

TGD AND CONDENSED MATTER

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November 28, 2021

0.1 PREFACE

This book belongs to a series of online books summarizing the recent state Topological Geometro-dynamics (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 Geometro-dynamics (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 region of Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrics 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 implies 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 energy ontology 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 Maximization Principle 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 combine 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. Zero energy ontology and the interpretation of parton orbits as light-like

“wormhole throats” suggests that virtual particles do not differ from on mass shell particles only in that the four- and three- momenta of wormhole throats fail to be parallel. The two throats of the wormhole contact defining virtual particle would contact carry on mass shell quantum numbers but for virtual particles the four-momenta need not be parallel and can also have opposite signs of energy.

The 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.

Karkkila, October, 30, Finland

Matti Pitkänen

ACKNOWLEDGEMENTS

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 have kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 32 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 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 about my work. I have had also 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. Pekka Rapinoja has offered his help in this respect and I am especially grateful for him for my Python skills. Also Matti Vallinkoski has helped me in computer related problems.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation to 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. In particular, I am grateful for Mark McWilliams and Ulla Matfolk for providing links to possibly interesting web sites and articles. 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 publicity through the iron wall of the academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as 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 a direct support from power holders- even in archives like arXiv.org.

Situation changed for five years ago as Andrew Adamatsky proposed the writing of a book about TGD when I had already got used to the thought that my work would not be published during my life time. 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 loop holes. 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 sixty year 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 the society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During last few years when the right wing has held the political power this trend has been steadily strengthening. 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, October, 30, 2015 Finland

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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 37 years ago - would emerge now it would be seen as an attempt trying to solve the difficulties of these approaches to unification.

The basic physical picture behind 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.

1.1.1 Basic 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 [K1].

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 imbedding 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 imbedding space metric and parallel translation using spinor connection of imbedding space.

The induction procedure applies to octonionic structure and the conjecture is that for preferred extremals the induced octonionic structure is quaternionic: again one just projects the octonion units. I have proposed that one can lift space-time surfaces in H to 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 [A15]. Now the twistor structure would be induced in some sense, and should co-incide 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 space-time surface. This poses constraint on the imbedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces.

3. 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 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. Imbedding space H has a number theoretic interpretation as 8-D space allowing octonionic tangent space structure. 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 imbedding 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. Particle in space-time can be identified as a topological inhomogeneity 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 distance 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 standard model and general relativity follow as a topological simplification however forcing to increase dramatically 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. A possible resolution of problem is implied by the condition that the modes of the induced spinor fields have well-defined electromagnetic charge. This forces their localization to 2-D string world sheets in the generic case having vanishing weak gauge fields so that parity breaking effects emerge just as they do in standard model. Also string model like picture emerges from TGD and one ends up with a rather concrete view about generalized Feynman diagrammatics. A possible objection is that the Kähler-Dirac gamma matrices do not define an integrable distribution of 2-planes defining string world sheet.

An even stronger condition would be that the induced classical gauge fields at string world sheet vanish: this condition is allowed by the topological description of particles. The CP_2 projection of string world sheet would be 1-dimensional. Also the number theoretical condition that octonionic and ordinary spinor structures are equivalent guaranteeing that fermionic dynamics is associative leads to the vanishing of induced gauge fields.

The natural action would be given by string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant would be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality condition. The hierarchy of Planck constants $\hbar_{eff}/\hbar = n$ 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 super string 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 also induced spinor fields associated with Kähler-Dirac action and de-localized inside 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 imbeddings: 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 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 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 serve 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 [A2] [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 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 imbedding 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 everyday world represent non-trivial topology of space-time in 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 hierarchies of Planck constants $h_{eff} = n \times h$ reducing to the quantum criticality of 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 41 years for the realization of this dream and this has resulted 24 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

1.1.2 Two Visions About TGD And Their Fusion

As already mentioned, TGD 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 [A11, A14, A6, A13].

The identification of the space-time as a sub-manifold [A12, A17] 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. 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 possibly 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. A.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 system does not possess this kind of field identity. The notion of magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology.

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. 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 is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian and interpreted as lines of generalized Feynman diagrams. Also the Euclidian 4-D regions would have 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 strong form of holography.

