations are not plausible inside pores. If this is the case, then the surface tension would be associated with the solid-liquid boundary inside pore.

19.1.6 TGD based model for freezing

In the sequal a model inspired by the finding that the water-air boundary involves an ice-like layer [D115, D96] (see `https://cutt.ly/DCVWM6C` and `https://cutt.ly/KC9Q2EA`). The proposal is that also at criticality for the freezing a similar layer exists and makes possible fluctuations of the size and shape of the ice blob. At criticality the change of the Gibbs free energy for water would be opposite that for ice and the Gibbs free energy liberated in the formation of ice layer would transform to the energy of surface tension at water-ice layer.

This leads to a geometric model for the freezing phase transition involving only the surface energy proportional to the area of the water-ice boundary and the constraint term fixing the volume of water. This reduces freezing as a 3-D critical phenomenon to a 2-D critical phenomenon. The partial differential equations for the boundary surface are derived and discussed.

If $\Delta P = 0$ at the critical for the two phases at the boundary layer, the boundary consists of portions, which are minimal surfaces analogous to soap films and conformal invariance characterizing 2-D critical systems is obtained. For $\Delta P \neq 0$, conformal invariance is lost and analogs of soap bubbles are obtained.

In the TGD framework, the generalization of the model to describe freezing as a dynamical time evolution of the solid-liquid boundary is suggestive. An interesting question is whether this boundary could be a light-like 3-surface in $M^4 \times CP_2$ and thus have a vanishing 3-volume. A huge extension of ordinary conformal symmetries would emerge.

This leads to a proposal for the space-time description of the phase transition using basic TGD. If the light-like 3-surface corresponds to the condition $det(g_4) = 0$, the normal isometry currents appearing in the boundary conditions are finite. Kähler Chern-Simons term is necessary as a boundary part of the action. In consistency with the original belief given up later, it is possible to have space-time surfaces with boundaries.

19.2 TGD based model for freezing

In the following a TGD based model of freezing is developed by posing questions inspired by the empirical findings.

19.2.1 Can one assign a surface tension to the boundary between solid and liquid phase?

Can one assign a surface tension to the boundary layer between water and ice when the boundary is at criticality?

If so, the increase of the size of the frozen volume inside (possibly supercooled) water near criticality increases the area of the boundary of the frozen volume between the two phases. If there is surface tension involved, energy is needed to increase the area.

The energy could come from the freezing proceeding by an addition of molecular thick boundary layers liberating the free energy as essentially thermal kinetic energy, which would transform to the energy assignable to the surface tension. Melting would be opposite to this process. If molecular layers are added, the liberated free energy (thermal energy) from the layer of water molecules is proportional to the area of the surface generated in this way as is also the energy of surface tension. Therefore one can have criticality and the area of of the surface between the two phases can fluctuate.

The boundary layer between the solid and liquid phases [D115, D96], consisting of few molecule layers, would be critical. This motivates the proposal that at criticality the liberated Gibbs free energy (`https://cutt.ly/tC3flRn`), essentially thermal kinetic energy, identifiable as the heat of freezing equals the energy assignable to the surface tension.

The situation would be highly unstable due to temperature fluctuations. The volume could increase at some areas of the surface and decrease at other areas. The volume possessed by either phase would fluctuate as it indeed does at criticality. The situation is analogous to the interphase between water and air, which supports the view that the notion of water-ice surface tension indeed makes sense at criticality.

If the increments of Gibbs free energy are the same apart at the critical temperature, temperature fluctuations make the situation highly critical. If the energy liberated in the freezing overcomes the energy of surface tension the additional heat tends to induce melting. If the energy is below that energy of surface tension, freezing is prevented.

19.2.2 Why the freezing temperature reduced with the decreasing pore size?

The freezing temperature inside nano pores (down to -70 °C) is considerably lower than the freezing temperature for a large volume of fluid. It would be tempting to assume that the freezing temperature at the ice-water boundary layer determines the freezing temperature T_{cr} and that for some reason T_{cr} is lower than at the limit of large volume.

1. The intuitive idea is that at criticality a layer of ice molecules can be generated as water molecules freeze [D115, D96]. Also the reverse transition is possible. The freezing would proceed as new layers would be added. The liberated thermal kinetic energy of liquid molecules would go to the energy assignable to the layer.

   The recent finding that the surface of water is accompanied by few molecule layers behaving like ice suggests that the additional energy of the layer has an interpretation as surface tension. At critical temperature T_{cr} this layer is highly dynamic and its size can vary.

At the criticality, the liberated energy per molecule equals the energy of surface tension per molecule. If the liberated energy is higher, it melts the molecular ice layer formed in this way. If the liberated energy is smaller, the formation of the layer is not possible. Small fluctuations of T around T_{cr} affect the shape and volume of the ice region in the ice phase, which are therefore highly sensitive to fluctuations of T.

2. T_cr should correlate with the pore size L. Gibbs free energy seems to be the correct thermodynamical function if only the change for number of ice molecules matters. Both ΔG_{water} and $\Delta G_{ice} = \Delta E_s$ could depend on T and pore size L. The naive first guess is that in nano scales the presence of hydrogen bonded regions, analogous to seeds for the formation of ice, would increase the freezing temperature. However, just the opposite occurs.

   One can argue that the increase of the number of hydrogen bonded structures already representing ice-like structures in the ice-water boundary layer reduces the size of ΔG_{water} liberated in the formation of a new boundary layer. Therefore ΔG_{water} decreases with the pore size L. Also the reduction of temperature reduces ΔG_{water}.

3. For instance, if $|\Delta G_{ice}| = \Delta E_s < |\Delta G_{water}|$ is true at the normal critical temperature and is not appreciably affected by the reduction of the temperature, the lowering of the temperature to T_{cr} cannot lead to to $\Delta E_s = \Delta G_{ice} = |\Delta G_{water}|$. Therefore no freezing would occur. On the other hand, the criticality at the infinite volume limit also gives $\Delta G_{ice} = \Delta G_{water}$ at the normal freezing temperature.

   A more realistic looking possibility is that $\Delta E_s = \Delta G_{ice}$ is of the form $a-b/L$ with $a = \Delta_{s,N}$ that is Δ_s at the normal freezing point at the infinite volume limit. Als a could have weak dependence on L As L is reduced below some critical value, ΔG_{ice} would decrease faster than $|\Delta G_{water}|$ and eventually one could have $\Delta G_{ice} = \Delta E_s = |\Delta G_{water}|$ at lowered T_{cr}.

   The core idea is that the freezing is not a 3-D phase transition but 2-D phase transition at the liquid-solid boundary which is critical. Critical temperature would characterize this boundary rather than the entire 3-D phase.

4. How could one understand the negative contribution b/L to Δ_s? Could one think that Coulomb energy is in question. Could a charge separation, analogous to that taking place in the Pollack effect, occur and give rise to a negative Coulomb interaction energy between dark protons at flux tubes and the negative charges in exclusion zone (EZ)? In short scales L this contribution would increase. This would mean that the new physics predicted by TGD would play a key role in freezing and presumably also in other phase transitions.

19.2.3 A more precise thermodynamical formulation using Gibbs free energy

Assume that one has $\Delta P = 0$ and $\Delta T = 0$ for the phase water-ice phase transition at criticality. If so, only the number of molecules in the two phases change and one has $\Delta N_{water} = -\Delta N_{ice}$.

1. Gibbs free energy $G = H - TS = F + pV$ is the proper thermodynamic function to describe the situation. One has $\Delta G = \Delta(H - TS) = S\Delta T + \sum \mu_i \Delta N_i + V\Delta P$. Let us assign index $i = 1 \rightarrow water$ to liquid phase and $i = 2 \rightarrow ice$ to ice so that one can define $G = G_{water} + G_{ice}$.

   For $\Delta P = 0$ and $\Delta T = 0$, one has $\Delta G = \mu_{water}\Delta N_{water} = \mu_{ice}\Delta N_{ice} = (\mu_{water} - \mu_{ice})\Delta N_{water}$. One cannot exclude the possibility $\Delta P \neq 0$.

2. At criticality, one has $\mu_{water} = \mu_{ice}$ if the new molecular layer assignable to the ice-water boundary is indeed analogous to that found to accompany the water-air boundary at criticality. This assumption is natural since at criticality the shape of ice regions is highly varying just like the shape of a water blob.

   If G_{ice} decreases with temperature (being analogous to the thermal energy of water molecules), the chemical potential μ_{water} decreases with the temperature. It is not obvious how the energy μ_{ice} per molecule assignable to surface tension depends on T and pore size L The first guess is that the dependence on T is weak. As proposed, the charge separation occurring in the Pollack effect could explain dependence on L as being caused by the attractive Coulomb potential.

3. Criticality at the interface means that water and ice molecules correspond to the same value of Gibbs free energy G so that their numbers N_i fluctuate but satisfy the condition $N_{water} + N_{ice} = constant$. This requires that $\Delta G_{water} < 0$ for water molecules identifiable as the thermal energy liberated in the freezing is apart from sign equal to the increase ΔG_{ice} for ice molecules at criticality, and is identifiable as the increase of energy of the surface tension assignable to the additional area of the solid-liquid boundary layer. This requires $\mu_{water} = \mu_{ice}$ at criticality. Otherwise the phase transition cannot proceed.

   If $\Delta G_{water} = \Delta N_{water}\mu_{water}$ and $\Delta E_s = \Delta G_{ice} = \Delta N_{ice}\mu_{ice}$, $\Delta N_{water} = -\Delta N_{ice}$, do not sum up to zero at the normal freezing temperature inside the pore, the transition does not occur until the temperature has been reduced to the critical temperature T_{cr} with $\Delta G_{water} = -\Delta G_{ice}$ so that one has $\mu_{water} = \mu_{ice}$.

   If $\mu_{ice} > \mu_{water}$ is true at the normal critical temperature at infinite volume limit, the reduction of the temperature should reduce μ_{ice} faster than μ_{water} so that eventually $\mu_{water} = \mu_{ice}$ would hold true. This should be due to the finite pore size. This could be due to the $\mu_{ice} = a - b/L$ type dependence on pore size caused by the charge separation as part of protons of water molecules are transferred to the magnetic flux tubes in the Pollack effect.

19.3 A geometrical model for the ice-liquid system

In the following a simple purely geometric model for water-gas system and ice-liquid system in a finite volume such as pore is developed.

1. For a water-gas system, one assumes that the water phase has a fixed volume $V = V_0$ (incompressible flow) and there is a water-air boundary layer analogous to ice layer giving rise to surface tension by the proposed model. It is assumed that the boundary is critical in the sense that its area can increase or decrease without a change in the total free energy of the 3-D system. This is true if one has $\Delta G_{water} = \Delta G_{ice} = \Delta E_s$, where E_s is the energy associated to the surface tension assumed to be assignable to the water-air boundary at criticality. This assumption involves new physics.

   The interesting part of the free energy of the ice-water system is assumed to be associated with the surface tension at the boundary layer with a constant thickness measured as the number of water molecule layers. This part of energy is proportional the surface area of the layer in the case that the layer has constant thickness measures as number of water molecule layers.

   The relevant part of the Gibss free energy of the system in this case is given by

$$G_s = \sigma S + \Lambda(V - V_0) \ , \tag{19.3.1}$$

   where Λ isz Lagrange multiplier guaranteeing that the volume V of the entire system is fixed: $V = V_0$. The shape of the water blob can however vary. Without the volume constraing the variation would give as a solution minimal surface, which cannot be closed.

   Note that Λ does not depend on the coordinates of X^2 and its value is chosen in such a way that the volume enclosed by X^2 equals to V_0.

2. The second model is for water-ice system inside a pore with volume V_{tot}. In this case, one can have several volumes V_i of ice phase and one can assume that the total volume of liquid is fixed $\sum V_i = V(water) = V(total) - V(gas)$. If only the boundary layers matter, one can treat each volume V_i separately and has

$$G_s = \sigma S + \Lambda(V - V_i) \ . \tag{19.3.2}$$

   Now the surface tension is assigned with the ice-water layer and it is assumed that it is at criticality also now so that one obtains large number of shapes for V_i.

The variation of G_s reduces to a variation of S and V to determine possible boundary solid-liquid boundary surfaces X^2.

1. The induced metric at X^2 is given by $g_{\alpha\beta} = g_{kl}\partial_\alpha x^k \partial_\beta x^l$. It is convenient to use Cartesian coordinates since in these coordinates one has $g_{kl} = \delta_{kl}$. One can always select the local representation of the surface in such a way that two coordinate, say x, y serve as coordinates x^α ($x^1 = x, y^1 = y$) for the surface and the third coordinate z is given by $z = z(x, y)$. For a closed surface such as a sphere z is two-valued.

2. The use of Cartesian coordinates for 3-space implies that the formulas are not completely general: in particular, the expression of second fundamental form lacks terms coming from Riemann connection od 3-space E^3, which is non-vanishing for a general coordinate choice (such as spherical or cylindrical coordinates). The general formulas are obtained by replacing ordinary derivatives by covariant ones in appropriate places. The vector x^k appearing in the Gauss formula, is a vector field of E^3 and has a simple expression only in Cartesian coordinates. The index raising for x^k is performed using the flat metric $g_{kl} = \delta_{kl}$ of E^3.

   In Cartesian coordinates for E^3 index raising is a trivial operation $X^k = x_k$. A distinction is however made between these indices since this allows us to use Einstein's summation convention for repeated indices meaning that $A^k B_k$ therefore involves summation over k.

19.3.1 Derivation of the variational equations

The deduction of the equations for X^2 from the variational principle is rather straightforward but due to the non-linearity rather tedious.

Variation of the area

The variation of the area term S gives the following expression

$$\begin{aligned}
\delta S &= \int_{X^2} \delta x^k Tr(H^k)\sqrt{g_2} dA \ , \\
H^k &\equiv g^{\alpha\beta} H^k_{\alpha\beta} \ , \\
H^k_{\alpha\beta} &= D_\beta(\partial_\alpha x^k) = \partial_\alpha\partial_\beta x^r P^k_r \ , \\
P^k_r &= g^k_r - g^{\mu\nu}\partial_\mu x^k \partial_\mu x_r \ .
\end{aligned} \tag{19.3.3}$$

Here $H^k_{\alpha\beta}$ is the second fundamental form defined as covariant derivatives of tangent vectors $\partial_\alpha x^k$. $H^k_{\alpha\beta}$ is orthogonal to the surface as the projection operator P^k_r projects to the normal space of the surface. dA is the coordinate area in the local coordinates of X^2, say $dA = dxdy$.

This gives the term $H^k = g^{\alpha\beta} H^k_{\alpha\beta}\sqrt{g_2}$ to the left hand side of equations for X^2. If the constraint term is absent, one obtains the equation of minimal surface:

$$H^k = D_\beta(\partial_\alpha x^k) = g^{\alpha\beta} H^k_{\alpha\beta} = 0 \ . \tag{19.3.4}$$

The equation states the conservation of momentum currents $j^{\alpha k} = \partial_\alpha x^k \sqrt{g_2}$.

The first interpretation is that the analog of acceleration for 2-D particle vanishes so that an analog of a geodesic line is in question. The second interpretation is as a non-linear geometrization of Laplace equation giving an analogy with electrostatics. The contribution from the volume consraint would give a non-line source term analogous to a density of electric charge.

As explained, closed minimal surfaces are not possible. It is however possible to have local regions which are minimal surfaces, say, the planar surface of a water blob. Physically the surface identifiable as pieces of crystal having planar faces and edges which meet at vertices are expected. These would correspond to surfaces, which possibly fail to be minimal surfaces at the edges serving as analogs of line charges. If the normal component of the conserverd current $j^{\alpha k}$ is continuous at the edge, one can say that the minimal surface equations hold true also at the edge.

Variation of the constraint term

The variation with respect to Λ (no dependence on the coordinates of X^2) gives rise to the constraint $V = V_0$. The variation of the volume V in the constraint term gives a source term to the right hand side of the minimal surface equation.

1. Gauss theorem allows to express the volume V as a surface integral

$$V = x^k n_k \sqrt{g_2} dA \quad . \tag{19.3.5}$$

Here n_k is a unit normal vector for X^2 and expressible in terms of H^k

$$n^k = \frac{H^k}{\sqrt{H^r H_r}} \equiv \frac{H^k}{H} \quad . \tag{19.3.6}$$

The unavoidable presence of the normal vector implies that the constraint term contains second derivatives. The naive expectation that the constraint terms give rise to third order partial differential equations. This expectation is in conflict with the intuitive expectations and is indeed wrong.

One can calculate n^k explicitly by taking two planar coordinates of E^3 as coordinates of X^2 so that one has $(x^1 = x, x^2 = y, x^3 = z(x,y))$. In these coordinates one has

$$H^k = (g^k_z - g^{\mu\nu}\partial_\mu x^k \partial_\nu z) g^{\alpha\beta}\partial_\alpha\partial_\beta z \quad . \tag{19.3.7}$$

All components of H^k are proportional to $(\partial_\alpha\partial_\beta z)$, which completely disappears from the expression for the second fundamental form so that n^k reduces to the form

$$n^k = \frac{h^k}{\sqrt{h^r h_r}} \equiv \frac{h^k}{h} = \frac{h^k}{\sqrt{h^k h_k}} \quad , \quad h^k = P^k_z \quad . \tag{19.3.8}$$

This makes manifest the fact that only the equation for $m^3 = z$ is needed: this is implied by general coordinate invariance.

2. The variation δV can be written as

$$\begin{aligned}
\delta V &= \delta V_1 + \delta V_2 + \delta V_3 , \\
\delta V_1 &= \int_{X^2} \delta x^k n_k \sqrt{g_2} dA \quad , \\
\delta V_2 &= \int_{X^2} x^k \delta n_k \sqrt{g_2} dA \quad , \\
\delta V_3 &= \int_{X^2} x^k n_k \delta(\sqrt{g_2}) dA \quad .
\end{aligned} \tag{19.3.9}$$

3. δV_1 gives to the source term a contribution

$$X^k_1 = n^k \sqrt{g_2} \quad . \tag{19.3.10}$$

having a direction normal to the surface.