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 imbedding 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. Particle topologically condenses to several space-time sheets simultaneously and experiences 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 imbeddability to 8-D imbedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation allows to understand the relationship to GRT space-time and how 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 space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical EP for the GRT limit in long length scales at least. One can consider also 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 very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of 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 things this leads to models for cell membrane, nerve pulse, and EEG.

1.1.4 P-Adic Variants Of Space-Time Surfaces

There is a further generalization of the space-time concept inspired by p-adic physics forcing a generalization of the number concept through the fusion of real numbers and various p-adic number fields. One might say that TGD space-time is adelic. Also the hierarchy of Planck constants forces a generalization of the notion of space-time but this generalization can be understood in terms of the failure of strict determinism for Kähler action defining the fundamental variational principle behind the dynamics of space-time surfaces.

A very concise manner to express how TGD differs from Special and General Relativities could be following. Relativity Principle (Poincare Invariance), General Coordinate Invariance, and Equivalence Principle remain true. What is new is the notion of sub-manifold geometry: this allows to realize Poincare Invariance and geometrize gravitation simultaneously. This notion also allows a geometrization of known fundamental interactions and is an essential element of all applications of TGD ranging from Planck length to cosmological scales. Sub-manifold geometry is also crucial in the applications of TGD to biology and consciousness theory.

1.1.5 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.

The theoretical framework involves several threads.

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 extremely 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 four.

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The eight online books [K44, K38, K30, K55, K41, K54, K53, K40] about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology [K42, K7, K32, K5, K16, K23, K25, K39, K50] are warmly recommended to the interested reader.

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:

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude 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. Particle reactions are identified as topology changes [A16, A19, A23]. 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.
2. 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 unexpected 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!
3. WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory ¹
4. WCW Dirac operator appearing in Super-Virasoro conditions, imbedding space Dirac operator whose modes define the ground states of Super-Virasoro representations, Kähler-Dirac operator at space-time surfaces, and the algebraic variant of M^4 Dirac operator appearing in

¹There 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 Kähler 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 Kähler Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

propagators. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operator of WCW so that this classical free field theory would dictate 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. Given M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.

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 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 algebra acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in well-defined sense.

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 [K47]. 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.

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. It turns out possible to construct a general representation for the U-matrix reducing its construction to that of S-matrix. S-matrix has interpretation as exponential of the Virasoro generator L_{-1} of the Virasoro algebra associated with super-symplectic algebra.

5. By quantum classical correspondence the construction of WCW spinor structure reduces to the second quantization of the induced spinor fields at space-time surface. The basic action is so called modified Dirac action (or Kähler-Dirac action) in which gamma matrices are replaced with the modified (Kähler-Dirac) gamma matrices defined as contractions of the canonical momentum currents with the imbedding space gamma matrices. In this manner one achieves super-conformal symmetry and conservation of fermionic currents among other things and consistent Dirac equation. The Kähler-Dirac gamma matrices define as anti-commutators effective metric, which might provide geometrization for some basic observables of condensed matter physics. One might also talk about bosonic emergence in accordance with the prediction that the gauge bosons and graviton are expressible in terms of bound states of fermion and anti-fermion.
6. An important result relates to the notion of induced spinor connection. If one requires that 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 neutrino generating super-symmetries forms an exception. The vanishing of also Z^0 field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that 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 simplifies enormously the mathematics 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 at which 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 massless Dirac equation is satisfied by the nodes so that Kähler-Dirac action gives massless Dirac propagator localizable at the boundaries of the string world sheets.

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 $\sqrt{g_4}$ factor 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 manner 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 manner 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.

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 hyper-counterparts of classical number fields identified as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product, and the notion of infinite prime.

1. *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 reduce 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 structures. 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 imbedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, imbedding space, and WCW.

The notion of p-adic manifold [K100] identified as p-adic space-time surface solving p-adic analogs of field equations and having real space-time sheet as chart map provided a possible solution of the basic challenge of relating real and p-adic classical physics. One can also speak of

real space-time surfaces having p-adic space-time surfaces as chart maps (cognitive maps, “thought bubbles”). Discretization required having interpretation in terms of finite measurement resolution is unavoidable in this approach and this leads to problems with symmetries: canonical identification does not commute with symmetries.