4. The calculation of δV_2 requires the calculation of δn^k

$$\begin{aligned}
&\delta n^k = B^k_l \delta h^l \ , \\
&B^k_l \equiv \frac{\partial (h^k/h)}{\partial h_l} = \frac{g^k_l}{h} - \frac{h^k h_l}{h^3} \ , \\
&\delta h^l = \delta(P^l_s) = -\delta[g^{\mu\nu}\partial_\mu x^l \partial_\nu x_s] = 2g^{\mu\rho}g^{\nu\sigma}g_{mn}\partial_\sigma x^n \delta(\partial_\rho x^m)\partial_\mu x^l \partial_\nu x_s \\
&-g^{\mu\nu}[\delta(\partial_\mu x^l)\partial_\nu x_s + \partial_\mu x l \delta(\partial_\nu x_s)] \ .
\end{aligned} \qquad (19.3.11)$$

The outcome of partial integrations transforming variations of the partial derivatives of x^k to x^k can be expressed as operator action in which partial derivatives and from left to the part of the integrand multiplying the variation.

1. The δV_2 is proportional to δP^l_s. The contribution of a given term in the partial differential equations is written after $\rightarrow$:

$$\begin{aligned}
&\delta P^l_z = -\delta[g^{\mu\nu}\partial_\mu x^l \partial_\nu z] = 2g^{\mu\rho}[g^{\nu\sigma}g_{mn}\partial_\sigma x^n \delta(\partial_\rho x^m)\partial_\mu x^l \partial_\nu z] - g^{\mu\nu}[\delta(\partial_\mu x_l)\partial_\nu z + \partial_\mu x^l \delta(\partial_\nu z)] \\
&\rightarrow -2\Lambda \delta x^k D_\alpha[g^{\mu\alpha}g^{\nu\sigma}g_{kn}\partial_\sigma x^n \partial_\mu x^l \partial_\nu z O^z_l] + \delta x^k D_\alpha[g^{\alpha\nu}\partial_\nu z O^z_k] \ , \\
&O^{zl} = x_k B^{kl}\sqrt{g_2} \ .
\end{aligned} \qquad (19.3.12)$$

2. The third term $\delta V_3 = \int_{X^2} x^k n_k \delta(\sqrt{g_2}) dA$ involves the variation of $\sqrt{g_2}$.

$$\begin{aligned}
&\delta\sqrt{g_2} = -\frac{1}{2}g^{\alpha\beta}\delta g_{\alpha\beta}\sqrt{g_2} = -g^{\alpha\beta}[g_{rs}\partial_\alpha x^r \delta(\partial_\beta x^s)]\sqrt{g_2} \\
&\rightarrow \Lambda \delta x^k D_\alpha[g^{\alpha\beta}g_{rs}\partial_\beta x^r B^{rl}h_l]\sqrt{g_2} \ ,
\end{aligned} \qquad (19.3.13)$$

Combining various terms one obtains the following equations for X^2.

$$\begin{aligned}
&D_\beta(g^{\alpha\beta}\partial_\beta x^k) = \frac{\Lambda}{\sigma}X^k \ , \\
&X^k = X^k_1 + X^k_2 + X^k_3 \ , \\
&X^k_1 = n^k \ , \\
&X^k_i = D_\alpha(X^{k\alpha}_i), \text{for } i = 2,3 \ , \\
&X^{k\alpha}_2 = -2[g^{\mu\alpha}g^{\nu\sigma}g_{kn}\partial_\sigma x^n \partial_\mu x_l \partial_\nu z O^{zl} + g^{\alpha\nu}\partial_\nu z O^{zk}] \ , \\
&X^{k\alpha}_3 = g^{\alpha\beta}\partial_\beta x^k x^s B_{sl}h^l\sqrt{g_2} \ , \\
&O^{zl} = x_k B^{kl}\sqrt{g_2} \ .
\end{aligned} \qquad (19.3.14)$$

Explicit form of equations

The equations can be written in two alternative forms

$$\begin{aligned}
&D_\alpha(g^{\alpha\beta}\partial_\beta x^k) = \frac{\Lambda}{\sigma}(n^k + D_\alpha X^{k\alpha}) \ , \\
&D_\alpha[g^{\alpha\beta}\partial_\beta x^k - \frac{\Lambda}{\sigma}X^{k\alpha}] = \frac{\Lambda}{\sigma}n^k \ .
\end{aligned} \qquad (19.3.15)$$

One can argue that by the general coordinate invariance of equations at the level of X^2, only the equation for $x^3 = z$ is needed. The objection is that the nice form of equations is due to a choice of linear coordinates at both X^2 and E^3. Also the presence of $n_k m^k$ and n^k in the equations might mean that all 3 equations are necessary.

19.3.2 Various solution types

For $\Lambda = 0$ the equations reduce to minimal surface equations (`https://cutt.ly/eC3aQYM`). Note that in the TGD framework space-time surfaces in $H = M^4 \times CP_2$ as preferred extremals of action are conjectured to be minimal surfaces [L155]. The fact that the second derivative terms vanish from the expression of n^k means that this limit involves no singular terms.

1. This option is favoured by the connection of the conformal invariance with 2-D criticality, which led to a very detailed understanding of the 2-D critical systems leading to the classification of critical systems in terms of criticality and conformal field theories [B21]. Minimal surface equations for z indeed allow solutions as real or imaginary parts of analytic functions of complex coordinate z for X^2.

2. Minimal surface equations cannot hold everywhere since minimal surfaces are not closed. One can however consider gluing portions of minimal surfaces together along their boundaries serving as singularities. A natural condition is that the normal components of the currents $J^{\alpha k} = g^{\alpha\beta} D_\beta x^k$ are continuous at the discontinuity line. This could pose conditions to the angles between faces meeting at the edges, which could be somewhat analogous to the frames of soap films. These discontinuities would be analogous to cuts of analytic functions. The edges of planar faces of an ice crystal would provide an example of this kind of discontinuities.

3. The simplest solutions for the minimal surface equations would have interpretation as planar boundaries of crystals. More general crystals would be obtained by gluing together portions of curved minimal surfaces along edges. This could be perhaps tested experimentally.

4. One can criticize this picture. The value of Λ should determine the volume. For genuine minimal surfaces $\Lambda = 0$ means infinite volume. For piece-wise minimal surfaces the volume is finite and not determined by Λ but by the boundary conditions expressing the continuity of the normal component of $J^{\alpha k}$ along edges. A possible interpretation is that $\Lambda = 0$ corresponds to the thermodynamic infinite volume limit.

The second option is just the general equation and gives up the conformal invariance.

1. The equation $D_\alpha[g^{\alpha\beta}\partial_\beta x^k - (\Lambda/\sigma)X^{k\alpha}] = (\Lambda/\sigma)n^k$ contains right-hand side as a source term and is analogous to the equation $D_\alpha[g^{\alpha\beta}\partial_\beta x^k] = (\Delta P/\sigma)n^k$ for a soap bubble, where ΔP is pressure difference and σ is surface tension. Λ is analogous to a constant pressure difference ΔP.

   This kind of surface is highly analogous to a soap bubble and could for instance correspond to a spherical region of ice phase. Note that if soap bubbles and films involve an ice-like critical layer, they could be seen as solutions to the proposed equations.

2. For the conformally invariant option $\Lambda = \Delta P = 0$ would hold true at criticality since ΔP is a dimensional parameter and dimensional parameters should vanish at criticality and for conformal invariance. One might think that these solutions, in particular the surfaces X^2 consisting of planar faces, are some kind of limiting solutions when ΔP approaches zero.

3. The warped solutions were already mentioned. For them z depends on a single linear coordinate and they have a flat metric. The equations reduce to ordinary differential equations for z and Λ and are therefore easy to solve numerically. These solutions are not minimal surfaces. They could represent surface waves in water.

Concerning the model, it seems that the crucial thermodynamic question is whether $\Delta P = 0$ is true at criticality as the associated conformal invariance, requiring the absence of dimensional parameters, suggests.

19.4 What about phase transitions as dynamical phenomena describable using TGD proper?

Could one generalize the proposed thermodynamic model, which is actually a static model, to a genuinely thermodynamic model for the freezing or its reversal?

19.4.1 The first guess does not quite work

The first naive guess, inspired by TGD in which space-time is 4-D surface in $H = M^4xCP_2$, would be the replacement of X^2 with its orbit X^3 in 4-D Minkowski space M^4 and a generalization of free energy to what one might call a thermodynamic action.

1. The four-volume V_4 of the system would be fixed by a Lagrange multiplier term $\Lambda(V_4 - V_{4,0})$ and a generalization of 3-D Gauss law to 4-D situation would be used to express the 4-volume as integral $\int x^k n_k dV$ over X^3. The ends X^2_i and X^2_f of the 3-surface at times t_i and t_f would be fixed and not subject to variation whereas space-like boundaries would be varied.

   Also now the surface tension would appear as the coefficient of 3-volume of X^3 and the Lagrange multiplier Λ would have an interpretation as Δp. The thermodynamic action has dimensions of $\hbar$ as required. Stationary solutions would correspond to the extrema of Gibbs free energy. One would obtain the 2-D criticality and conformal invariance for these solutions.

2. What makes this so interesting is that for 3-surfaces X^3, which are light-like, and therefore have vanishing (and indeed minimal!) volume V_3, the induced metric is metrically 2-dimensional. This implies a huge extension of conformal symmetries and even the isometries form an infinite-dimensional group [L147, L172]. Could these light-like 3-surfaces represent phase transitions as dynamical phenomena?

   This raises the question whether there any need for the 3-D volume action if light-likeness implies minimal surface property in the strongest possible form? This implies also that the mere light-likeness of X^3 might be enough. Could-likeness follow from some deeper principle. One can also ask, whether there any need for the 4-D volume constraint either.

3. What about extended conformal invariance? The effective 2-dimensionality plus the fact that 2-D surface X^2 as a spacelike section of X^3 always allows Kähler " structure with complex coordinate W suggests that extended conformal invariance is possible.

Consider now the objections against the naivest proposal.

1. There is a strong mathematical objection related to light-likeness. By a suitable choice of coordinates 3-D metric can be always made diagonal. Now this metric would be of the form $(g_{uu}, g_{w,\overline{W}})$ since transversal degrees of freedom allow always Kähler metric. By light-likeness, one would have $g_{uu} = 0$ so that $g^{uu} H^{k_{uu}} \sqrt{g_3}$ would in general diverge and could be non-vanishing or ill-defined even if $H^k_{uu} = 0$ holds true. Therefore the 3-D volume term as thermodynamic action is not a promising idea.

2. The physical objection is that the light-like 3-surfaces X^3 of M^4 are unrealistic as evolutions of solid-liquid boundary: X^3 would represent an expanding light front.

3. The stability of light-like 3-surfaces is questionable. This suggests that they are such that their small variations cannot affect the light-likeness.

19.4.2 Could the phase transition have a space-time description at the level of basic TGD?

These objections suggest a modification of the naive proposal.

1. The basic observation, natural in the TGD framework, is that if one allows X^3 to be a surface of $H = M^4 \times CP_2$, the situation changes since light-likeness as 3-surface of H does not imply that the M^4 projection of X^3 expands with light-velocity. One could also have 3-D minimal

surfaces in $M^4§^1 \subset M^4 \times CP_2$, where S^1 is rotating geodesic circle, with an E^3 projection, which is closed and has a finite size [L155] so that the problem due to the infinite size of minimal surfaces might be solved.

For instance, one might think that the light-like coordinate varies along a light-like geodesic in M^4xS^1 involving a rotation along the geodesic circle S^1. If the lightlike geodesic of $M^2 \times S^1$ has the form $(t, z, R\Phi) = K(w, \overline{w}) \times (\omega, k, \omega_1)U$ $\omega^2 - k^2 - \omega_1^2) = 0$ its Minkowski projection corresponds to a sub-luminal velocity. The 2-surface in E^3 corresponds to $z = K(w, \overline{w})$ and can be closed if K is two-valued.

2. One should add to the action a 4-D part, say volume term or a more general term. If the description is a fundamental quantum description for the phase transition, one can ask whether one should give up the interpretation as a thermodynamic action and use the action defining classical TGD. This action contains a 4-D volume term and the Kähler action. This action would give rise to a boundary term representing a normal flow of isometry currents through the boundary. The boundary conditions would replace the minimal surface equations.

3. There could also be a 3-D part in the action but by light-likeness it cannot depend on induced metric. The Chern-Simons term for the Kähler action is the natural choice. Twistor lift suggests that it is present also in M^4 degrees of freedom. Topological field theories utilizing Chern-Simons type actions are standard in condensed matter physics, in particular in the description of anyonic systems, so that the proposal is not so radical as one might think. One might even argue that in anyonic systems, the fundamental dynamics of the space-time surface is not masked by the information loss caused by the approximations leading to the field theory limit of TGD.

   Boundary conditions would state that the normal components of the isometry currents are equal to the divergences of Chern-Simons currents and in this way guarantee conservation laws. In CP_2 degrees of freedom the conditions would be for color currents and in M^4 degrees of freedom for 4-momentum currents.

4. This picture would conform with the general view of TGD. In zero energy ontology (ZEO) [L105, L142] phase transitions would be induced by macroscopic quantum jumps at the level of the magnetic body (MB) of the system. In ZEO, they would have as geometric correlates classical deterministic time evolutions of space-time surface leading from the initial to the final state [L90]. The findings of Minev et al provide [L90] lend support for this picture.

19.4.3 Light-like 3-surfaces from $det(g_4) = 0$ condition

How the light-like 3- surfaces could be realized?

1. A very general condition considered already earlier is the condition $det(g_4) = 0$ at the light-like 4-surface. This condition means that the tangent space of X^4 becomes metrically 3-D and the tangent space of X^3 becomes metrically 2-D. In the local light-like coordinates, $(u, v, W, \overline{W})$ $guv = g_{vu})$ would vanish (g_{uu} and g_{vv} vanish by definition.

   Could $det(g_4) = 0$ and $det(g_3) = 0$ condition implied by it allow a universal solution of the boundary conditions? Could the vanishing of these dimensional quantities be enough for the extended conformal invariance?

2. 3-surfaces with $det(g_4) = 0$ could represent boundaries between space-time regions with Minkowskian and Euclidean signatures or genuine boundaries of Minkowskian regions.

   A highly attractive option is that what we identify the boundaries of physical objects are indeed genuine space-time boundaries so that we would directly see the space-time topology. This was the original vision. Later I became cautious with this interpretation since it seemed difficult to realize, or rather to understand, the boundary conditions.

   The proposal that the outer boundaries of different phases and even molecules make sense and correspond to 3-D membrane like entities [L155], served as a partial inspiration for this article but this proposal is not equivalent with the proposal that light-like boundaries defining genuine space-time boundaries can carry isometry charges and fermions.

3. How does this relate to $M^8 - H$ duality [L114, L115]? At the level of rational polynomials P determined 4-surfaces at the level of M^8 as their "roots" and the roots are mass shells. The points of M^4 have interpretation as momenta and would have values, which are algebraic integers in the extension of rationals defined by P.

   Nothing prevents from posing the additional condition that the region of $H^3 \subset M^4 \subset M^8$ is finite and has a boundary. For instance, fundamental regions of tessellations defining hyperbolic manifolds (one of them appears in the model of the genetic code [L137]) could be considered. $M^8 - H$ duality would give rise to holography associating to these 3-surfaces space-time surfaces in H as minimal surfaces with singularities as 4-D analogies to soap films with frames.

   The generalization of the Fermi torus and its boundary (usually called Fermi sphere) as the counterpart of unit cell for a condensed matter cubic lattice to a fundamental region of a tessellation of hyperbolic space H^3 acting is discussed is discussed in [L157]. The number of tessellations is infinite and the properties of the hyperbolic manifolds of the "unit cells" are fascinating. For instance, their volumes define topological invariants and hyperbolic volumes for knot complements serve as knot invariants.

This picture resonates with an old guiding vision about TGD as an almost topological quantum field theory (QFT) [K53, K7, K123], which I have even regarded as a third strand in the 3-braid formed by the basic ideas of TGD based on geometry-number theory-topology trinity.

1. Kähler Chern-Simons form, also identifiable as a boundary term to which the instanton density of Kähler form reduces, defines an analog of topological QFT.

2. In the recent case the metric is however present via boundary conditions and in the dynamics in the interior of the space-time surface. However, the preferred extremal property essential for geometry-number theory duality transforms geometric invariants to topological invariants. Minimal surface property means that the dynamics of volume and Kähler action decouple outside the singularities, where minimal surface property fails. Coupling constants are present in the dynamics only at these lower-D singularities defining the analogs of frames of a 4-D soap film.

   Singularities also include string worlds sheets and partonic 2-surfaces. Partonic two-surfaces play the role of topological vertices and string world sheets couple partonic 2-orbits to a network. It is indeed known that the volume of a minimal surface can be regarded as a homological invariant.

3. If the 3-surfaces assignable to the mass shells H^3 define unit cells of hyperbolic tessellations and therefore hyperbolic manifolds, they also define topological invariants. Whether also string world sheets could define topological invariants is an interesting question.

Chern-Simons term appears also in the topological quantum field theories (TQFTs) used to model topological quantum computation (TQC). The TGD picture would be that fermions form braids at light-like 3-surfaces of mesoscopic or even macroscopic size and time-like braiding induces space-like braiding of the strings (defining string world sheets) connecting fermions at different light-like 3-surfaces. Anyons would correspond to irreps of a non-Abelian Galois group [L167, L170].

A second model considers magnetic flux tubes as counterparts of space-like braid strands. These two pictures are consistent if the strings are associated with magnetic flux tubes. If the flux tubes are monopole flux tubes, the light-like boundaries represent light-like orbits of Kähler magnetic monopoles. Whether this is allowed by boundary conditions, is not clear. Monopole property is consistent with the boundary condition $J_{uv} = 0$, where u, v are light-like coordinates of X^4.