It is now clear that much more elegant approach based on abstraction exists [K98]. The map of real preferred extremals to p-adic ones is not induced from a local correspondence between points but is global. Discretization occurs only for the parameters characterizing string world sheets and partonic 2-surfaces so that they belong to some algebraic extension of rationals. Restriction to these 2-surfaces is possible by strong form of holography. 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 (imaginings) 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 [K26].

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.

2. The role of classical number fields

The vision about the physical role of the classical number fields relies on certain speculative questions inspired by the idea that space-time dynamics could be reduced to associativity or co-associativity condition. Associativity means here associativity of tangent spaces of space-time region and co-associativity associativity of normal spaces of space-time region.

1. Could space-time surfaces X^4 be regarded as associative or co-associative (“quaternionic” is equivalent with “associative”) surfaces of H endowed with octonionic structure in the sense that tangent space of space-time surface would be associative (co-associative with normal space associative) sub-space of octonions at each point of X^4 [K93]. This is certainly possible and an interesting conjecture is that the preferred extremals of Kähler action include associative and co-associative space-time regions.
2. Could the notion of compactification generalize to that of number theoretic compactification in the sense that one can map associative (co-associative) surfaces of M^8 regarded as octonionic linear space to surfaces in $M^4 \times CP_2$ [K93] ? This conjecture - $M^8 - H$ duality - would give for $M^4 \times CP_2$ deep number theoretic meaning. CP_2 would parametrize associative planes of octonion space containing fixed complex plane $M^2 \subset M^8$ and CP_2 point would thus characterize the tangent space of $X^4 \subset M^8$. The point of M^4 would be obtained by projecting the point of $X^4 \subset M^8$ to a point of M^4 identified as tangent space of X^4 . This would guarantee that the dimension of space-time surface in H would be four. The conjecture is that the preferred extremals of Kähler action include these surfaces.
3. $M^8 - H$ duality can be generalized to a duality $H \rightarrow H$ if the images of the associative surface in M^8 is associative surface in H . One can start from associative surface of H and assume

that it contains the preferred M^2 tangent plane in 8-D tangent space of H or integrable distribution $M^2(x)$ of them, and its points to H by mapping M^4 projection of H point to itself and associative tangent space to CP_2 point. This point need not be the original one! If the resulting surface is also associative, one can iterate the process indefinitely. WCW would be a category with one object.

4. G_2 defines the automorphism group of octonions, and one might hope that the maps of octonions to octonions such that the action of Jacobian in the tangent space of associative or co-associative surface reduces to that of G_2 could produce new associative/co-associative surfaces. The action of G_2 would be analogous to that of gauge group.
5. One can also ask whether the notions of commutativity and co-commutativity could have physical meaning. The well-definedness of em charge as quantum number for the modes of the induced spinor field requires their localization to 2-D surfaces (right-handed neutrino is an exception) - string world sheets and partonic 2-surfaces. This can be possible only for Kähler action and could have commutativity and co-commutativity as a number theoretic counterpart. The basic vision would be that the dynamics of Kähler action realizes number theoretical geometrical notions like associativity and commutativity and their co-notions.

The notion of number theoretic compactification stating that space-time surfaces can be regarded as surfaces of either M^8 or $M^4 \times CP_2$. As surfaces of M^8 identifiable as a sub-space of complexified octonions (addition of commuting imaginary unit i) their tangent space or normal space is quaternionic- and thus maximally associative or co-associative. These surfaces can be mapped in natural manner to surfaces in $M^4 \times CP_2$ [K93] provided one can assign to each point of tangent space a hyper-complex plane $M^2(x) \subset M^4 \subset M^8$. One can also speak about $M^8 - H$ duality.

This vision has very strong predictive power. It predicts that the preferred extremals of Kähler action correspond to either quaternionic or co-quaternionic surfaces such that one can assign to tangent space at each point of space-time surface a hyper-complex plane $M^2(x) \subset M^4$. As a consequence, the M^4 projection of space-time surface at each point contains $M^2(x)$ and its orthogonal complement. These distributions are integrable implying that space-time surface allows dual slicings defined by string world sheets Y^2 and partonic 2-surfaces X^2 . The existence of this kind of slicing was earlier deduced from the study of extremals of Kähler action and christened as Hamilton-Jacobi structure. The physical interpretation of $M^2(x)$ is as the space of non-physical polarizations and the plane of local 4-momentum.

Number theoretical compactification has inspired large number of conjectures. This includes dual formulations of TGD as Minkowskian and Euclidian string model type theories, the precise identification of preferred extremals of Kähler action as extremals for which second variation vanishes (at least for deformations representing dynamical symmetries) and thus providing space-time correlate for quantum criticality, the notion of number theoretic braid implied by the basic dynamics of Kähler action and crucial for precise construction of quantum TGD as almost-topological QFT, the construction of WCW metric and spinor structure in terms of second quantized induced spinor fields with modified Dirac action defined by Kähler action realizing the notion of finite measurement resolution and a connection with inclusions of hyper-finite factors of type II_1 about which Clifford algebra of WCW represents an example.

The two most important number theoretic conjectures relate to the preferred extremals of Kähler action. The general idea is that classical dynamics for the preferred extremals of Kähler action should reduce to number theory: space-time surfaces should be either associative or co-associative in some sense.

Associativity (co-associativity) would be that tangent (normal) spaces of space-time surfaces associative (co-associative) in some sense and thus quaternionic (co-quaternionic). This can be formulated in two manners.

1. One can introduce octonionic tangent space basis by assigning to the “free” gamma matrices octonion basis or in terms of octonionic representation of the imbedding space gamma matrices possible in dimension $D = 8$.
2. Associativity (quaternionicity) would state that the projections of octonionic basic vectors or induced gamma matrices basis to the space-time surface generates associative (quaternionic)

sub-algebra at each space-time point. Co-associativity is defined in analogous manner and can be expressed in terms of the components of second fundamental form.

3. For gamma matrix option induced rather than Kähler-Dirac gamma matrices must be in question since Kähler-Dirac gamma matrices can span lower than 4-dimensional space and are not parallel to the space-time surfaces as imbedding space vectors.

3. 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 rational (hyper-)quaternions and (hyper-)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.

1.1.6 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 [E1] 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 $\hbar_{gr}$. 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 $\hbar_{gr}$ would be much smaller. Large $\hbar_{gr}$ 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 [K88].

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 manner 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 fermionic 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 [K33, K34, K48]) support the view that dark matter might be a key player in living matter.

Does the hierarchy of Planck constants reduce to the vacuum degeneracy of Kähler action?

This starting point led gradually to the recent picture in which the hierarchy of Planck constants is postulated to come as integer multiples of the standard value of Planck constant. Given integer multiple $\hbar = n\hbar_0$ of the ordinary Planck constant $\hbar_0$ is assigned with a multiple singular covering of the imbedding space [K77]. One ends up to an identification of dark matter as phases with non-standard value of Planck constant having geometric interpretation in terms of these coverings providing generalized imbedding space with a book like structure with pages labelled by Planck constants or integers characterizing Planck constant. The phase transitions changing the value of

Planck constant would correspond to leakage between different sectors of the extended imbedding space. The question is whether these coverings must be postulated separately or whether they are only a convenient auxiliary tool.

The simplest option is that the hierarchy of coverings of imbedding space is only effective. Many-sheeted coverings of the imbedding space indeed emerge naturally in TGD framework. The huge vacuum degeneracy of Kähler action implies that the relationship between gradients of the imbedding space coordinates and canonical momentum currents is many-to-one: this was the very fact forcing to give up all the standard quantization recipes and leading to the idea about physics as geometry of the “world of classical worlds”. If one allows space-time surfaces for which all sheets corresponding to the same values of the canonical momentum currents are present, one obtains effectively many-sheeted covering of the imbedding space and the contributions from sheets to the Kähler action are identical. If all sheets are treated effectively as one and the same sheet, the value of Planck constant is an integer multiple of the ordinary one. A natural boundary condition would be that at the ends of space-time at future and past boundaries of causal diamond containing the space-time surface, various branches co-incide. This would raise the ends of space-time surface in special physical role.

A more precise formulation is in terms of presence of large number of space-time sheets connecting given space-like 3-surfaces at the opposite boundaries of causal diamond. Quantum criticality presence of vanishing second variations of Kähler action and identified in terms of conformal invariance broken down to sub-algebras of super-conformal algebras with conformal weights divisible by integer n is highly suggestive notion and would imply that n sheets of the effective covering are actually conformal equivalence classes of space-time sheets with same Kähler action and same values of conserved classical charges (see **Fig. <http://tgdtheory.fi/appfigures/planckhierarchy.jpg>** or **Fig. ??** the appendix of this book). n would naturally correspond the value of h_{eff} and its factors negentropic entanglement with unit density matrix would be between the n sheets of two coverings of this kind. p -Adic prime would be largest prime power factor of n .