Mopoles can be avoided if the light-like 3-surface is not a genuine boundary but a boundary between a Minkowskian region and an Euclidean space-time region representing wormhole contact with mesoscopic or even larger size. The monopole flux would flow through the wormhole contact to the second Minkowskian space-time sheet and closed flux lines would be possible. Elementary particles would be topologically these kinds of entities. A very large deformation of CP_2 type vacuum extremal in M^4 directions would be in question.

19.4.4 Can one allow macroscopic Euclidean space-time regions

Euclidean space-time regions are not allowed in General Relativity. Can one allow them in TGD?

1. CP_2 extremals with a Euclidean induced metric and serving as correlates of elementary particles are basic pieces of TGD vision. The quantum numbers of fundamental fermions would reside at the light-like orbit of 2-D wormhole throat forming a boundary between Minkowskian space-time sheet and Euclidean wormhole contact- parton as I have called it. More precisely, fermionic quantum numbers would flow at the 1-D ends of 2-D string world sheets connecting the orbits of partonic 2-surfaces. The signature of the 4-metric would change at it.

2. It is difficult to invent any mathematical reason for excluding even macroscopic surfaces with Euclidean signature or even deformations of CP_2 type extremals with a macroscopic size. The simplest deformation of Minkowski space is to a flat Euclidean space as a warping of the canonical embedding $M^4 \subset M^4 \times S^1$ changing its signature.

3. I have wondered whether space-time sheets with an Euclidean signature could give rise to black-hole like entities. One possibility is that the TGD variants of blackhole-like objects have a space-time sheet which has, besides the counterpart of the ordinary horizon, an additional inner horizon at which the signature changes to the Euclidean one. This could take place already at Schwarzschild radius if g_{rr} component of the metric does not change its sign.

19.4.5 Conformal confinement at the level of H

The proposal of [L173], inspired by p-adic thermodynamics, is that all states are massless in the sense that the sum of mass squared values vanishes for physical states. Conformal weight, as essentially mass squared value, is naturally additive and conformal confinement as a realization of conformal invariance would indeed mean that the sum of mass squared values vanishes. Since complex mass squared values with a negative real part are allowed as roots of polynomials, the condition is highly non-trivial.

M^8-H duality [L114, L115] would make it natural to assign time-like masses with time-like space-time regions and tachyonic masses with CP_2 type extremals and the Euclidean regions of the space-time surface. What looks like a problem is that the regions with Euclidean signature look Minkowskian to the outsider since the M^4 projection is time-like. The resolution of the problem could be simple: the light-like momenta assignable with the light-like boundaries of the Euclidean regions would make them look like Minkowskian regions.

19.4.6 But are the normal components of isometry currents finite?

Whether this scenario works depends on whether the normal components for the isometry currents are finite.

1. $det(g_4)=0$ condition gives boundaries of Euclidean and Minkowskian regions as 3-D light-like minimal surfaces. There would be no scales in accordance with generalized conformal invariance. g_{uv} in light-cone coordinates for M^2 vanishes and implies the vanishing of $det(g_4)$ and light-likeness of the 3-surface.

   What is important is that the formation of these regions would be unavoidable and they would be stable against perturbations.

2. $g^{uv}\sqrt{|g_4|}$ is finite if $det(g_4)=0$ condition is satisfied, otherwise it diverges. The terms $g^{ui}\partial_i h^k\sqrt{|g_4|}$ must be finite. $g^{ui}=cof(g_{iu})/det(g_4)$ is finite since $g_{uv}g_{vu}$ in the cofactor cancels it from the determinant in the expression of g^{ui}. The presence of $\sqrt{|g_4|}$ implies that the these contributions to the boundary conditions vanish. Therefore only the condition boundary condition for g^{uv} remains.

3. If also Kähler action is present, the conditions are modified by replacing $T^{uk} = g^{u\alpha}\partial_\alpha h^k\sqrt{|g_4|}$ with a more general expression containing also the contribution of Kähler action. I have discussed the details of the variational problem in [K14, K7].

   The Kähler contribution involves the analogy of Maxwell's energy momentum tensor, which comes from the variation of the induced metric and involves sum of terms proportional to $J_{\alpha\mu}J^{beta}_{\mu}$ and $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}$.

   In the first term, the dangerous index raisings by g^{uv} appear 3 times. The most dangerous term is given by $J^{uv}J^v_v\sqrt{|g|} = g^{u\mu}g^{v\nu}J_{\alpha\beta}g^{vu}J_{vu}\sqrt{|g|}$. The divergent part is $g^{uv}g^{vu}J_{uv}g^{vu}J_{vu}\sqrt{|g|}$. The diverging g^{uv} appears 3 times and $J_{uv} = 0$ condition eliminates two of these. $g^{vu}\sqrt{|g|}$ is finite by $\sqrt{|g|} = 0$ condition. $J_{uv} = 0$ guarantees also the finiteness of the most dangerous part in $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}\sqrt{|g|}$.

   There is also an additional term coming from the variation of the induced Kähler form. This to the normal component of the isometry current is proportional to the quantity $J^{n\alpha}J^k_l\partial_\beta h^l\sqrt{|g|}$. Also now, the most singular term in $J^{u\beta} = g^{u\mu}g^{\beta\nu}J_{\mu\nu}$ corresponds to J^{uv} giving $g^{uv}g^{vu}J^{uv}\sqrt{|g|}$. This term is finite by $J_{uv} = 0$ condition.

   Therefore the boundary conditions are well-defined but only because $det(g_4) = 0$ condition is assumed.

4. Twistor lift strongly suggests that the assignment of the analogy of Kähler action also to M^4 and also this would contribute. All terms are finite if $det(g_4) = 0$ condition is satisfied.

5. The isometry currents in the normal direction must be equal to the divergences of the corresponding currents assignable to the Chern-Simons action at the boundary so that the flow of isometry charges to the boundary would go to the Chern-Simons isometry charges at the boundary.

   If the Chern-Simons term is absent, one expects that the boundary condition reduces to $\partial_v h^k = 0$. This would make X^3 2-dimensional so that Chern-Simons term is necessary. Note that light-likeness does not force the M^4 projection to be light-like so that the expansion of X^2 need not take with light-velocity. If CP_2 complex coordinates are holomorphic functions of W depending also on $U = v$ as a parameter, extended conformal invariance is obtained.

19.4.7 $det(g_4) = 0$ condition as a realization of quantum criticality

Quantum criticality is the basic dynamical principle of quantum TGD. What led to its discovery was the question "How to make TGD unique?". TGD has a single coupling constant, Kähler couplings strength, which is analogous to a critical temperature. The idea was obvious: require quantum criticality. This predicts a spectrum of critical values for the Kähler coupling strength. Quantum criticality would make the TGD Universe maximally complex. Concerning living matter, quantum critical dynamics is ideal since it makes the system maximally sensitive and maximallt reactive.

Concerning the realization of quantum criticality, it became gradually clear that the conformal invariance accompanying 2-D criticality, must be generalized. This led to the proposal that super symplectic symmetries, extended isometries and conformal symmetries of the metrically 2-D boundary of lightcone of M^4, and the extension of the Kac-Moody symmetries associated with the light-like boundaries of deformed CP_2 type extremals should act as symmetries of TGD extending the conformal symmetries of 2-D conformal symmetries. These huge infinite-D symmetries are also required by the existence of the Kähler geometry of WCW [K53, K29, K91] [L147, L172].

However, the question whether light-like boundaries of 3-surfaces with scale larger than CP_2 are possible, remained an open question. On the basis of preceding arguments, the answer seems to be affirmative and one can ask for the implications.

1. At M^8 level, the concrete realization of holography would involve two ingredients. The intersections of the space-time surface with the mass shells H^3 with mass squared value determined as the roots of polynomials P and the tlight-like 3-surfaces as $det(g_4) = 0$ surfaces as boundaries (genuine or between Minkowskian and Euclidean regions) associated by $M^8 - H$ duality to 4-surface of M^8 having associative normal space, which contains

commutative 2-D subspace at each point. This would make possible both holography and M^8-H duality.

Note that the identification of the algebraic geometric characteristics of the counterpart of $det(g_4)=0$ surface at the level of H remains still open.

Since holography determines the dynamics in the interior of the space-time surface from the boundary conditions, the classical dynamics can be said to be critical also in the interior.

2. Quantum criticality means ability to self-organize. Number theoretical evolution allows us to identify evolution as an increase of the algebraic complexity. The increase of the degree n of polynomial P serves as a measure for this. $n=h_{eff}/h_0$ also serves as a measure for the scale of quantum coherence, and dark matter as phases of matter would be characterized by the value of n.

3. The 3-D boundaries would be places where quantum criticality prevails. Therefore they would be ideal seats for the development of life. The proposal that the phase boundaries between water and ice serve as seats for the evolution of prebiotic life, is discussed from the point of TGD based view of quantum gravitation involving huge value of gravitational Planck constant $\hbar_{eff}=\hbar_{gr}=GMm/v_0$ making possible quantum coherence in astrophysical scales [L161]. Density fluctuations would play an essential role, and this would mean that the volume enclosed by the 2-D M^4 projection of the space-time boundary would fluctuate. Note that these fluctuations are possible also at the level of the field body and magnetic body.

4. It has been said that boundaries, where the nervous system is located, distinguishes living systems from inanimate ones. One might even say that holography based on $det(g_4)=0$ condition realizes nervous systems in a universal manner.

5. I have considered several variants for the holography in the TGD framework, in particular strong form of holography (SH). SH would mean that either the light-like 3-surfaces or the 3-surfaces at the ends of the causal diamond (CD) determine the space-time surface so that the 2-D intersections of the 3-D ends of the space-time surface with its light-like boundaries would determine the physics.

This condition is perhaps too strong but a fascinating, weaker, possibility is that the internal consistency requires that the intersections of the 3-surface with the mass shells H^3 are identifiable as fundamental domains for the coset spaces $SO(1,3)/\Gamma$ defining tessellations of H^3 and hyperbolic manifolds. This would conform nicely with the TGD inspired model of genetic code [L137].

Chapter 20

A Possible Explanation of Shnoll Effect

20.1 Introduction

As I wrote the first version of this chapter about Shnoll effect for about decade ago [L15], I did not yet have the recent vision about adelic physics [L63, L64] as a unification of real physics and various p-adics and real number based physics to describe the correlates of both sensory experience and cognition.

The recent view is that the hierarchy of extensions of rational numbers induces a hierarchy of extensions of p-adic number fields in turn defining adele. This hierarchy gives rise to dark matter hierarchy labelled by a hierarchy of Planck constants and also evolutionary hierarchy. The hierarchy of Planck constants $h_{eff} = n \times h_0$ is and essential element of quantum TGD and adelic physics suggests the identification of n as the dimension of extension of rationals. n could be seen as a kind of IQ for the system.

What is also new is the proposal that preferred p-adic primes labelling physical systems could correspond to so called ramified primes, call them p, of extension of rationals for which the expression of the rational p-adic prime as product of primes of extension contains less factors than that the dimension n of extension so that some primes of extension appear as higher powers. This is analog for criticality as the appearance of multiple roots of a polynomial so that the derivative vanishes at the root besides the polynomial itself.

Before continuing it is good to make some confessions. Already in the earlier approach [L15] I considered two options for explaining the Shnoll effect: either in terms of p-adic fractality or in terms of quantum phase q of both. I however too hastily concluded that the p-adic option fails and choose the quantum phase option.

In the following both options are seen as parts of the story relying on a principle: the approximate scaling invariance of probability distribution $P(n)$ for fluctuations under scalings by powers of p-adic prime p implying that $P(n)$ is approximately identical for the divisions for which the interval Δ defining division differs by a power of p.

Second new idea is the lift of $P(n)$ to wave function $\Psi(n)$ in the space of counts. For quantum phase q_m, $m = p$, Ψ_m would have quantum factor proportional to a wave function in finite field F_p, and the notion of counting modulo p suggests that the wave function corresponds to particle in box - standing wave - giving rise to $P(n)$ representing diffraction pattern.

20.1.1 Basic facts about Shnoll effect

Usually one is not interested in detailed patterns of the fluctuations of physical variables, and assumes that possible deviations from the predicted spectrum are due to the random character of the phenomena studied. Shnoll and his collaborators have however studied during last four decades the patterns associated with random fluctuations and have discovered a strange effect described in detail in [E26] , [E26, E37, E38, E27, E44, E28]. The examples of [E26]. [E26] give the reader a clear picture about what is involved.

1. Some examples studied by Shnoll and collaborators are fluctuations of chemical and nuclear decay rates, of particle velocity in external electric field, of discharge time delay in a neon lamp RC oscillator, of relaxation time of water protons using the spin echo technique, of amplitude of concentration fluctuations in the Belousov-Zhabotinsky reaction. Shnoll effect appears also in financial time series [E46] which gives additional support for its universality. Often the measurement reduces to a measurement of a number of events in a given time interval τ. More generally, it is plausible that in all measurement situations one divides the value range of the studied observable to intervals of fixed length and counts the number of events in each interval to get a histogram representing the distribution $N(n)$, where n is the number of events in a given interval and $N(n)$ is the number of intervals with n events. These histograms allow to estimate the probability distribution $P(n)$, which can be compared with theoretical predictions for the spectrum of fluctuations of n. Typical theoretical expectations for the fluctuation spectrum are characterized by Gaussian and Poisson distributions.

2. Contrary to the expectations, the histograms describing the distribution of $N(n)$ has a distribution having several maxima and minima (see the figures in the article of Shnoll and collaborators (see `http://tinyurl.com/6kehe9b`). Typically -say for Poisson distribution - one expects single peak. As the duration of the measurement period increases, this structure becomes gets more pronounced: standard intuition would suggest just the opposite to take place. The peaks also tend to be located periodically. According to [E26] [E26] the smoothed out distribution is consistent with the expected distribution in the case that it can be predicted reliably.

3. There are also other strange features involved with the effect. The anomalous distribution for the number n of events per fixed time interval (or more general value interval of measured observable) seems to be universal as the experiments carried out with biological, chemical, and nuclear physics systems demonstrate. The distribution seems also to be same at laboratories located far away from each other. The comparison of consecutive histograms shows that the histogram shape is likely to be similar to the shape of its nearest temporal neighbors. The shapes of histograms tend to recur with periods of 24 hours, 27 days, or 365 days. The regular time variation of consecutive histograms, the similarity of histograms for simultaneous independent processes of different nature and occurring in different geographical positions, and the above mentioned periods, suggest a common reason for the phenomenon possibility related to gravitational interactions in Sun-Earth and Earth-Moon system.

In the case that the observable is number n of events per given time interval, theoretical considerations predict a distribution characterized by some parameters. For instance, for Poisson distribution the probabilities $P(n)$ are given by the expression

$$P(n|\lambda) \quad = \quad exp(-\lambda)\frac{\lambda^n}{n!} \ . \tag{20.1.1}$$

The mean value of n is $\lambda > 0$ and also variance equals to λ. The replacement of distribution with a many-peaked one means that the probabilities $P(n|\lambda)$ are modified so that several maxima and minima result. This can occur of course by the randomness of the events but for large enough samples the effect should disappear.

The universality and position independence of the patterns suggest that the modification changes slowly as a function of geographic position and time. The interpretation of the periodicities as periods assignable to gravitational interactions in Sun-Earth system is highly suggestive. It is however very difficult to imagine any concrete physical models for the effect since distributions look the same even for processes of different nature. It would seem that the very notion of probability somehow differs from the ordinary probability based on real numbers and that this deformation of the notion of probability concept somehow relates to gravitation.

20.1.2 Quantum group inspired model for Shnoll effect

Usually quantum groups are assigned with exotic phenomena in Planck length scale. In TGD they are assignable to a finite measurement resolution [K121]. TGD inspired quantum measurement theory describes finite measurement resolution in terms of inclusions of hyper-finite factors of type II_1 (HFFs) and quantum groups related closely to the inclusions and appear also in the models of topological quantum computation [B25] based on topological quantum field theories [A29].

Consider first the original version of the proposed model. If I would rewrite it now correcting also the small errors, the summary would be as follows. This slightly revised model can be included as such to the new model.

1. The possibility that direct p-adic variants of real distribution functions such as Poisson distribution might allow to understand the findings was discussed also in the original version. The erratic conclusion was that this cannot the case. In fact, for $\lambda = 1/p^k$ the sum of probabilities $P(n)$ without normalization factor is finite, and the appriximate scaling symmetry $P(n) \simeq P(p^r n)$ emerges for $k = 1$. p-Adicity predicts approximate p-periodicity corresponding to the periodic variation of n_R with the lowest pinary digit of n.

2. It was argued that one should replace the integer $n!$ in $P(n)$ with quantum integer [A23] $(n!)_{q_m}$, $q = exp(i\pi/m)$, identified as the product of quantum integers $r_{q_m} = (q^r - q^{-r})/(q - q^{-1})$, $r < n$.

   This however leads to problems since r_{q_m} can be negative. The problem can be circumvented by interpreting $n!$ as p-adic number and expanding it in powers of p with pinary digits $x_k < p$. For $m = p$ the replacement of x_k with quantum integer yields positive pinary digits.

   The resulting quantum variant of p-adic integer can be mapped to its real counterpart by a generalization of canonical identification $x = \sum x_n p^n \to \sum x_n p^{-n}$. Whatever the detailed definition, quantum integers are non-zero and positive. The quantum replacement $r \to r_{q_m}$ of the integers appearing in rational parameters in $P(n|\lambda_i)$ might therefore make sense. It however does not make sense in the exponents like λ^n and $\lambda = p^k$, $k > 1, 2, ..$, is forced by convergence condition.

3. I proposed also another modification of quantum integers x_{q_m}, $x < p = m - 1$ appearing in as pinary digits by decomposing x into a product of primes $s < p$ and replacing s with quantum primes s_{q_p} so that also the notion of quantum prime would make sense: one might talk about quantum arithmetics [K77, K75]. This is possible but is not necessary.

20.1.3 Adelic model for Shnoll effect

At the first re-reading the original model looked rather tricky, and this led to a revised model feeding in the adelic wisdom [L63, L64]. One implication hierarchy of Planck constants $h_{eff}/h_0 = n$ with n identified as the dimension of Galois extension.