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} .

1.1.7 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 [K94]. 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 [A15]. 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 imbeddings 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 imbedding 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 [L47].

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 imbedding 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 adèle [L38]. 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, Holger-Bek Nielsen, and Leonard Susskind to N-particle amplitude (see <http://tinyurl.com/yyvnx7as>) 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 width.

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 algebra (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 QFT 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 the Book

This book tries to provide a view about the applications of TGD to condensed matter physics. Quantum TGD in its recent form. Quantum TGD relies on two different views about physics: physics as an infinite-dimensional spinor geometry based on the notion of "World of Classical Worlds" (WCW) and physics as a generalized number theory. WCW picture generalizes Einstein's geometrization program to a geometrization of the entire quantum physics. Number theoretic vision states that so-called adelic physics provides a dual view about physics.

$M^8 - H$ duality realizes these dual views in terms of space-time surfaces $X^4 \subset H$ and $X^4 \subset M^8$ mapped to each other by $M^8 - H$ duality. This duality turns out to be a generalization of momentum-position duality of wave mechanics. Also the duality of number theory and geometry suggested by Langlands correspondence pops up into mind.

1.2.1 The view about physics at the level of H

An important guiding principle in the development of TGD has been quantum classical correspondence (QCC), whose most profound implications follow almost trivially from the basic structure of the classical theory forming an exact part of quantum theory (here TGD differs from quantum field theories (QFTs)).

1. 4-D General Coordinate Invariance (GCI) forces holography: the space-time surface associated with a given 3-surface is almost unique as an analog of Bohr orbit. X^4 is therefore a preferred extremal of an action principle. This realizes QCC at space-time level and leads to zero energy ontology (ZEO) generalizing the ontology of standard physics.
2. The new view about space-time as 4-surface $X^4 \subset H = M^4 \times CP_2$ is central for applications. One manner to formulate this is that X^4 is simultaneously minimal surface and extremal of Kähler action S_K analogous to Maxwell action. The twistor lift of TGD forces the presence of both S_K and the volume term in the action.
3. Especially important minimal surfaces are CP_2 type extremals representing building bricks of elementary particles, cosmic strings and magnetic flux tubes as their deformations so that their M^4 and CP_2 projections have dimension larger than 2, and so called massless extremals (MEs). Magnetic flux tubes appear as two variants depending on whether they carry monopole flux or not. Monopole flux tubes require no current to create the magnetic field and are not possible in Maxwellian theory. Both are in a crucial role also in condensed matter applications.
4. The new view about space-time differs dramatically from that of GRT. The space-time surface is topologically non-trivial in all scales and many-sheeted in the sense that CP_2 coordinates as function of M^4 coordinates and vice versa are many-valued. The space-time of GRT is obtained from the many-sheeted one in long length scale limit by replacing the sheets with a single region of M^4 and by deforming its metric. The gauge potentials are defined as sums of induced gauge potentials for sheets. The deviation of the metric is the sum of the deviations of the induced metric from the M^4 metric.

The new physics related to the many-sheetedness is not describable in terms of the QFT approach.

5. The classical field equations reduce to conservation laws for the conserved charges defined by the isometries of H . Therefore they are essentially hydrodynamical and this together with QCC is essential for TGD inspired quantum hydrodynamics (QHD). The conjecture that the extremals allow generalized Beltrami property, which implies the existence of a global coordinate varying along the flow lines of flow. For instance, Beltrami property provides purely classical geometric correlates for supra flows and supracurrents. Global coordinates allow identification of order parameters having interpretation in terms of quantum coherence.
6. 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 if the corresponding Killing vectors with proportionality factor constant along the projections of their flow lines. This implies as generalization of the energy conservation along flow lines of hydrodynamical flow ($\rho v^2/2 + p = \text{constant}$).

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.

1.2.2 The view about physics at the level of M^8

Over the years, the number theoretical vision has evolved to what I call adelic physics [L39, L38]. $M^8 - H$ duality as analog of momentum-position duality and of Complementarity Principle crystallizes number theoretical vision.