One also ends up to the proposal that preferred p-adic primes p correspond to so called ramified primes of the extension of rationals inducing the extensions of p-adic number fields defining the adele. This kind of prime would naturally define a small-p p-adicity associated with Shnoll effect, which would thus serve as a direct signature of adelic physics.

1. The first observation in conflict with the original belief is that one can actually define purely p-adic variant of the Poisson distribution $P(n|\lambda)$ by replacing $1/n!$ with its image $(n!)_R$ under canonical identification. For instance, for Poisson distribution one must have $\lambda = p^{-k}$, $k = 1, 2, ..$ for both real and p-adic distributions to nake sense. The sum of the probabilities $P(n)$ is finite. Poisson distribution with trivial quantum part is determined uniquely.

2. One can also consider quantization $P(n) = |\Psi(n)|^2$, suggested by the vision about quantum TGD as complex square root of thermodynamics and hierarchy of Planck constants making possible macroscopic quantum coherence in arbitrarily long scales. The complexity of $\Psi(n)$ could genuine quantum interpretation. Quantum factor of $\Psi(n)$ allows interpretation as a wave function in finite field F_p representing the space of counts modulo p. The existence of quantum p-adics requires $m = p$. Scaling by p is not a symmetry but multiplication by $0 < k < p$ and shift by $0 \leq k < p$ act as symmetries analogous to rotations and translations acting on waves functions in Euclidian 3-space.

3. The objections against Shnoll effect lead to an additional condition - or should one say principle - stating that the $P(n)$ is approximately invariant under scalings $n \rightarrow p^k n$. This could be seen as a manifestation of p-adic fractality in turn reflecting quantum criticality of TGD Universe.

4. Taking n as the observable simplifies p-adicization crucially since the highly non-unique p-adicization of classical observables is avoided. One could speak of quantum measurement in the space of counts n defining universal observables. In quantum measurements the results are typically expressed as numbers of counts in given bin so that this kind of p-adicization is physically natural. The division of measurement interval would define an ensemble and n would be measured in each interval. State function reduction would localize $\Psi(n)$ to n in each interval.

This picture leads to an alternative and simpler view about Shnoll effect. The scaling invariance is an essential additional condition now.

1. The factorials $n!$ appearing in $P(n) = (d^n f/dx^n)/n!$ identified as coefficients of Taylor series of its generating function developed in pinary expansion for $p = m$. In this expansion one must invert powers of p in $(n!)_R$ and could also replace the coefficients of powers of p with quantum integers or replace even primes in their prime composition with quantum primes. For given norm $(n!)_R$ has period p approximately.

2. The n:th derivative $X(n) = d^n f/dx^n$ appearing as coefficient of $1/n!$ is replaced with $X(n)_R/X(n)_p$ giving approximate periodicity and scaling invariance $n \rightarrow pn$.

3. Quantum phase is associated with the ansatz stating $P(n) = |\Psi(n)|^2$. In the "diffractive" situation quantum counterpart corresponds to $|(kn)_{q_m}|^2$, $0 < k < p - 1$. This gives rise to periodicity with period $m = p$.

The universal modifications of the probability distributions $P(n|\lambda_i)$ considered predict patterns analogous to the ones observed by Shnoll. The p-adic prime $p = m$ characterizes the deformation of the probability distribution and implies approximate p-periodicity, which could explain the periodically occurring peaks of the histograms for $N(n)$ as function of n.

One can imagine several explanations for the dependence of the time series distribution $P(n)$ on the direction of the momentum of alpha particle [E27, E44] and on the dependence of $P(n)$ on time.

1. The change of ramified prime p induced by the change of the extension of rationals would affect the periods. An interesting question is whether the effects understood in terms of the effect of the measurement apparatus on many-sheeted space-time topology and geometry on p. Can one speak about measurement of p and of extension of rationals?

2. The extension of rationals (and thus p) need not change. The "quantum factor" of Ψ in $P(n) = |\Psi(n)|^2$ has part depending on q_p. The dependence on q_p could change without change in p so that the extension of rationals need not change. One could speak about measurement of an observable related to the quantum factor of Ψ. A more concrete model relies on wave function proportional to $(kn)_{q_p} \propto q_m^{kn} + q_m^{-kn}$ - analog to a superposition of plane waves with momenta k propagating to opposite directions in the space of counts and producing in $P(n)$ diffraction pattern proportional to $(qn)^2_{q_p}$. Change of momentum k by scaling or shift induced by variation of the gravitational parameters or time evolution could be in question.

The p-adic primes p in question are rather small, not much larger than 100 and the periods of $P(n)$ provide a stringent test for the proposal. If p corresponds to ramified prime as adelic physics suggests, it can be indeed small.

20.1.4 Quantum gravitational model of the Shnoll effect

One can criticize the above described models as too formal. What comes to mind is that the states split into several states with different decay rates. The basic problem is to understand how extremely weak gravitational interaction can have such drastic effects on the states of even nuclei.

The third number theoretic model is much simpler and is based on the notion of the spectrum of effective Planck constants. The rates depend on the value of effective Planck constant and this could explain the decomposition of peaks to several ones. Gravitational quantum coherence in astrophysical scales is predicted and the gravitational Planck constant of even the Milky Way can affect the rates. In this framework the Shnoll effect could be seen as a direct empirical evidence for the hierarchy of Planck constants.

To sum up, I cannot avoid the thought that fluctuations regarded usually as a mere nuisance could be actually a treasure trove of new physics. While we have been busily building bigger and bigger particle accelerators, the truth would have been staring directly at our face and even winking eye to us.

For the reader not familiar with TGD the article series in Prespace-time journal [L9, L10, L13, L14, L11, L8, L12, L2] and the two articles about TGD inspired theory of consciousness and of quantum biology in Journal of Consciousness Research and Exploration [L7, L6, L5] are recommended. Also the online books at my homepage provide the needed background.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L21].

20.2 Adelic view about Shnoll effect

In the sequel the adelic model for Shnoll effect is developed. The earlier model - with errors corrected - can be seen as a variant of this model.

20.2.1 General form for the deformation of $P(n|\lambda)$

Could Shnoll effect be a direct manifestation of adelic physics [L63, L64]? In TGD framework adelic physics is motivated as physics of cognition and sensory experience, and this could explain why Shnoll effect is associated even with financial time series. Instead of starting to make ad hoc guesses, consider first what kind of constraints adelic physics could pose on the deformation.

1. The basic idea is that since the effect is universal, the form of the probability distribution $P(n|\lambda_i)$ should be modified in a universal manner, which depends on the experimental situation only very weakly.

2. Adelic physics suggests that the deformation of probability distributions $P(n|\lambda_i)$ could depend on small p-adic prime p identifiable as ramified prime and on integer m defining defining quantum phase $q_m = exp(i2pi/m)$ and giving rise to effective angle resolution in terms of allowed phases as roots of unity.

   The first guess is that m could give rise to the periodic occurrence of the maxima and minima in the deformed distribution due to the m-periodicity of n_{q_m}. p-Adic prime p would define finite length scale resolution: it turns that also the map of factorials $n!$ interpreted as p-adic numbers by canonical identification to their counterparts gives an approximately p-periodic modulation of $P(n)$.

3. According to the standard definition quantum integers are real and given by $n_q = (q^n - q^{-n})/(q - q^{-1})$. The problem is that n_{q_m} vanishes if n is divisible by m so that one cannot replace the factorials appearing in Poisson distribution (say) with their quantum counterparts. The solution of the problem is the interpretation of n as p-adic integer and the replacement of pinary coefficients with quantum integers n_{q_p} $(m = p)$, which are positive. One could also decompose them into a product of prime factors and replace them with their quantum counterparts n_{q_p}.

In the power λ^{-n} one could consider the replacement of n with n_{q_p} but this does not work in the p-adic case because p^{-n_q} in general does not belong to a finite extension of p-adics used. In the p-adic case $\lambda = 1/p^k$ turns out to be the only possible option. For $k = 1$ one obtains approximate scaling invariance $n \rightarrow pn$.

4. The hierarchy of Planck constants makes possible quantum coherence in all scales. This inspires the idea that the probabilities $P(n)$ are moduli squared for a complex probability amplitude $\Psi(n)$: $P(n) = |\Psi(n)|^2$. Ψ_n could have having "quantum factor" Ψ_q containing a phase depending on n.

   The simplest option is that quantum factor is has phase $U(n) = q_m^n$ or its power. This does not give any effect visible in $P(n)$. A more general options is a quantum factor $\Psi_q = \sum c_k q_m^k$. In this case on obtains interference effects in the modulus squared. Complex quantum integer $n_q = (q^n - q^{-n})/(1 - q)$ as a multiplicative factor would give rise to a diffractive factor $sin^2(n\pi/m)/sin^2(\pi/m)$ in $P(n)$.

   Speaking about amplitude for fluctuations and quantum diffraction in an ensemble defined by a division of the range of observable or a division of time interval to smaller intervals is of course quite a generalization of quantum mechanical thinking but it is interesting to look whether this could lead to sensible predictions. One could however whether the slow variations of the fluctuation patterns could correspond to different outcomes for quantum measurements measuring p-adic prime P and m.

Usually objections are the best manner to proceed and now the objections leads to an approximate scaling invariance $n \rightarrow p$ of $P(n)$ suggested also by the p-adic fractality implied by the quantum criticality of TGD Universe.

1. The first objection is that the findings of Shnoll are special in the sense that the replacement of observable with its diffeomorph cannot preserve the character of distribution $P(n)$. One can however claim that in practice the choice of observables is highly unique from physical constraints. Only simple scalings of the observable can be considered in same cases.

2. Second objection is that replacing the interval ΔO for observable with $\Delta O/m$ cannot leave the general shape of the distribution invariant. The naïve guess is that one has $P(n) \rightarrow P(nm)$ for large enough values of n. This condition in a suitably restricted form can be posed as a constraint. The natural assumption is that the condition holds true only for the p-adic scalings $m = p^k$.

   This condition can be used as a constraint on $P(n)$. $P(n)$ would depend on n only through functions of n invariant under p-adic scalings $n \rightarrow pn$. An example about scaling invariant is provided by the function $x_R = n_R/n_p$, where n_p is the p-adic norm of n and n_R is obtained by canonical identification $n = \sum n_k p^k \rightarrow n_k p^k \rightarrow n_R = \sum n_k p^{\rightarrow} n_k p^{-k}$.

   Any function of x_R is invariant under p-adic scalings and one can construct analogs for Gaussian, Poisson distribution, etc... by replacing n with x_R. Periodicity with period p is obtained if one replaces the p-adic unit nn_p with $nn_p \ mod \ p$. Since the higher pinary digits do not affect strongly the behavior of x_R, approximate p-periodicity is obtain in any case.

3. The factorial $n!$ appears in probability distributions having Taylor series as a generating function. A little calculation below using Legendre's theorem shows that apart from an approximately periodic multiplicative function of n with period p one has $p^{-n}/(n!)_R = p^{-s(n)}$, where $s(n)$ is the sum of the pinary digits of n in the expansion in powers of p. $s(n)$ is invariant under scalings $n \rightarrow p^k n$. Therefore the deformed Poisson distribution is unique from the approximate scaling invariance and given apart from normalization by $P(n) = p^{-n}/(n!)_R = p^{-s(n)}$.

4. What about more general scalings $n \rightarrow kn$? Under the scalings $n \rightarrow kn$ for k not divisible by p, the norm of n is invariant. The rough scaling behavior of $P(n)$ is however un-affected. The lowest pinary digit is replaced in $n \rightarrow n + 1$ with $n + k \ mod \ p$ so that approximate p-periodicity is still present.

Consider next quantum phases.

1. The dependence on the quantum phase $q_m = expi(ipi/m)$, $m = p$, cannot be invariant under p-adic scalings. The reason is that scaling by p takes all powers of q_p to unit and is thus not a bijection.

   One can however consider different kind of symmetries. The integers $n\ mod\ p$ form finite field G_p in which multiplication and sum define transformations analogous to rotations and translations acting naturally as symmetries in the space of probability amplitudes defined in the space of counts $n\ mod\ p$ - modulo arithmetics means finite phase resolution for n represented as a phase. The wave functions can be interpreted as elements of finite-field algebra analogous to group algebra consisting of probability amplitudes in group.

   One can interpret the plane waves q_p^{kn} as analogs of plane waves with momentum k. Multiplication and translations by r would correspond naturally to symmetries analogous to rotations and translations in Euclidian space.

2. $\Psi(n)$ would have "quantum factor" expressible as a wave function in the space of counts n. For plane wave q_p^{kn}, the plane wave would not be visible in $P(n)$. The superposition $q_p^{kn} + q_p^{-kn}$ of two plane waves propagating in opposite directions in the space of counts modulo p is proportional to quantum integer $(kn)_{q_p} = sin^2(kn\pi/p)/sin(\pi/p)$ defining the analog of diffraction pattern. One has the analog of standing wave in a box having $n = 0$ and $n = p$ as its boundaries.

This is really nice mathematics but is "quantum factor" really needed? Can one do using just the deformation of say Poisson distribution or its quantum analog obtained by replacing $n!$ interpreted as p-adic integer with its quantum counterpart? Or is "quantum factor" all that is needed? Or does this depend on situation? The following is just a list about the questions, which pop into mind and reflect my confusion more than my understanding.

1. The "quantum factor" of $\Psi(n)$ - to be distinguished from "classical factor" depending on n without any analysis to pinary digits interpreted as p-adic or quantum p-adic integers - can be regarded as a wave function in finite field F_p for the lowest pinary digit of n. $n_{q_p}^2$ gives the probability for the count $n\ mod\ p$. The modulo p condition for the pinary digit of n can be interpreted as particle in box condition $0 < n\ mod\ p < p$ so that states correspond to standing waves propagating in the space of counts and representable as sums of plane waves with wave vector $0 \leq k < p$ propagating in opposite directions. This implies that quantum part of $P(n)$ is universal and give by $n_{q_p}^2 = sin^2(kn\pi/p)/sin^2(\pi/p)$. Diffractive pattern results. Also p-periodicity is obtained from modulo p arithmetics. Approximate scale invariance $n \rightarrow p^k n$ is not obtained. This could explain Shnoll effect.

   "Quantum factor" alone is non-realistic since the probabilities for large values of n must be small. Should one interpret the "classical factor" of Ψ as a wave function for the remaining pinary digits defining n_{rem}? This would give the needed decrease for large values of n: $p^{-s(k)}$ for Poisson distribution. Now approximate scaling p-adic scaling invariance would be true as also p-periodicity in the lowest pinary digit.

3. Does it make sense to talk about separate wave functions for the lowest pinary digits as wave functions for $n_{rem} = n\ mod\ p^k - m\ mod\ p^{k-1}$ so that one would have product $P(n) \propto \prod_k (n_k)_{q_p}^2$ of single digit wave functions? Physical intuition tells that the lowest digits are the most important ones and cannot be independent. Could one consider lowest k pinary digits as single entity with $m = p^k$ and generalize quantum group picture by using quantum integers $n_{q_{p^k}}$ with p^k-periodicity?

4. Note that for $p > n$ one would have only single pinary digit and $P(n) \propto n_{q_p}^2 = sin^2(n\pi/p)/sin^2(\pi/p)$? For $n > p$ but near to it $P(n)$ one would have single maximum: this would be nearer to what one expects with Gaussian intuition. Could one think of the analog of p-adic length scale hierarchy so that the increase of p would lead from quantum description to a classical description? Do ramified primes of extension determine this kind of hierarchy? The number of pinary digits in "quantum factor" would correlate with the measurement resolution for n.

20.2.2 Deformation of Poisson distribution as an example

Consider next the p-adic modification of $P(n)$ based on canonical identification, which I gave up in the original approach since I erratically concluded that the sum of probabilities without normalization fails to converge.

1. Adelic physics suggests that prime p and quite generally, all preferred p-adic primes, could correspond to ramified primes for the extension of rationals defining the adele. Ramified prime divides discriminant $D(P)$ of the irreducible polynomial P (monic polynomial with rational coefficients) defining the extension (see `http://tinyurl.com/oyumsnk`).

   Discriminant $D(P)$ of polynomial whose, roots give rise to extension of rationals, is essentially the resultant $Res(P,P')$ for P and its derivative P' defined as the determinant of so called Sylvester polynomial (see `http://tinyurl.com/p67rdgb`). $D(P)$ is proportional to the product of differences $r_i - r_j$, $i \neq j$ the roots of p and vanishes if there are two identical roots.

   Remark: For second order polynomials $P(x) = x^2 + bx + c$ one has $D = b^2 - 4c$.

   Ramified primes divide D. Since the matrix defining $Res(P,P')$ is a polynomial of coefficients of p of order $2n-1$, the size of ramified primes is bounded and their number is finite. The larger coefficients $P(x)$ has, the larger the value of ramified prime can be. Small discriminant means small ramified primes so that polynomials having nearly degenerate roots have also small ramifying primes. Galois ramification is of special interest: for them all primes of extension in the decomposition of p appear as same power. For instance, the polynomial $P(x) = x^2 + p$ has discriminant $D = -4p$ so that primes 2 and p are ramified primes.

2. One can consider a p-adic modification of $n!$ by expanding $n! \equiv x$ as series $x \sum x_n p^n$ in powers of the ramified prime and mapping the result to a real number by canonical identification $\sum x_n \rightarrow \sum x_n p^{-n}$. The outcome is approximately periodic for large n since the lowest pinary digit gives dominating contribution and is periodic with period p. There would be two approximate periodicities for the peaks corresponding to p.

   Remark: Canonical identification is applied in p-adic mass calculations [K61] [L113] and at the level of scattering amplitudes it would map Lorenz invariants appearing in the scattering amplitudes expressible in terms of rational functions with coefficients which are rational (or in an extension of rationals) to their real counterparts.

3. Also the powers of λ should make sense p-adically, and the replacement of λ by a power of p indeed makes sense p-adically. In the case of Poisson distribution this would predict

   $$P(n) \propto \frac{p^{-nk}}{(n!)_R} \quad .$$

   for $\lambda_R = p^{-k}$.