1. Complexified octonions M_c^8 have interpretation as an analog of momentum space [L60, L61]. There are 4-surfaces in both M^8 and H and they are related by $M^8 - H$ duality. 4-surfaces $X^4 \subset M^8$ have associative normal spaces and are defined as "roots" of an octonionic polynomial defined as an algebraic continuation of a real polynomial P with rational coefficients.

A real polynomial (its roots) therefore defines the entire 4-surface, which means holography taken to an extreme. This also motivates the preferred extremal property at the H side, where one has partial differential equations and variational principle instead of algebraic equations. The analog of Bohr orbit property is one manner to formulate the restrictions.

2. The notion of cognitive representation is motivated by adelic physics, and corresponds to a subset of points of $X^4 \subset M^8$ in M_c^8 such that the coordinates of the points are in the extension of rationals defined by P . They define a unique discretization of the 4-surface. Cognitive representation contains common points of the real 4-surface and its p -adic variants and makes possible the number-theoretical universality of adelic physics. It is not completely clear whether the cognitive representations are needed only on the M^8 side or at both sides of the duality.
3. The interpretation of the points of M^8 as momenta leads to the proposal that the points of cognitive representation are algebraic integers. Contrary to the naive expectations, all algebraic numbers of extension belong to the cognitive representation for the roots of octonionic polynomials [L60, L61]. A natural restriction is that 4-momenta correspond to algebraic integers. A further restriction is that the "active" points of the cognitive representation are occupied by quarks (in TGD leptons can correspond to bound states of quarks [L57, L71]). Therefore the 4-surface in H is analogous to the Fermi ball containing discrete quark momenta as an analog of cognitive representation. Condensed matter physics relies strongly on the use of momentum space so that M^8 picture is central for the applications in condensed matter.
4. Galois group of the polynomial defining $X^4 \subset M^8$ acts as symmetries for the roots of the polynomials. The order of Galois group of P is identified as effective Planck constant $h_{eff}/h_0 = n$, where the ordinary Planck constant is a multiple of h_0 . n is in general not the same as the dimension of extension defined by the degree of P . The original identification was as the dimension of extension counting the number of roots. One must keep an open mind here.

The identification of h_{eff} as the order of the Galois group (rather than dimension of extension) finds support from the following. The order gives the number of regions at the orbit of Galois group (in the case that the isotropy group of the point is trivial!) and at the level of H , the action is sum of identical contributions over these regions so that Planck constant would be nh_0 .

The phases of matter with different values of h_{eff} behave like dark matter relative to each other (this does not of course imply that galactic dark matter and energy correspond to $h_{eff} > h$ phases). Various quantum scales, typically proportional to h_{eff} , can be arbitrarily long and quantum coherence is possible in all scales and assigned with the magnetic body (MB). Galois confinement [L83] generalizes the notion of periodic boundary conditions and could serve as a universal mechanism for the formation of bound states. One implication is that the total momentum of a bound state formed by quarks has total momentum, which is a rational integer. This serves as an extremely powerful constraint.

The evolutionary hierarchies formed by the extensions of rationals defined by functional composition of polynomials are characterized by root inheritance if the condition $P(0) = 0$ is satisfied. This gives rise to an evolutionary hierarchy of bound states such that the new

level contains all bound states of the previous level (conserved genes serve as an analogy). What is nice is that the states of Galois representations which are not Galois singlets can serve as composites of Galois singlets at the next level. For these reasons Galois confinement is expected to play a fundamental role in TGD and in the TGD based view about condensed matter.

5. Nottale introduced the notion of gravitational Planck constant [E1] $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, which allows us to understand the planetary planets as Bohr orbits. The form of $\hbar_{gr}$ is dictated by the Equivalence Principle. In the TGD framework, the hierarchy of Planck constants, the infinite range of gravitational interaction, and the absence of screening motivate this notion [K88, K84, K85, K63].

The gravitational Compton length for a particle with mass m is $\Lambda_{gr} = GM/v_0 = r_s c/2v_0$ and thus expressible in terms of Schwarzschild radius and has $r_s/2$ as lower bound. For Earth of order TGD view about living matter involves $\hbar_{gr}$ in an essential manner.

Amazingly, there are indications that Λ_{gr} for Earth could play a key role in superconductivity [L72], superfluidity, and in quantum analogies of hydrodynamical systems [L82]. Also the role of Λ_{gr} for Sun is suggestive. Note that the original motivation for the large value of $\hbar_{eff}$ was the TGD based model for effects of em radiation at ELF frequencies on the vertebrate brain [K22, K33, K34].

1.2.3 $M^8 - H$ duality

The proposal is that the description of physics in terms of geometry and number theory are dual to each other. There are several observations motivating $M^8 - H$ duality.

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?

1. Actually a complexification $M_c^8 \equiv E_c^8$ 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_c^8 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_c^4 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_c^8 would provide a number theoretic description: no partial differential equations, no Riemannian metric, no connections...

M_c^8 has only the number theoretic norm squared and bilinear form, which are real only if M_c^8 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 [L60, L61]. 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_c^8 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.

One implication of $M^8 - H$ duality is that the image of a generic point of $X^4 \subset M^8$ is a single point of CP_2 . There is complete localization in color degrees of freedom in Einsteinian regions of space-time having 4-D M^4 projection and one cannot even speak of color. This would solve in a trivial manner the problem of color confinement.

CP_2 type extremals however correspond to singularities for which a single point of line has ill-defined normal space and normal spaces correspond to a 3-D surface in CP_2 . In this case, one can assign representations of color group $SU(3)$ to the image of the line which is essentially CP_2 . Color therefore makes sense inside the Euclidean wormhole contacts.

For the string-like entities, the singularity at a given point of string world sheets corresponds to a 2-D surface of CP_2 , which is a complex manifold or Lagrangian manifold. For the two geodesic spheres the color group reduces to $U(2)$ or $SO(3)$, and one can speak about spontaneous breaking of the color symmetry. Also S^1 singularity is possible for objects with 3-D M^4 projection. In this case the color symmetry reduces to $U(1)$.

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 only 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.

1. The first part of the book is devoted to the most recent (2021-) work related to TGD view about condensed matter.
2. Second part of the book contains some material related to the earlier work on this topic.

1.3 Sources

The eight online books about TGD [K44, K38, K55, K41, K30, K54, K53, K40] and nine online books about TGD inspired theory of consciousness and quantum biology [K42, K7, K32, K5, K16, K23, K25, K39, K50] 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: THE MOST RECENT WORK RELATED TO CONDENSED MATTER PHYSICS

TGD Towards the End of 2021

This article tries to give a rough overall view about Topological Geometrodynamics (TGD) as it is towards the end of 2021. The two views about TGD and their relationship are discussed at the general level.

- (a) The first view generalizes Einstein's program for the geometrization of physics. Entire quantum physics is geometrized in terms of the notion of "world of classical worlds" (WCW), which by its infinite dimension has unique Kähler geometry.
- (b) Second vision reduces physics to number theory. Classical number fields (reals, complex numbers, quaternions, and octonions) are central as also p-adic number fields and extensions of rationals. The physics is classically coded by algebraic 4-surfaces in complexified M^8 having octonionic structure and "roots" of octonionic polynomials obtained as algebraic continuations of real polynomials with rational coefficients. M_c^8 has an interpretation as an analog of momentum space.

The preparation of this summary led to considerable progress in several aspects of TGD.

- (a) 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.

- (b) 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.
- (c) 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.
- (d) 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.

Article includes also a section about neutrinos and TGD. The motivation is that the recent results related to neutrino mixing led to a dramatic progress in the understanding of the role of right-handed neutrino solving long-standing problems of quantum TGD.

TGD and Condensed Matter Physics

Condensed matter physics is under rapid evolution, 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 general view about condensed matter in TGD Universe is following.

- (a) 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.
- (b) 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.
- (c) 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. TGD description of Cooper pairs is consistent with fermion number conservation and the notion of Bogoliubov quasiparticles does not seem necessary or relevant in TGD.
- (d) 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. Galois confinement suggests a universal mechanism for the formation of bound states. 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.

- (e) TGD also provides new insights about topological physics and space-time topology provides a new element of topological physics.

In this article, 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.

TGD and Quantum Hydrodynamics

The purpose of this article is to consider possible applications of Topological Geometro-dynamics (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.

Comparing Berry phase model of super-conductivity with 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.

- (a) 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.

- (b) 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.
- (c) 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?