4. $n!$ contains some power $\nu_p(n!)$ of p given by Legendre's formula (see `http://tinyurl.com/jdvwaph`):

   $$\nu_p(n!) = \sum_{i=1}^{\infty} [\frac{n}{p^i}] \quad ,$$

   where $[x]$ denotes the value of floor function replacing xt with the largest integer smaller than x. The p-adic norm of the $n!$ equals to $p^{-\nu_p(n!)}$ so that the sum of probabilities converges for all values of k of one has $\nu_(n!) < p$. It seems that this is the case quite generally. In fact, there is in the same sources also another formula for $\nu_p(n!)$ making this manifest.

   $$\nu_p(n!) = \frac{n - s_p(n)}{p-1} \quad .$$

   Here $s_p(n)$ is the sum of pinary digits of n expressed as power series of p. For $k=1$ the n:th term is $p^{-s_p(n)}$ divided by the canonical images of a p-adic number with unit p-adic norm.

Since $s_p(n)$ increases in step-wise manner, one obtains asymptotically a periodically modulated series with period p since the canonical image of $n!$ approaches periodic function. The generalization to any $P(n)$ expressible as n:th term in a Taylor series of some function serving as generating function for $P(n)$ is obvious.

As already explained, one can modify this distribution by adding to $\Psi(n) = \sqrt{P(n)}$ "quantum factor" as a wave function in the space of counts modulo p forming a finite field and particle in box analogy gives essentially $(kn)_{q_p}$ as quantum factor characterized by momentum k leading to diffraction patter described by $(kn)^2_{q_p}$. This standing wave quantum factor could be universal and describe modulo p counter.

20.3 Explanation for some findings of Shnoll

One should be able to undertand both the many-peaked character of the distributions as well as their spatial and temporal variation involving correlations with the gravitational physics of Sun-Earth and Earth-Moon systems.

The really difficult problem is to understand how astrophysical objects could affect microscopic physics in even nuclear scales where physics is local.

In the sequel two kinds explanations inspired by number theory are considered. The first model is rather formal. The second model relies on the notion of gravitatonal Planck constant introduced by Nottale and explains the rate variations as being induced by the variation of the Planck constant.

20.3.1 The temporal and spatial dependence of the distributions

One should also understand the variation of the shape of the distribution with time and its spatial variation.

1. The correlation of the fluctuation periods with astrophysical periods assignable to Earth-Sun system (diurnal period and period of Earth's orbit) suggests that the gravitational interaction of the measurement apparatus with Sun is involved. Also the period 27.28 days which corresponds to sidereal period of Moon measured in the system defined by distant star. In [E26] , [E26] this period is somewhat confusingly referred to as synodic period of Sun with respect to Earth (recall that synodic period corresponds to a period for the appearance of third object (say Moon) in the same position relative to two other objects (say Earth and Moon)). Therefore also Moon-Earth gravitational force seems to be involved. Moon-Earth and Earth-Sun gravitational accelerations indeed have roughly the same order of magnitude.

   That gravitational accelerations would determine the effect conforms with Equivalence Principle. The most natural dimensionless parameter characterizing the situation is $|\Delta \mathbf{a_{gr}}|/\mathbf{a_{gr}}$ expressible in terms of $\Delta R/R$ and $\Delta r/r$, where R *resp* r denotes the distance between Earth and Sun *resp.* Earth and Moon, and the ratio R/r and cosine for the angle θ between the direction vectors for the positions of Moon and Sun from Earth. The observed palindrome effect [E28] is consistent with the assumed dependence of the effect on the distances of Earth from Sun and Moon. Also the smallness of the effect as one approaches North Pole conforms with the fact that the variations of distances fro Sun and Moon become small at this limit.

2. In 24 hour time scale it is enough to take into account only the Earth-Sun gravitational interaction. One could perform experiments at different positions at Earth's surface to see whether the variation of distributions correlates with the variation of the gravitational potential. The maximal amplitude of $\Delta R/R$ is $2R_E/R \simeq .04$ so that for $\Delta p/p = k\Delta R/R$ one would have $\Delta p/p = .04k$. Already for $p \sim 100$ the variation range would be rather small. For $\Delta m/m$ one expects that analogous estimate holds true.

3. One observes in alpha decay rates periodicities which correspond to both sidereal and solar day [E27]. The periodicity with respect to solar day can be understood in terms of the periodic variation of Sun-Earth distance. The periodicity with respect to sidereal day would be due to the diurnal variation of the Earth-Moon distance. Similar doubling of periodicities are predicted in other relevant time scales.

4. In the case of alpha decay the effect reveals intricacies not explained by the simplest model [E27, E44]. In this case one studies random fluctuations for the numbers of alpha particles emitted in a fixed direction. Collimators are used to select the alpha particles in a given direction and this is important for what follows. Two especially interesting situations correspond to a detector which is located to North, East, or West from the sample. What is observed that the effect is different for East and West directions and there is a phase shift of 12 hours between East and West. In Northern direction the effect vanishes. Also other experiments reveal East-West asymmetry called local time effect by the authors [E37, E38].

The distribution for the counts of alpha particles in a given angle depend on time and the time dependence is sensitive to the direction angle of the alpha particle. This might be however only apparent since collimators are used to select alpha particles in given direction. The authors speak about anisotropy of space-time and Finsler geometry [A1] could be considered as a possible model. In this approach the geometry of space-time would be something totally independent of measurement apparatus.

One can identify a candidate for a scalar on which the magnitude of effect should depend.

1. At quantitative level the distribution for counts in a given direction can depend on angles defined by the vectors formed from relevant quantities. These include at least the tangential rotational velocity $v = \omega \times r$ of the laboratory at the surface of Earth, the direction of the velocity v_α of alpha particle with respect to sample actually reflecting the geometry of collimators, the net gravitational acceleration a_{net} caused by Earth, Sun, and Moon, and the direction of acceleration g in the Earth's gravitational field.

2. The first task is to construct from these vectors a scalar or a pseudo-scalar (if one is ready to allow large parity breaking effects), which vanishes for North-East direction, has opposite signs for East and West direction and has at least approximately a behavior consistent with the phase shift of 12 hours between East and West. The constraints are satisfied by the scalar

$$X = E \cdot a_{net} \ , \ E = \frac{(v \times g) \times v_\alpha}{|(v \times g) \times v_\alpha|} \ . \tag{20.3.1}$$

Unit vector E changes sign in East-West permutation and also with a period of 12 hours meaning the change of the roles of East and West with this period in the approximation that the net acceleration vector is same at the opposite sides of Earth. The approximation makes sense if the change of sign induces much large variation than the change of the Earth-Sun and Earth-Moon distances. If the parameters of the model are even functions of X, the predicted effect can be consistent with the experimental findings in the approximation that a_{net} is constant in 24 hour time scale.

This could explain the difference in the fluctuations associated with alpha particles emitted in East and West direction and the fact that there is no effect in North direction. $v \times g$ points to North and North direction for v_{alpha} has $E = 0$ so that the magnitude of E proportional to the sine of the angle between North and v_α should dictate the magnitude of the effect.

20.3.2 TGD based model for the Shnoll effect in alpha decay

In TGD framework the space-time is topologically non-trivial and dynamical in macroscopic scales and the presence of collimators making possible to select alpha particles in a given direction affect the geometry of many-sheeted space-time sheets describing the measurement apparatus and therefore the details of the interaction with the gravitational fields of Earth, Sun, and Moon. As a consequence, the value of $p = m$ should reflect the geometry of the measurement apparatus and depend only apparently on the direction of v_α. If this interpretation is correct, a selection of events from a sample without collimators should yield distributions without any dependence on the direction of v_α.

The situation is sensitive to the value of $p = m$ in the model described above. The changes should be such that the parameters of the smoothed out real probability distribution are not affected much. For instance, in the case of q-Poisson distribution the value of $p = m$ should change in such a way that $\langle n \rangle = \lambda$ is not unaffected much. The change of p would affect the positions of the peaks but small changes of p would not mean too dramatic changes. Periodic time dependence of these parameters would explain the findings of Shnoll. Gravitational interactions in Sun-Earth-Moon system and therefore the periodic variations of Sun-Earth and Earth-Moon distances is the first guess for the cause of the periodic variations.

In the case of alpha decay Shnoll effect is associated with temporal fluctuations in the number n of the measured events in time interval ΔT characterized by $P(n)$. $P(n)$ is reported to depend on the gravitational accelerations assignable to Earth-Moon and Earth-Sun systems. It is claimed that this dependence on gravitational parameters is quite general. In TGD framework this looks natural since gravitational flux tubes and gravitational Planck constant h_{gr} play a central role in TGD inspired biology. These accelerations have same order of magnitude.

There are two possible sources for the effect in the proposed model.

1. Classical option: the representation $P(n) = |\Psi(n)|^2$ is not assumed. If one accepts the proposed scaling invariant ansatz, the only parameter affecting the p-adic part of the deformation determined by canonical identification is the value of p. Thus the change of p and presumably of also extension of rationals would be involved. p-periodicity is approximate.

2. Quantum option: $P(n) = |\Psi(n)|^2$ is assumed. The existence of quantum p-adics requires $p = m$ so that the space of counts modulo p is finite field G_p. The quantum factor of wave function $\Psi(n)$ in the space of counts the most general quantum phase dependent combination $\sum c_k (kn)_{q_p}$ in $\Psi(m)$, the parameters c_k appear as additional quantal parameters besides the parameters fixing the original distribution $P(n)$ (Gaussian, Poisson,..). For quantum factor the p-periodicity in n is exact. Particle in box description for modulo p counter property suggests standing wave interpretation so that wave function would be $|(kn)_q|^2$ with k having interpretation as an analog of momentum. The outcome would be diffraction pattern $sin^2(kn\pi/p)/sin(\pi/p)$. The value of k could be seen as analogous to G_p-valued momentum varying from measurement to measurement.

   In this case the slow variations of $P(n)$ could reflect slow change of c_k even when P remains unaffected. For instance, a scaling of complex quantum integer n_q to $(kn)_q$, $0 < k < p$ would induce permutation of the peaks of the diffraction pattern. The interpretation would be as finite field permutation induced by multiplication. Also finite field translation of n_q to $(n + k)_q$. This is the minimal option and suggests that genuine quantum effect is in question: the value of k could be seen as analogous to Z_m-valued momentum varying from measurement to measurement.

Suppose that the emitted alpha particle propagates along a magnetic flux tube. A natural question is whether the direction of a_{net} corresponds to a direction of flux tubes at which the gravitational effects of Sun and Moon sum up.

Classical option: The parameters λ_i - such as the parameter defining Poisson distribution - determining $P(n|\lambda_i)$ could depend on X but only through $P(X)$ in the model obeying the scaling invariance $n \to pn$.

The dependence could be through $p = p(X)$ would affect the approximate p-periodicity. A purely p-adic deformation would require that the ramified prime p depends on X so that gravitational effects modify decay rates directly via the relative direction of the alpha particle flux tubes and various kinds of gravitational flux tubes. The extension of rationals assignable to the flux tubes along which alpha particles propagate would depend on X. Alpha particle interactions with gravitational flux tubes via wormhole contacts and this should determine the value of p.

Quantum option: If P and extension are not affected, only the diffractive quantum degrees of freedom remain under consideration.This would provide the minimal model. In quantum sector the quantum part of the distribution could depend on X, say by a scaling of the momentum $k \to r(X)k$ or shift $k \to k + r(X)$ modifying the diffraction pattern. Since the change is slow, shift looks more plausible option having interpretation as a discrete version of slow classical dynamics. Now the peaks of diffraction pattern would be permuted.

1. The dependence of the scaling factor $r(X)$ on the parameter X appearing in $n \to r(X)n$ in quantum factor would be given by piecewise constant function and discontinuities would occur at certain values of X. X is of form

$$X = vv_\alpha g a_{net} \times cos(\theta_1)sin(\theta_2)sin(\theta_3) \ .$$

Here θ_3 is the angle between v and g, θ_2 is the angle between $v \times g$ and v_α and θ_1 is the angle between E and a_{net}. X has dimension $(v^2/T^2)^2$.

2. If only the relative directions matter, one could try to assign the ineger $r(X)$ to the quantity

$$X_0 = cos(\theta_1)sin(\theta_2)sin(\theta_3) \ .$$

X_0 does not depend on the absolute values of various parameters such as v_α, which is presumably the observable measured.

3. Some unit should be chosen for the trigonometric functions involved. $cos(2\pi/m)$ *resp.* $sin(2\pi/m)$ is the first$P$ guess for the unit of $cos(\theta_1)$ *resp.* $sin(\theta_i)$, $i = 2,3$ so that $n(X_0)$ would be given by

$$n(X_0) = [\frac{cos(\theta_1)sin(\theta_2)sin(\theta_3)}{cos(2\pi/m)sin^2(2\pi/m)}] \ .$$

To sum up, the minimal model for the Shnoll effect would be based on the modification of diffractive part by scaling $n \rightarrow r(X)n$ so that diffraction peaks are permuted but also the change of $p = m$ can be consider.

20.3.3 What can one say about values about the period of $P(n)$?

The basic prediction is that the presence of an approximate period $p = m$ identified as ramified prime for extension of rationals. In one of the experiments (see `http://tinyurl.com/6kehe9b` **Fig.**1 of [E26], [E26]) the histogram for $N(n)$ has peaks, which seem to occur periodically with a separation Δn of about 100 units. If these periods correspond to P, its value must be smaller than 100. The nearest primes are $p = 89, 97, 101, 113$. In **Fig.** 2 of same reference one has also periodicity and p must be near 10. Hence there are good hopes that the proposed model might be able to explain the findings.

There is an intriguing empirical finding possibly related to the value of p and to the dependence on gravitational fields bringing in basic periods of solar system.

1. The fluctuations appear with temporal periods of 24 hours, 27 days and 365 days. Quite recently I learned about 160 minute period which appears in astrophysics in very wide range starting from solar oscillations and ending to the physics of quasars [L92]. TGD inspired interpretation relies on the observation that Fe^{2+} cyclotron frequency in endogenous magnetic field $B_{end} = .2$ Gauss playing key role in TGD inspired quantum biology is 10 Hz and in the interstellar magnetic field with average value of 2 nTesla this frequency corresponds to a period of 160 minutes. Cosmic alpha rhythm could be in question!

2. What is intriguing that 24 hours corresponds to 3^2-multiple and 27 days to 3^5-multiple of this period! Does this mean that $p = 3$-adicity is involved with Shnoll effect $p = 3$ would be a ramified prime of the extension in question. 3-adicity is also observed to be characterize big steps in evolution besides 2-adicity [K72].

20.3.4 Are these models too formal?

The proposed rather formal models in principle have the potential of explaining the findings of Shnoll but detailed numerical work is required to find whether the model works also at the level of details.

1. Taking n as the observable simplifies p-adicization crucially since the p-adicization of classical observables is avoided. One could speak of quantum measurement in the space of counts n defining a universal observable. In quantum measurements the results are typically expressed as numbers of counts in given bin so that this kind of p-adicization is physically natural.

The division of measurement interval would define an ensemble and n would be measured in each interval. State function reduction would localize Ψ_n to n in each interval.

2. The universality of the modified distributions would reduce to the interpretation of the integer n in the distribution $P(n|\lambda)$ as a p-adic integer mapped by canonical identification to a real number n_R appearing as argument of $P(n|\lambda)$. Same can be applied to $n!$.

   It is essential that the sum of probabilities without normalization factor converges and that the distribution is approximately scaling invariant under $n \rightarrow p^k n$. Approximate scaling invariance can be interpreted in terms of fractality implied by the quantum criticality of TGD Universe.

3. One can consider also the quantum variant of p-adic integer n mapped to n_R by canonical identification. The parameter m defining quantum group and being possible for possible "quantum factor" in the complex square root of $P(n)$ having interpretation as wave function satisfies $m = p$ from the condition that the canonical images of quantum p-adics are positive. There are 2 candidates for quantum-padics depending on whether the pinary digits are interpreted as quantum integers as such or mapped to a product of quantum primes.

   Various additional rational-valued parameters characterizing the probability distribution can be mapped to (possibly quantum-) p-adics mapped to reals by canonical identification. The parameters taking care of the converge such as the parameter λ in Poisson distribution must be mapped to a power of p in p-adic context.

4. The small value of p-adic prime p involved can be understood in TGD framework in terms of adelic physics suggesting that preferred primes are so called ramified primes of extension of rationals. For given irreducible polynomial determining the extension one can calculate the ramified primes from the discriminant of the polynomial.

Model can be applied to the results of Shnoll.

1. The model makes rather detailed predictions about the periodically occurring positions of the peaks of $P(n)$ as function of p based on number theoretical considerations and in principle allows to determine these parameters for given distribution.

2. The value of p could be characterized by the sum a_{net} of gravitational accelerations assignable to Earth-Sun and Earth-Moon systems and could vary. If the value of p is outcome of state function process, it is not determined by deterministic dynamics but should have a distribution. If this distribution is peaked around one particular value, one can understand the findings of Shnoll.

   The periodic variations occurring with both solar and sidereal periods could be understood in two ways. The slow variation of $p = m$ could explain the slow variation of the distributions with position and time. An alternative explanation would be based on slow dependence of quantum factor of $\Psi(n)$ on gravitational parameters and on time. For instance, one could have wave functions proportional $(kn)_{q_m}$, $k = 1, , ...p$, so that the change of k would permute the diffraction peaks.

3. Various effects such as the dependence of the probability distributions on the direction of alpha particles selected using collimators and 12 hour phase shift between the directions associated with East and West direction could be perhaps understood as direct evidence for the effects of measurement apparatus on the many-sheeted space-time affecting either the value of p or the "quantum factor": say the dependence of k on the momentum parameter X defined earlier.

However, one has good reasons to argue that these models are very formal and the connection with the empirical findings is rather loose.

20.3.5 Shnoll effect and quantum gravitation

Thanks for Ed Oberg for sending an email in which he mentioned Shnoll effect. I have discussed the Shnoll effect from the TGD point of view in [L184]. Now I must say that the number theoretical ideas involved with explanation look a little bit too formal an approach when one wants to understand the splitting of the distribution for the number of counts per time interval in say alpha decays. A more direct connection with physics would be badly needed. Therefore I decided to take a fresh look on Shnoll effect with inspiration coming from the increase of the understanding of quantum gravitation in the TGD framework [L180, L181].

1. For instance, alpha decay rates are studied: overall decay rates or in fixed direction for alpha rays. Number of counts per time interval τ varies. Poisson distribution becomes many-peaked.
2. Is there a dependence on the period τ? How many peaks? Are the numbers of peaks the same for various values of τ? The natural assumption is that there are several rates. If so, the number N at the maximum of the peak I is $N = rate(I) \times \tau$.
3. There are periodicities of the peak structure related to sidereal time and solar time. There are correlations with the dynamics of the Sun, Earth, and even galaxy. There is also a dependence on the direction of the alpha ray.
4. The splitting of the decay rates as the emergence of almost degenerate states of nuclei would be the simplest explanation. The astrophysical correlations suggest that this should be due to the gravitational effects.

The recent TGD view of quantum gravitation could provide a simple explanation.

1. A splitting of the state of the emitting nucleus to N states occurs such that the N states have different decay rates. Where does this degeneracy come from? Could the degenerate states be dark variants of the ordinary nucleus in the TGD sense and therefore have different values of h_{eff}. The gravitational Planck constants $\hbar_{gr}$ for astrophysical objects are suggested by the observed astrophysical correlations.
2. Why would these almost degenerate states of nuclei have different alpha decay rates? These rates are determined by nuclear physics. In the TGD framework, the only variable parameter is effective Planck h_{eff} which affects the rates in higher order in perturbation expansion. Lowest order is not affected. In higher orders the effect is non-trivial and could be large for strong interactions.
3. The quantum gravitational effects characterized by $\hbar_{gr}$ are expected to be the largest ones. Could the almost degenerate nuclei be attached to gravitational flux tubes of different astrophysical objects and have different effective/gravitational Planck constants? Sun, Earth, Moon, galaxy, and planest come first in mind.
4. The Shnoll effect depends on the directions and distances of the Sun and Moon and there is a periodic variation. The dependence on the sidereal time suggests that even galactic gravitational fields matter. Since the attachment of the local system to the gravitational flux tube is required, the probability for the presence of a gravitational flux tube connecting Earth and the gravitational source is what matters. The probability is proportional to the density of flux tubes per unit area and decreases with the distance between the Earth and the source. This could explain the periodic variations of the rates.
5. This model applies also to electromagnetic interactions and could explain the Shnoll effect in chemistry. The basic prediction is that the splitting of the Poisson distribution is qualitatively similar independent of the system studied.

It is perhaps fair to conclude that the explanation of the Shnoll effect in terms of gravitational quantum coherence in astrophysical scales is the more plausible option. The study of fluctuations could open a completely new field of research and a very abstract form of quantum theory. From TGD point of view this could mean theoretical and experimental work to deduce and test the predictions of adelic physics.

20.4 Appendix: p-Adic primes as ramified primes, quantum p-adics, and quantum primes

The following describes still rather speculative ideas about the physical role of number theory inspired by adelic physics.

20.4.1 Preferred p-adic primes as ramified primes?

As I wrote the first version of this chapter, I had not yet developed the vision about adelic physics. Adelic physics corresponds to a hierarchy of extensions of rationals inducing extensions of p-adic number fields and the proposal is that ramified primes of extension correspond to preferred p-adic primes.

1. Adelic physics suggests that prime p and quite generally, all preferred p-adic primes, could correspond to ramified primes for the extension of rationals defining the adele. Ramified prime divides discriminant $D(P)$ of the irreducible polynomial P (monic polynomial with rational coefficients) defining the extension (see `http://tinyurl.com/oyumsnk`).

   Discriminant $D(P)$ of polynomial whose, roots give rise to extension of rationals, is essentially the resultant $Res(P, P')$ for P and its derivative P' defined as the determinant of so called Sylvester polynomial (see `http://tinyurl.com/p67rdgb`). $D(P)$ is proportional to the product of differences $r_i - r_j$, $i \neq j$ the roots of p and vanishes if there are two identical roots.

   Remark: For second order polynomials $P(x) = x^2 + bx + c$ one has $D = b^2 - 4c$.

2. Ramified primes divide D. Since the matrix defining $Res(P, P')$ is a polynomial of coefficients of p of order $2n - 1$, the size of ramified primes is bounded and their number is finite. The larger coefficients $P(x)$ has, the larger the value of ramified prime can be. Small discriminant means small ramified primes so that polynomials having nearly degenerate roots have also small ramifying primes. Galois ramification is of special interest: for them all primes of extension in the decomposition of p appear as same power. For instance, the polynomial $P(x) = x^2 + p$ has discriminant $D = -4p$ so that primes 2 and p are ramified primes.

   Remark: All polynomials having pair of complex conjugate roots have $p = 2$ as ramified prime.

3. What does ramification mean algebraically? The ring $\mathcal{O}(K)/(p)$ of integers of the extension K modulo $p = \pi_i^{e_i}$ can be written as product $\prod_i \mathcal{O}/\pi_i^{e_i}$ (see `http://tinyurl.com/y6yskkas`). If p is ramified, one has $e_i > 1$ for at least one i. Therefore there is at least one nilpotent element in $\mathcal{O}(K)/(p)$.

Could one interpret nilpotency quantum physically?

1. For Galois extensions one has $e_i = e > 1$ for ramified primes. e divides the dimension of extension. For the quadratic extensions ramified primes have $e = 2$. Quadratic extensions are fundamental extensions - kind of conserved genes -, whose further extensions give rise to physically relevant extensions.

   On the other hand, fermionic oscillator operators and Grassmann number used to describe fermions "classically" are nilpotent. Could they correspond to nilpotent elements of order $e_i = e = 2$ in $\mathcal{O}(K)/(p)$? Fermions are building bricks of all elementary particles in TGD. Could this number theoretic analogy for the fermionic statistics have a deeper meaning?

2. What about ramified primes with $e_i = e > 2$? Could they correspond to para-statistics (see `http://tinyurl.com/y4mq6j22`) or braid statistics (see `http://tinyurl.com/psuq45j`)?

   Both parabosonic and parafermionic fields of order n have the representation $\Psi = \sum_{i=1}^{n} \Psi_i$. For parafermion field one has $\{\Psi_i(x), \Psi_i(y)\} = 0$ and $[\Psi_i(x), \Psi_j(y)] = 0$, $i \neq j$, when x and y have space-like separation. For parabosons the roles of commutator and anti-commutator are changed.

The states containing N identical parafermions are described by a representation of symmetric group S_N with N rows with at most n columns (anti-symmetrization). For states containing N identical parabosons one has N columns and at most n rows. For parafermions the wave function is symmetric in horizontal direction but the modes are different so that Bose-Einstein condensation is not possible.

For parafermion of order n operator $\sum_{i=1}^{n} \Psi_i$ one has $(\sum_{i=1}^{n} \Psi_i)^n = \prod \Psi_1\Psi_2...\Psi_n$ and higher powers vanish so that one would have $n+1$-nilpotency. Therefore the interpretation for the nilpotent elements of order e in $\mathcal{O}(K)/(p)$ in terms of parafermion of order $n = e-1$ might make sense.

It seems impossible to build a nilpotent operator from parabosonic field $\Psi = \sum_i \Psi_i$: the reason is that the powers Ψ_i^n are non-vanishing for arbitrarily high values of n.

3. Braid statistics differs from para-statistics and is assigned with quantum groups. It would naturally correspond to quantum phase $exp(i\pi/p)$ assignable to the exchange of particles by braid operation regarded as a homotopy permuting braid strands. Could ramified prime p would correspond to braid statistics and the index $e_i = e$ characterizing it to parafermion statistics of order $e-1$? This possibility cannot be excluded since this exotic physics would be associated in TGD framework to dark matter assigned to algebraic extensions of rationals whose dimension n equals to h_{eff}/h_0.

Why the primes, which do not split maximally in given extension would be physically special?

1. Do ramified primes possess exceptional evolutionary fitness and are ramified primes present for lower-dimensional extensions present also for higher-dimensional extensions? If higher extensions are formed as extensions of already existing extensions, this is the case. Hierarchy of polynomials of polynomials would to this kind of hierarchy with ramified primes of starting point polynomials analogous to conserved genes.

2. Quadratic extensions are the simplest ones and could serve as starting point extensions. Polynomials of form $x^2 - c$ are the simplest among them. Discriminant is now $D = -4c$.

3. Why $c = M_n = 2^n - 1$ allowing $p = 2$ and Mersenne prime $p = M_n$ as ramified primes would be favored? Extension of rationals defined by $x = 2^n$ is non-trivial for odd n and is equivalent with extension containing $\sqrt{2}$. $c = M_n = 2^n - 1$ as a small deformation of $c = 2^n$ gives an extension having both 2 as M_n as ramified primes.

   For $c = M_n$ the number of ramified primes is smallest possible and equal to 2: why minimal number of ramified primes would give rise to a fittest extension? Why smallest number of fermionic p-adic mass scales assignable to the ramified primes would be the fittest option?

   The p-adic length scale corresponding ro M_n would be maximal and mass scale minimal. Could one think that other quadratic extension are unstable against transforming to Mersenne extensions with smallest p-adic mass scale?

20.4.2 p-Adic topology and canonical identification

p-Adic physics has become gradually a central part of quantum TGD [K106] and the notion of p-adic probability has already demonstrated its explanatory power in the understanding of elementary particles masses using p-adic thermodynamics [K61]. This encourages the attempt to understand Shnoll effect in terms of an appropriate modification of probability concept based on p-adic numbers.

p-Adic topology [A8] is characterized by p-adic norm given by $|x|_p = p^{-k}$ for $x = p^k(x_0 + \sum_{k>0} x_k p^k)$, $x_0 > 0$. This notion of nearness differs radically from its real counterpart. For instance, numbers differing bya large power of p are p-adically near to each other. Therefore p-adic continuity means short range chaos and long range correlations in real sense. One might hope that p-adic notion of nearness allow the existence of p-adic variants of standard probability distributions characterized by rational valued parameters and transcendental numbers existing also p-adically such that these distributions can be mapped to their real counterparts by canonical identification mapping sum of probabilities to the sum of the images of the probabilities.

In the case of p-adic thermodynamics [K61] the map of real integers to p-adic integers and vice versa relies on canonical identification and its various generalizations and canonical identification is also now a natural starting point.

1. The basic formula for the canonical identification for given prime p characterizing p-adic number field Q_p is obtained by using for a real number x pinary expansion $x = \sum x_n p^{-n}$, $x_n \in \{0, p-1\}$ analogous to decimal expansion. The map is very simple and given by

$$\sum_n x_n p^{-n} \to I(x) = \sum_n x_n p^n \quad . \tag{20.4.1}$$

   The map from reals to p-adics is two-valued in the case of real numbers since pinary expansion itself is non-unique ($p = (p-1)\sum_{k\geq 0} p^{-k}$ as the analog of 1=.99999.. for decimal expansion). The inverse of the canonical identification has exactly the same form. Canonical identification maps p-adic numbers to reals in a continuous manner and also the inverse map is continuous apart from the 2-valuedness eliminated if one introduces pinary cutoff which is indeed natural when finite measurement resolution is assumed.

2. The first modification of canonical identification replaces pinary expansion of real number in powers of p with expansion in powers of p^k: $x = \sum x_n p^{-nk}$, $x_n \in \{0, p^k - 1\}$ and reads as

$$\sum_n x_n p^{-nk} \to I_k(x) = \sum_n x_n p^{nk} \quad . \tag{20.4.2}$$

3. A further variant applies to rational numbers. By using the unique representation $q = r/s$ of given rational number as ratio of co-prime integers one has

$$I_k(q = \frac{r}{s}) = \frac{I_k(r)}{I_k(s)} \quad . \tag{20.4.3}$$

20.4.3 Quantum integers

TGD based motivation for the notion of quantum integer comes from the fact that the so called hyper-finite factors of type II_1 (HFFs) play a key role in quantum TGD and allow to formulate the notion of finite measurement resolution in terms of inclusions of HFFs [K121] to which the quantum groups assignable to roots of unity are closely related. The findings of Shnoll would therefore relate to the delicacies of quantum measurement theory with finite measurement resolution.

In TGD framework one can consider modifications of the notion of quantum integer [A23]. One can ask what is the quantum counterpart of p-adic integer. One an also wonder whether prime decomposition of ordinary integers could generalize in some manner. Ordinary integers are positive and on can ask whether quantum integers should also have this property.

The quantum group is parameterize quantum phase

$$q = q_m = exp(i\phi_m) \ \ , \ \ \phi_m = \frac{\pi}{m} \ \ . \ m \geq 3 \tag{20.4.4}$$

appear in TGD framework and the long standing intuitive expectation has been that there might exist a deep connection between p-adic length scale hypothesis and quantum phases defined by roots of unity defining algebraic extensions of p-adic numbers.

The standard definition of quantum integer has problems

The first thing to do is to see whether the standard notions of quantum integer and quantum factorial [A23] could allow to get rid of the problems.

The definition of quantum integers for $q = q_m$ is given by

$$n_{q_m} = \frac{q_m^n - \overline{q}_m^n}{q_m - \overline{q}_m} = \frac{sin(n\phi_m)}{sin(\phi_m)} . \tag{20.4.5}$$

For $n \ll m$ one has

$$n_{q_m} \simeq n . \tag{20.4.6}$$

These quantum integers are real. This property makes quantum integers a good candidate if one wants to generalize the notion of Poisson distribution and more generally, any probability distribution $P(n|\lambda_i)$ parameterized by rationals. The rule would be very simple: replace all integers by their quantum counterparts: $n \to n_q$.

The proposal has however some problematic features.

1. n_q is negative for $n \ mod \ 2m > m$ so that in the case of Poisson distribution modified by replacing $n!$ by its quantum counterpart one would have negative probabilities in real context. In the p-adic context there is no well-defined notion of negative number so that one might avoid this difficulty if one can map p-adic probabilities to positive real probabilities. Quantum integers have unit norm p-adically so that p-adic Poisson distribution makes sense for $N_p(\lambda) < 1$.

2. n_{q_m} vanishes for $n = m$ always. Therefore $n_q!$ defined as a product of quantum integers smaller than n vanishes for all $n > m$. One way out is to restrict the values of n to satisfy $n < m$. This number theoretic cutoff would mean in the p-adic case that the sum of p-adic probabilities is finite without the condition $N_p(\lambda) < 1$.

Quantum p-adicity guarantees positivity of quantum integers

The elegant solution to the negativity problem comes from a simple observation. If one has $m = p$, the quantum integers $n_{q_m} = (q^n - q^{-n})(q - q^{-1})$ ($q_p = exp^{i\pi/p}$) are positive for $n < p$, vanish for $n = p$ and become negative at $n = p + 1$. Scaling invariance $n \to np$ is not obtained. One has however more general invariance. For $m = p$, the integers $0 \leq k < p$ and therefore the phases q_m^k behave elements of finite field G_p and the scaling $r \ mod \ p \neq 0$ for the quantum factor of Ψ acts as a permutation in the set formed by them. One has Z_p invariance. Also translations $n \to n + r$ act as symmetries of G_p.

This suggest the interpretation of n as a p-adic integer so that one can write $n = \sum n_k p^k$. Assume $m = p$. The pinary coefficients $0 \leq n_k < p = m$ satisfy $n_k < m$ so that their quantum counterparts are positive. One can regard them as numbers in algebraic extensions of p-adic numbers defined by the q_m. One can call these numbers quantum p-adics.

One can also map quantum p-adics to reals by using identification map as such. The same map is used also for algebraic extensions of p-adic numbers. There are however restrictions on p and m: m must be such that q_m does not allow representation as non-vanishing ordinary p-adic number. For $p = m$ the condition is satisfied.

Should quantum integers allow a factorization to quantum primes

.

Physics as a generalized number theory vision [K106] suggests a way to circumvent above described problems.

1. Quantum integers defined in the standard manner do not respect the decomposition of integers to a product of factors- that is one does not have

$$(mn)_q = m_q n_q \quad . \tag{20.4.7}$$

The preferred nature of the quantum phases associated with primes in TGD context however suggests that one should guarantee this property by hand by simply defining the quantum integer as a product of quantum integers associated with its prime factors:

$$n_q \equiv \prod (p_i)_q^{n_i} \ \text{ for } \ n = \prod p_i^{n_i} \quad . \tag{20.4.8}$$

This would guarantee that the notion of primeness and related notions crucial for p-adic physics would make sense also for quantum integers. Note that this deformation would not be made for the exponents of integers for which sum is the natural operation.

2. This definition has problems. The quantum primes can have negative sign and if m is prime, quantum prime p_{q_m} vanishes. For $m = p$ allowing the definition of quantum p-adics and their real counterparts, one can restrict prime decomposition to the primes appearing as factors of the pinary digits $k < p$ of quantum primes.

Acknowledgements: I am grateful for Dainis Zeps for references related to Shnoll effect.

Chapter i

Appendix

A-1 Introduction

Originally this appendix was meant to be a purely technical summary of basic facts but in its recent form it tries to briefly summarize those basic visions about TGD which I dare to regarded stabilized. I have added illustrations making it easier to build mental images about what is involved and represented briefly the key arguments. This chapter is hoped to help the reader to get fast grasp about the concepts of TGD.

The basic properties of embedding space and related spaces are discussed and the relationship of CP_2 to the standard model is summarized. The basic vision is simple: the geometry of the embedding space $H = M^4 \times CP_2$ geometrizes standard model symmetries and quantum numbers. The assumption that space-time surfaces are basic objects, brings in dynamics as dynamics of 3-D surfaces based on the induced geometry. Second quantization of free spinor fields of H induces quantization at the level of H, which means a dramatic simplification.

The notions of induction of metric and spinor connection, and of spinor structure are discussed. Many-sheeted space-time and related notions such as topological field quantization and the relationship many-sheeted space-time to that of GRT space-time are discussed as well as the recent view about induced spinor fields and the emergence of fermionic strings. Also the relationship to string models is discussed briefly.

Various topics related to p-adic numbers are summarized with a brief definition of p-adic manifold and the idea about generalization of the number concept by gluing real and p-adic number fields to a larger book like structure analogous to adele [L64, L63]. In the recent view of quantum TGD [L172], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L114, L115] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L105] [K125] has become a central part of quantum TGD and leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory having quantum biology as an application. Also these aspects of TGD are briefly discussed.

A-2 Embedding space $M^4 \times CP_2$

Space-times are regarded as 4-surfaces in $H = M^4 \times CP_2$ the Cartesian product of empty Minkowski space - the space-time of special relativity - and compact 4-D space CP_2 with size scale of order 10^4 Planck lengths. One can say that embedding space is obtained by replacing each point m of empty Minkowski space with 4-D tiny CP_2. The space-time of general relativity is replaced by a 4-D surface in H which has very complex topology. The notion of many-sheeted space-time gives an idea about what is involved.

Fig. 1. Embedding space $H = M^4 \times CP_2$ as Cartesian product of Minkowski space M^4 and complex projective space CP_2. `http://tgdtheory.fi/appfigures/Hoo.jpg`

Denote by M^4_+ and M^4_- the future and past directed lightcones of M^4. Denote their intersection, which is not unique, by CD. In zero energy ontology (ZEO) [L105, L142] [K125] causal diamond (CD) is defined as cartesian product $CD \times CP_2$. Often I use CD to refer just to $CD \times CP_2$ since CP_2 factor is relevant from the point of view of ZEO.

Fig. 2. Future and past light-cones M^4_+ and M^4_-. Causal diamonds (CD) are defined as their intersections. `http://tgdtheory.fi/appfigures/futurepast.jpg`

Fig. 3. Causal diamond (CD) is highly analogous to Penrose diagram but simpler. `http://tgdtheory.fi/appfigures/penrose.jpg`

A rather recent discovery was that CP_2 is the only compact 4-manifold with Euclidian signature of metric allowing twistor space with Kähler structure. M^4 is in turn is the only 4-D space with Minkowskian signature of metric allowing twistor space with Kähler structure [A21] so that $H = M^4 \times CP_2$ is twistorially unique.

One can loosely say that quantum states in a given sector of "world of classical worlds" (WCW) are superpositions of space-time surfaces inside CDs and that positive and negative energy parts of zero energy states are localized and past and future boundaries of CDs. CDs form a hierarchy. One can have CDs within CDs and CDs can also overlap. The size of CD is characterized by the proper time distance between its two tips. One can perform both translations and also Lorentz boosts of CD leaving either boundary invariant. Therefore one can assign to CDs a moduli space and speak about wave function in this moduli space.

In number theoretic approach it is natural to restrict the allowed Lorentz boosts to some discrete subgroup of Lorentz group and also the distances between the tips of CDs to multiples of CP_2 radius defined by the length of its geodesic. Therefore the moduli space of CDs discretizes. The quantization of cosmic recession velocities for which there are indications, could relate to this quantization.

A-2.1 Basic facts about CP_2

CP_2 as a four-manifold is very special. The following arguments demonstrate that it codes for the symmetries of standard models via its isometries and holonomies.

CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-2.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three coordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [A17] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-2.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-2.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. `http://tgdtheory.fi/appfigures/cp2.jpg`

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-2.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-2.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-2.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-2.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-2.9}$$

are given by

$$\begin{aligned} e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \frac{r\sigma_2}{\sqrt{F}} \ , & e^3 &= \frac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$
\begin{array}{llllll}
e^0 & = & \frac{dr}{F} \ , & e^1 & = & \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\
e^2 & = & \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 & = & \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ .
\end{array}
\tag{A-2.11}
$$

The explicit representation of the line element is given by the expression

$$
ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-2.12}
$$

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$
de^A = -V^A_B \wedge e^B \ , \tag{A-2.13}
$$

is given by

$$
\begin{array}{llllll}
V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\
V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\
V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ .
\end{array}
\tag{A-2.14}
$$

The representation of the covariantly constant curvature tensor is given by

$$
\begin{array}{llllll}
R_{01} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
R_{02} & = & e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} & = & -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\
R_{03} & = & 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} & = & 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ .
\end{array}
\tag{A-2.15}
$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$
J = -is_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.16}
$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$
J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-2.17}
$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$
J = dB \ , \tag{A-2.18}
$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

$dJ = ddB = 0$ gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality $*J = J$ reduces the remaining equations to $dJ = 0$. Hence the Kähler form can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling).

The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta \wedge d\Phi \ . \end{aligned} \tag{A-2.19}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \ , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{aligned} \tag{A-2.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= -\frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \tag{A-2.21}$$

Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A10]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0,1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1-factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential

$exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the embedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [A28] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B24] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.23}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4)$ having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \qquad \text{(A-2.24)}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{lllllll} V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ , \end{array} \qquad \text{(A-2.25)}$$

and

$$B = 2re^3 \ , \qquad \text{(A-2.26)}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \qquad \text{(A-2.27)}$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \qquad \text{(A-2.28)}$$

A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \qquad \text{(A-2.29)}$$

where $W^\pm$ denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$\begin{array}{l} R_{01} = -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} = -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} = 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} = 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \qquad \text{(A-2.30)}$$

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$
\begin{array}{l}
W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\
W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ .
\end{array} \tag{A-2.31}
$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$
\begin{aligned}
X &= re^3 \ , \\
Y &= \frac{e^3}{r} \ ,
\end{aligned} \tag{A-2.32}
$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$
\begin{aligned}
\bar{\gamma} &= aX + bY \ , \\
\bar{Z}^0 &= cX + dY \ ,
\end{aligned} \tag{A-2.33}
$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$
\begin{aligned}
A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\
&+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ .
\end{aligned} \tag{A-2.34}
$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5 \Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$
c = -d \ . \tag{A-2.35}
$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$
A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.36}
$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$
\begin{aligned}
Q_{em} &= \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\
I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ .
\end{aligned} \tag{A-2.37}
$$

The fields γ and Z^0 are defined via the relations

$$
\begin{aligned}
\gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\
Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ .
\end{aligned} \tag{A-2.38}
$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0\wedge e^3 + e^1\wedge e^2) , \\ R_{12} &= 2(e^0\wedge e^3 + 2e^1\wedge e^2) , \\ J &= 2(e^0\wedge e^3 + e^1\wedge e^2) , \end{aligned} \tag{A-2.41}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} , \\ Z^0 &= 2R_{03} . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) , \end{aligned} \tag{A-2.45}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\ K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \end{aligned} \quad \text{(A-2.46)}$$

This parameter can be calculated by substituting the values of quark and lepton charges and weak isospins.

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18+2n_i^2)sin^2\theta_W}{9} \right] \ , \quad \text{(A-2.47)}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18+n_i^2))} \ . \quad \text{(A-2.48)}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \quad \text{(A-2.49)}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is not far from the typical value 9/24 of GUTs at high energies [B5]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $sin^2\theta_W = 1 - (m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \rightarrow 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \rightarrow 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).

2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.

3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0, the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L183] contains, besides the induced Kähler form, also the induced curvature form R_{12}, which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \quad , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \qquad \text{(A-2.51)} \\ per. & \qquad \text{(A-2.52)} \end{aligned}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \ .$$

For $sin^2\theta_W = 3/4 \ langle\gamma\rangle$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron.

2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

   Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

   A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

1. Symmetries must be realized as purely geometric transformations.

2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B8] .

   The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger\gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP$_2$ projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP$_2$ projection, only vacuum extremals and space-time surfaces for which CP$_2$ projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP$_2$ projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \ .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP$_2$ projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. `http://tgdtheory.fi/appfigures/manysheeted.jpg`

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields.This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. `http://tgdtheory.fi/appfigures/wormholecontact.jpg`

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg`

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. `http://tgdtheory.fi/appfigures/field.jpg`

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an $n = 1$ ($n = 3$) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of $SU(3)$ Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.

2. Spinor harmonics of embedding space correspond to triality $t = 1$ ($t = 0$) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.

2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.

4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.

5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r,Θ,Ψ,Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ F &= 1+r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+(3+p)\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2F}(d(r^2)/d\Theta)(k+cos(\Theta)) &+ (3+p)sin(\Theta)=0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$
\begin{aligned}
r &= \sqrt{\frac{X}{1-X}} \ , \\
X &= D\left[|\frac{k+u}{C}|\right]^{\epsilon} \ , \\
u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ ,
\end{aligned}
\tag{A-3.4}
$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$
sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k+1 \ ,
$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$
\begin{aligned}
J &= -\frac{p}{3+2p} X du \wedge d\Phi \ , \\
Z^0 &= -\frac{6}{p} J \ .
\end{aligned}
\tag{A-3.5}
$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$
\begin{aligned}
Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ , \\
r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\
\gamma &= -\frac{p}{2} Z^0 \ .
\end{aligned}
\tag{A-3.6}
$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \end{aligned} \tag{A-3.7}$$

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ . \end{aligned} \tag{A-3.8}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4-surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K53, K29, K91] [L147, L172].

Fig. 5. TGD replaces point-like particles with 3-surfaces. `http://tgdtheory.fi/appfigures/particletgd.jpg`

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M^4_+ = S^2 \times R_+$- of 4-D light-cone M^4_+ is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2-local scaling of the light-like radial coordinate of R_+. These simple facts mean that 4-dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M^4_+ \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM^4_+ plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. `http://tgdtheory.fi/appfigures/fermistring.jpg`

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.

2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. `http://tgdtheory.fi/appfigures/elparticletgd.jpg`

Particle interactions involve both stringy and QFT aspects.

1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their super-conformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of space-time topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. `http://tgdtheory.fi/appfigures/tgdgraphs.jpg`

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K53, K91].

How unique is the choice of the action defining WCW Kähler metric? The problem is that twistor lift strongly suggests the identification of the preferred extremals as 4-D surfaces having 4-D generalization of complex structure and that a large number of general coordinate invariant actions constructible in terms of the induced geometry have the same preferred extremals.

A-5.1 Could twistor lift fix the choice of the action uniquely?

The twistor lift of TGD [L65] [L147, L156, L157] generalizes the notion of induction to the level of twistor fields and leads to a proposal that the action is obtained by dimensional reduction of the action having as its preferred extremals the counterpart of twistor space of the space-time surface identified as 6-D surface in the product $T(M^4) \times T(CP_2)$ twistor spaces of $T(M^4)$ and

$T(CP_2)$ of M^4 and CP_2. Only M^4 and CP_2 allow a twistor space with Kähler structure [A21] so that TGD would be unique. Dimensional reduction is forced by the condition that the 6-surface has S^2-bundle structure characterizing twistor spaces and the base space would be the space-time surface.

1. Dimensional reduction of 6-D Kähler action implies that at the space-time level the fundamental action can be identified as the sum of Kähler action and volume term (cosmological constant). Other choices of the action do not look natural in this picture although they would have the same preferred extremals.

2. Preferred extremals are proposed to correspond to minimal surfaces with singularities such that they are also extremals of 4-D Kähler action outside the singularities. The physical analogue are soap films spanned by frames and one can localize the violation of the strict determinism and of strict holography to the frames.

3. The preferred extremal property is realized as the holomorphicity characterizing string world sheets, which generalizes to the 4-D situation. This in turn implies that the preferred extremals are the same for any general coordinate invariant action defined on the induced gauge fields and induced metric apart from possible extremals with vanishing CP_2 Kähler action.

   For instance, 4-D Kähler action and Weyl action as the sum of the tensor squares of the components of the Weyl tensor of CP_2 representing quaternionic imaginary units constructed from the Weyl tensor of CP_2 as an analog of gauge field would have the same preferred extremals and only the definition of Kähler function and therefore Kähler metric of WCW would change. One can even consider the possibility that the volume term in the 4-D action could be assigned to the tensor square of the induced metric representing a quaternionic or octonionic real unit.

Action principle does not seem to be unique. On the other hand, the WCW Kähler form and metric should be unique since its existence requires maximal isometries.

Unique action is not the only way to achieve this. One cannot exclude the possibility that the Kähler gauge potential of WCW in the complex coordinates of WCW differs only by a complex gradient of a holomorphic function for different actions so that they would give the same Kähler form for WCW. This gradient is induced by a symplectic transformation of WCW inducing a U(1) gauge transformation. The Kähler metric is the same if the symplectic transformation is an isometry.

Symplectic transformations of WCW could give rise to inequivalent representations of the theory in terms of action at space-time level. Maybe the length scale dependent coupling parameters of an effective action could be interpreted in terms of a choice of WCW Kähler function, which maximally simplifies the computations at a given scale.

1. The 6-D analogues of electroweak action and color action reducing to Kähler action in 4-D case exist. The 6-D analog of Weyl action based on the tensor representation of quaternionic imaginary units does not however exist. One could however consider the possibility that only the base space of twistor space $T(M^4)$ and $T(CP_2)$ have quaternionic structure.

2. Kähler action has a huge vacuum degeneracy, which clearly distinguishes it from other actions. The presence of the volume term removes this degeneracy. However, for minimal surfaces having CP_2 projections, which are Lagrangian manifolds and therefore have a vanishing induced Kähler form, would be preferred extremals according to the proposed definition. For these 4-surfaces, the existence of the generalized complex structure is dubious.

   For the electroweak action, the terms corresponding to charged weak bosons eliminate these extremals and one could argue that electroweak action or its sum with the analogue of color action, also proportional Kähler action, defines the more plausible choice. Interestingly, also the neutral part of electroweak action is proportional to Kähler action.

Twistor lift strongly suggests that also M^4 has the analog of Kähler structure. M^8 must be complexified by adding a commuting imaginary unit i. In the E^8 subspace, the Kähler structure of E^4 is defined in the standard sense and it is proposed that this generalizes to M^4 allowing also generalization of the quaternionic structure. M^4 Kähler structure violates Lorentz invariance but could be realized at the level of moduli space of these structures.

The minimal possibility is that the M^4 Kähler form vanishes: one can have a different representation of the Kähler gauge potential for it obtained as generalization of symplectic transformations acting non-trivially in M^4. The recent picture about the second quantization of spinors of $M^4 \times CP_2$ assumes however non-trivial Kähler structure in M^4.

A-5.2 Two paradoxes

TGD view leads to two apparent paradoxes.

1. If the preferred extremals satisfy 4-D generalization of holomorphicity, a very large set of actions gives rise to the same preferred extremals unless there are some additional conditions restricting the number of preferred extremals for a given action.

2. WCW metric has an infinite number of zero modes, which appear as parameters of the metric but do not contribute to the line element. The induced Kähler form depends on these degrees of freedom. The existence of the Kähler metric requires maximal isometries, which suggests that the Kähler metric is uniquely fixed apart from a conformal scaling factor Ω depending on zero modes. This cannot be true: galaxy and elementary particle cannot correspond to the same Kähler metric.

Number theoretical vision and the hierarchy of inclusions of HFFs associated with supersymplectic algebra actings as isometries of WcW provide equivalent realizations of the measurement resolution. This solves these paradoxes and predicts that WCW decomposes into sectors for which Kähler metrics of WCW differ in a natural way.

The hierarchy subalgebras of supersymplectic algebra implies the decomposition of WCW into sectors with different actions

Supersymplectic algebra of $\delta M^4_+ \times CP_2$ is assumed to act as isometries of WCW [L172]. There are also other important algebras but these will not be discussed now.

1. The symplectic algebra A of $\delta M^4_+ \times CP_2$ has the structure of a conformal algebra in the sense that the radial conformal weights with non-negative real part, which is half integer, label the elements of the algebra have an interpretation as conformal weights.

   The super symplectic algebra A has an infinite hierarchy of sub-algebras [L172] such that the conformal weights of sub-algebras $A_{n(SS)}$ are integer multiples of the conformal weights of the entire algebra. The superconformal gauge conditions are weakened. Only the subalgebra $A_{n(SS)}$ and the commutator $[A_{n(SS)}, A]$ annihilate the physical states. Also the corresponding classical Noether charges vanish for allowed space-time surfaces.

   This weakening makes sense also for ordinary superconformal algebras and associated Kac-Moody algebras. This hierarchy can be interpreted as a hierarchy symmetry breakings, meaning that sub-algebra $A_{n(SS)}$ acts as genuine dynamical symmetries rather than mere gauge symmetries. It is natural to assume that the super-symplectic algebra A does not affect the coupling parameters of the action.

2. The generators of A correspond to the dynamical quantum degrees of freedom and leave the induced Kähler form invariant. They affect the induced space-time metric but this effect is gravitational and very small for Einsteinian space-time surfaces with 4-D M^4 projection.

   The number of dynamical degrees of freedom increases with $n(SS)$. Therefore WCW decomposes into sectors labelled by $n(SS)$ with different numbers of dynamical degrees of freedom so that their Kähler metrics cannot be equivalent and cannot be related by a symplectic isometry. They can correspond to different actions.

Number theoretic vision implies the decomposition of WCW into sectors with different actions

The number theoretical vision leads to the same conclusion as the hierarchy of HFFs. The number theoretic vision of TGD based on M^8-H duality [L172] predicts a hierarchy with levels labelled by the degrees $n(P)$ of rational polynomials P and corresponding extensions of rationals characterized by Galois groups and by ramified primes defining p-adic length scales.

These sequences allow us to imagine several discrete coupling constant evolutions realized at the level H in terms of action whose coupling parameters depend on the number theoretic parameters.

1. Coupling constant evolution with respect to $n(P)$

The first coupling constant evolution would be with respect to $n(P)$.

1. The coupling constants characterizing action could depend on the degree $n(P)$ of the polynomial defining the space-time region by M^8-H duality. The complexity of the space-time surface would increase with $n(P)$ and new degrees of freedom would emerge as the number of the rational coefficients of P.

2. This coupling constant evolution could naturally correspond to that assignable to the inclusion hierarchy of hyperfinite factors of type II_1 (HFFs). I have indeed proposed [L172] that the degree $n(P)$ equals to the number $n(braid)$ of braids assignable to HFF for which super symplectic algebra subalgebra $A_{n(SS)}$ with radial conformal weights coming as $n(SS)$-multiples of those of entire algebra A. One would have $n(P) = n(braid) = n(SS)$. The number of dynamical degrees of freedom increases with n which just as it increases with $n(P)$ and $n(SS)$.

3. The actions related to different values of $n(P) = n(braid) = n(SS)$ cannot define the same Kähler metric since the number of allowed space-time surfaces depends on $n(SS)$.

   WCW could decompose to sub-WCWs corresponding to different actions, a kind of theory space. These theories would not be equivalent. A possible interpretation would be as a hierarchy of effective field theories.

4. Hierarchies of composite polynomials define sequences of polynomials with increasing values of $n(P)$ such that the order of a polynomial at a given level is divided by those at the lower levels. The proposal is that the inclusion sequences of extensions are realized at quantum level as inclusion hierarchies of hyperfinite factors of type II_1.

   A given inclusion hierarchy corresponds to a sequence $n(SS)_i$ such that $n(SS)_i$ divides $n(SS)_{i+1}$. Therefore the degree of the composite polynomials increases very rapidly. The values of $n(SS)_i$ can be chosen to be primes and these primes correspond to the degrees of so called prime polynomials [L162] so that the decompositions correspond to prime factorizations of integers. The "densest" sequence of this kind would come in powers of 2 as $n(SS)_i = 2^i$. The corresponding p-adic length scales (assignable to maximal ramified primes for given $n(SS)_i$) are expected to increase roughly exponentially, say as 2^{r2^i}. $r = 1/2$ would give a subset of scales $2^{r/2}$ allowed by the p-adic length scale hypothesis. These transitions would be very rare.

   A theory corresponding to a given composite polynomial would contain as sub-theories the theories corresponding to lower polynomial composites. The evolution with respect to $n(SS)$ would correspond to a sequence of phase transitions in which the action genuinely changes. For instance, color confinement could be seen as an example of this phase transition.

5. A subset of p-adic primes allowed by the p-adic length scale hypothesis $p \simeq 2^k$ defining the proposed p-adic length scale hierarchy could relate to n_S changing phase transition. TGD suggests a hierarchy of hadron physics corresponding to a scale hierarchy defined by Mersenne primes and their Gaussian counterparts [K66, K67]). Each of them would be characterized by a confinement phase transition in which n_S and therefore also the action changes.

2. Coupling constant evolutions with respect to ramified primes for a given value of $n(P)$

For a given value of $n(P)$, one could have coupling constant sub-evolutions with respect to the set of ramified primes of P and dimensions $n = h_{eff}/h_0$ of algebraic extensions. The action would only change by U(1) gauge transformation induced by a symplectic isometry of WCW. Coupling parameters could change but the actions would be equivalent.

The choice of the action in an optimal manner in a given scale could be seen as a choice of the most appropriate effective field theory in which radiative corrections would be taken into account. One can interpret the possibility to use a single choice of coupling parameters in terms of quantum criticality.

The range of the p-adic length scales labelled by ramified primes and effective Planck constants h_{eff}/h_0 is finite for a given value of $n(SS)$.

The first coupling constant evolution of this kind corresponds to ramified primes defining p-adic length scales for given $n(SS)$.

1. Ramified primes are factors of the discriminant $D(P)$ of P, which is expressible as a product of non-vanishing root differents and reduces to a polynomial of the n coefficients of P. Ramified primes define p-adic length scales assignable to the particles in the amplitudes scattering amplitudes defined by zero energy states.

   P would represent the space-time surface defining an interaction region in $N-$-particle scattering. The N ramified primes dividing $D(P)$ would characterize the p-adic length scales assignable to these particles. If $D(P)$ reduces to a single ramified prime, one has elementary particle [L162], and the forward scattering amplitude corresponds to the propagator.

   This would give rise to a multi-scale p-adic length scale evolution of the amplitudes analogous to the ordinary continuous coupling constant evolution of n-point scattering amplitudes with respect to momentum scales of the particles. This kind of evolutions extend also to evolutions with respect to $n(SS)$.

2. According to [L162], physical constraints require that $n(P)$ and the maximum size of the ramified prime of P correlate.

   A given rational polynomial of degree $n(P)$ can be always transformed to a polynomial with integer coefficients. If the integer coefficients are smaller than $n(P)$, there is an upper bound for the ramified primes. This assumption also implies that finite fields become fundamental number fields in number theoretical vision [L162].

3. p-Adic length scale hypothesis [L173] in its basic form states that there exist preferred primes $p \simeq 2^k$ near some powers of 2. A more general hypothesis states that also primes near some powers of 3 possibly also other small primes are preferred physically. The challenge is to understand the origin of these preferred scales.

   For polynomials P with a given degree $n(P)$ for which discriminant $D(P)$ is prime, there exists a maximal ramified prime. Numerical calculations suggest that the upper bound depends exponentially on $n(P)$.

   Could these maximal ramified primes satisfy the p-adic length scale hypothesis or its generalization? The maximal prime defines a fixed point of coupling constant evolution in accordance with the earlier proposal. For instance, could one think that one has $p \simeq 2^k$, $k = n(SS)$? Each p-adic prime would correspond to a p-adic coupling constant sub-evolution representable in terms of symplectic isometries.

Also the dimension n of the algebraic extension associated with P, which is identified in terms of effective Planck constant $h_{eff}/h_0 = n$ labelling different phases of the ordinary matter behaving like dark matter, could give rise to coupling constant evolution for given $n(SS)$. The range of allowed values of n is finite. Note however that several polynomials of a given degree can correspond to the same dimension of extension.

Number theoretic discretization of WCW and maxima of WCW Kähler function

Number theoretic approach involves a unique discretization of space-time surface and also of WCW. The question is how the points of the discretized WCW correspond to the preferred extremals.

1. The exponents of Kähler function for the maxima of Kähler function, which correspond to the universal preferred extremals, appear in the scattering amplitudes. The number theoretical approach involves a unique discretization of space-time surfaces defining the WCW coordinates of the space-time surface regarded as a point of WCW.

   In [L172] it is assumed that these WCW points appearing in the number theoretical discretization correspond to the maxima of the Kähler function. The maxima would depend on the action and would differ for ghd maxima associated with different actions unless they are not related by symplectic WCW isometry.

2. The symplectic transformations of WCW acting as isometries are assumed to be induced by the symplectic transformations of $\delta M^4_+ \times CP_2$ [K53, K29]. As isometries they would naturally permute the maxima with each other.

A-6 Number theoretic vision of TGD

Physics as number theory vision is complementary to the physics as geometry vision and has developed gradually since 1993. Langlands program is the counterpart of this vision in mathematics [L168].

The notion of p-adic number fields emerged with the motivation coming from the observation that elementary particle mass scales and mass ratios could be understood in terms of the so-called p-adic length scale hypothesis [K70, K61, K27]. The fusion of the various p-adic physics leads to what I call adelic physics [L64, L63]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K34, K35, K36, K36].

Eventually this led to that the values of effective Planck constant could be identified as the dimension of an algebraic extension of rationals assignable to polynomials with rational coefficients. This led to the number theoretic vision in which so-called $M^8 - H$ duality [L114, L115] plays a key role. M^8 (actually a complexification of real M^8) is analogous to momentum space so that the duality generalizes momentum position duality for point-like particles. M^8 has an interpretation as complexified octonions.

The dynamics of 4-surfaces in M^8 is coded by polynomials with rational coefficients, whose roots define mass shells H^3 of $M^4 \subset M^8$. It has turned out that the polynomials satisfy stringent additional conditions and one can speak of number theoretic holography [L162, L168]. Also the ordinary 3$\rightarrow$ 4 holography is needed to assign 4-surfaces with these 3-D mass shells. The number theoretic dynamics is based on the condition that the normal space of the 4-surface in M^8 is associative (quaternionic) and contains a commutative complex sub-space. This makes it possible to assign to this surface space-time surface in $H = M^4 \times CP_2$.

At the level of H the space-time surfaces are by holography preferred extremals and are assumed to be determined by the twistor lift of TGD [L65] giving rise to an action which is sum of the Kähler action and volume term. The preferred extremals would be minimal surfaces analogous to soap films spanned by frames. Outside frames they would be simultaneous extremals of the Kähler action, which requires a generalization of the holomorphy characterizing string world sheets.

In the following only p-adic numbers and hierarchy of Planck constants will be discussed.

A-6.1 p-Adic numbers and TGD

p-Adic number fields

p-Adic numbers (p is prime: 2, 3, 5, ...) can be regarded as a completion of the rational numbers using a norm, which is different from the ordinary norm of real numbers [A8]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k\geq k_0} x(k)p^k ,\ x(k) = 0, ..., p-1 \ . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| = p^{-k_0(x)} \ . \tag{A-6.2}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x = p^{k_0}\varepsilon(x) \ , \tag{A-6.3}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \leq max\{d(x,y), d(y,z)\} \ . \tag{A-6.4}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \leq D \ . \tag{A-6.5}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.
2. Distances of points x and y inside single class are smaller than distances between different classes.
3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B19]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I : R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y &= \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} \ , \\ y_k &\in \{0,1,..,p-1\} \ . \end{aligned} \tag{A-6.6}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique ($1 = 0.999...$) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^{N} x_k p^{-k} \quad , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \quad . \end{aligned} \tag{A-6.7}$$

The p-adic images associated with these expansions are different

$$\begin{aligned} y_1 &= \sum_{k=N_0}^{N} x_k p^{k} \quad , \\ y_2 &= \sum_{k=N_0}^{N-1} x_k p^{k} + (x_N - 1)p^{N} + (p-1)p^{N+1} \sum_{k=0,..} p^{k} \\ &= y_1 + (x_N - 1)p^N - p^{N+1} \quad , \end{aligned} \tag{A-6.8}$$

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. `http://tgdtheory.fi/appfigures/norm.png`

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |x|_p|y|_R \leq (xy)_R &\leq x_R y_R \ , \end{aligned} \qquad \text{(A-6.9)}$$

where $|x|_p$ denotes p-adic norm. These inequalities can be generalized to the case of $(R_p)^n$ (a linear vector space over the p-adic numbers).

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |\lambda|_p|y|_R \leq (\lambda y)_R &\leq \lambda_R y_R \ , \end{aligned} \qquad \text{(A-6.10)}$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R \ . \qquad \text{(A-6.11)}$$

These inequalities resemble those satisfied by the vector norm. The only difference is the failure of linearity in the sense that the norm of a scaled vector is not obtained by scaling the norm of the original vector. Ordinary situation prevails only if the scaling corresponds to a power of p.

These observations suggests that the concept of a normed space or Banach space might have a generalization and physically the generalization might apply to the description of some non-linear systems. The nonlinearity would be concentrated in the nonlinear behavior of the norm under scaling.

3. Modified form of the canonical identification

The original form of the canonical identification is continuous but does not respect symmetries even approximately. This led to a search of variants which would do better in this respect. The modification of the canonical identification applying to rationals only and given by

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \qquad \text{(A-6.12)}$$

is uniquely defined for rationals, maps rationals to rationals, has also a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals n-dimensional space R^n must be covered by 2^n copies of the p-adic variant R_p^n of R^n each of which projects to a copy of R_+^n (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \ mod \ p = 1$.

Fig. 15. Various number fields combine to form a book like structure. `http://tgdtheory.fi/appfigures/book.jpg`

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. `http://tgdtheory.fi/appfigures/padmanifold.jpg`

There are some problems.

1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used

2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution

3. Canonical identification violates general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if $\hbar$ has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manfolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2. For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2.

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the light-likeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2-fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1-valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix **??**) has changed considerably towards the end 2021 [L147] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \rightarrow m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L147] of the $M^8 - H$ duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size $L(m)$ defines the image point. This is not yet quite enough to satisfy UP but the additional details [L147] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M^8_c$ (M^8 is complexified to M^8_c) as a "root" of its octonionic continuation [L114, L115]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$.

This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L98]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L147]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L129] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L147]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

A-7 Zero energy ontology (ZEO)

ZEO is implied by the holography forced in the TGD framework by general coordinate invariance.

A-7.1 Basic motivations and ideas of ZEO

The following gives a brief summary of ZEO [L105] [K125].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution. One can say that in the TGD framework general coordinate invariance implies holography and the slight failure of its determinism in turn forces ZEO.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L105].

2. To avoid getting totally confused it is good to emphasize some aspects of ZEO.

   (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.

   (b) ZEO means two times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.

3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.

   (a) The findings of Minev et al [L90] in atomic scale can be explained by the same mechanism [L90]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

(b) Libets' experiments about active aspects of consciousness [J6] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.

(c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L96]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L102, L191].

A-7.2 Some implications of ZEO

ZEO has profound implications for understanding self-organization and self-organized quantum criticality in terms of dissipation with non-standard arrow of time looking like generation of structures [L102, L191]. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

   Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

A-8 Some notions relevant to TGD inspired consciousness and quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology.

A-8.1 The notion of magnetic body

Topological field quantization inspires the notion of field body about which magnetic body is especially important example and plays key role in TGD inspired quantum biology and consciousness theory. This is a crucial departure fromt the Maxwellian view. Magnetic body brings in third level to the description of living system as a system interacting strongly with environment. Magnetic body would serve as an intentional agent using biological body as a motor instrument and sensory receptor. EEG would communicated the information from biological body to magnetic body and Libet's findings from time delays of consciousness support this view.

The following pictures illustrate the notion of magnetic body and its dynamics relevant for quantum biology in TGD Universe.

Fig. 18. Magnetic body associated with dipole field. `http://tgdtheory.fi/appfigures/fluxquant.jpg`

Fig. 19. Illustration of the reconnection by magnetic flux loops. `http://tgdtheory.fi/appfigures/reconnect1.jpg`

Fig. 20. Illustration of the reconnection by flux tubes connecting pairs of molecules. `http://tgdtheory.fi/appfigures/reconect2.jpg`

Fig. 21. Flux tube dynamics. a) Reconnection making possible magnetic body to "recognize" the presence of another magnetic body, b) braiding, knotting and linking of flux tubes making possible topological quantum computation, c) contraction of flux tube in phase transition reducing the value of h_{eff} allowing two molecules to find each other in dense molecular soup. `http://tgdtheory.fi/appfigures/fluxtubedynamics.jpg`

A-8.2 Number theoretic entropy and negentropic entanglement

TGD inspired theory of consciousness relies heavily p-Adic norm allows an to define the notion of Shannon entropy for rational probabilities (and even those in algebraic extension of rationals) by replacing the argument of logarithm of probability with its p-adic norm. The resulting entropy can be negative and the interpretation is that number theoretic entanglement entropy defined by this formula for the p-adic prime minimizing its value serves as a measure for conscious information. This negentropy characterizes two-particle system and has nothing to do with the formal negative negentropy assignable to thermodynamic entropy characterizing single particle. Negentropy Maximization Principle (NMP) implies that number theoretic negentropy increases during evolution by quantum jumps. The condition that NMP is consistent with the standard quantum measurement theory requires that negentropic entanglement has a density matrix proportional to unit matrix so that in 2-particle case the entanglement matrix is unitary.

Fig. 22. Schrödinger cat is neither dead or alive. For negentropic entanglement this state would be stable. `http://tgdtheory.fi/appfigures/cat.jpg`

A-8.3 Life as something residing in the intersection of reality and p-adicities

In TGD inspired theory of consciousness p-adic space-time sheets correspond to space-time correlates for thoughts and intentions. The intersections of real and p-adic preferred extremals consist of points whose coordinates are rational or belong to some extension of rational numbers in preferred embedding space coordinates. They would correspond to the intersection of reality and various p-adicities representing the "mind stuff" of Descartes. There is temptation to assign life to the intersection of realities and p-adicities. The discretization of the chart map assigning to real space-time surface its p-adic counterpart would reflect finite cognitive resolution.

At the level of "world of classical worlds" (WCW) the intersection of reality and various p-adicities would correspond to space-time surfaces (or possibly partonic 2-surfaces) representable in terms of rational functions with polynomial coefficients with are rational or belong to algebraic extension of rationals.

The quantum jump replacing real space-time sheet with p-adic one (vice versa) would correspond to a buildup of cognitive representation (realization of intentional action).

Fig. 23. The quantum jump replacing real space-time surface with corresponding p-adic manifold can be interpreted as formation of though, cognitive representation. Its reversal would correspond to a transformation of intention to action. `http://tgdtheory.fi/appfigures/padictoreal.jpg`

A-8.4 Sharing of mental images

The 3-surfaces serving as correlates for sub-selves can topologically condense to disjoint large space-time sheets representing selves. These 3-surfaces can also have flux tube connections and this makes possible entanglement of sub-selves, which unentangled in the resolution defined by the size of sub-selves. The interpretation for this negentropic entanglement would be in terms of sharing of mental images. This would mean that contents of consciousness are not completely private as assumed in neuroscience.

Fig. 24. Sharing of mental images by entanglement of subselves made possible by flux tube connections between topologically condensed space-time sheets associated with mental images. `http://tgdtheory.fi/appfigures/sharing.jpg`

A-8.5 Time mirror mechanism

Zero energy ontology (ZEO) is crucial part of both TGD and TGD inspired consciousness and leads to the understanding of the relationship between geometric time and experience time and how the arrow of psychological time emerges. One of the basic predictions is the possibiity of negative energy signals propagating backwards in geometric time and having the property that entropy basically associated with subjective time grows in reversed direction of geometric time. Negative energy signals inspire time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig.** 24 in the appendix of this book) providing mechanisms of both memory recall, realization of intentational action initiating action already in geometric past, and remote metabolism. What happens that negative energy signal travels to past and is reflected as positive energy signal and returns to the sender. This process works also in the reverse time direction.

Fig. 25. Zero energy ontology allows time mirror mechanism as a mechanism of memory recall. Essentially "seeing" in time direction is in question. `http://tgdtheory.fi/appfigures/timemirror.jpg`

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