1.4.2 PART II: SOME EARLIER WORK (BEFORE 2021) RELATED TO CONDENSED MATTER

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 factor 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 imbedding 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 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 $\hbar_{eff} = n \times \hbar$.

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. Tetrahedral clusters allow an interpretation in terms of magic $Z=8$ protonic dark nuclei. The icosahedral clusters consisting of 20 tetrahedral 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.

Quantum Model for Bio-Superconductivity: I

The model for generalized EEG relates very closely to the general model of high T_c superconductivity. This motivates a separate discussion of the vision about bio-super-conductivity in TGD Universe.

1. *General mechanisms of bio-superconductivity*

The many-sheeted space-time concepts suggested a very general mechanism of superconductivity based on the “dropping” of charged particles from atomic space-time sheets to larger space-time sheets. 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 “dropping” is that particle can topologically condense on several space-time sheets which therefore are not separate worlds: this is indeed assumed in the recent view about GRT and QFT limit of TGD. Dropping could therefore occur only at larger space-time sheet at the boundary of the smaller one. The expansion of the space-time sheet (flux tube) in p-adic phase transition liberates also zero point kinetic energy (cyclotron energy).

The possibility of large $\hbar$ quantum coherent phases makes the assumption about thermal isolation between space-time sheets unnecessary. The establishment of thermal equilibrium would rely on the phase transitions transforming ordinary to dark matter and vice versa. Biophotons could be produced from dark photons in this manner. The flow from a flux tube portion with larger value of $\hbar_{eff}$ to that with a smaller value liberates cyclotron energy.

A crucial element is quantum criticality predicting a new kind of superconductivity explaining the strange features of high T_c super-conductivity. This led to the proposal that there are two kinds of Cooper pairs, exotic Cooper pairs with spin $S = 1$ and counterparts of ordinary BCS type Cooper pairs with spin $S = 0$. Both correspond to a large value of Planck constant. Exotic Cooper pairs are quantum critical meaning that they can decay to ordinary electrons. Below temperature $T_{c1} > T_c$ only exotic Cooper pairs with spin are present and their finite lifetime implies that super-conductivity is broken to ordinary conductivity satisfying scaling laws characteristic for criticality. At T_c spinless BCS type Cooper pairs become stable and exotic Cooper pairs can decay to them and vice versa. An open question is whether the BCS type Cooper pairs can be present also in the interior of cell.

These two superconducting phases would compete in certain narrow interval around critical temperature for which body temperature of endotherms is a good candidate in the case of living matter. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

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. 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.

This mechanism is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T_c bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability at room temperature and it seems that only electron, neutrino, and proton Cooper pairs are possible at room temperature besides Bose-Einstein condensates of all bosonic ions and their exotic counterparts resulting when some nuclear color bonds become charged.

2. Hierarchies of preferred p-adic length scales and values of Planck constant

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 .

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 p-adic length scales with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μ m) 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. This hypothesis - to be referred to as Mersenne hypothesis - replaces the earlier rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant.

3. Fractal hierarchy of magnetic flux sheets and the hierarchy of genomes

The notion of magnetic body is central in the TGD inspired theory of living matter. Every system possesses magnetic body and there are strong reasons to believe that the magnetic body associated with human body is of order Earth size and that there could be an entire hierarchy of these bodies with even much larger sizes. Therefore the question arises what one can assume about these magnetic bodies. The quantization of magnetic flux suggests an answer to this question.

- (a) The quantization condition for magnetic flux reads in the most general form as $\oint (p - eA) \cdot dl = n\hbar$. If supra currents flowing at the boundaries of the flux tube are absent one obtains $e \int B \cdot dS = n\hbar$, which requires that the scaling of the Planck constant scales up the flux tube thickness by r^2 and scaling of B by $1/r$. If one assumes that the radii of flux tubes do not depend on the value of r , magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint (p - eA) \cdot dl = 0$. 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.
- (b) From the point of view of EEG especially interesting are the flux sheets which have thickness $L(151) = 10$ nm (the thickness of cell membrane) carrying magnetic field having strength of endogenous magnetic field. In absence of supra currents these flux sheets have very large total transversal length proportional to r^2 . The condition that the values of cyclotron energies are above thermal energy implies that the value of r is of order 2^{k_d} , $k_d = 44$. Strongly folded flux sheets of this thickness might be associated with living matter and connect their DNAs to single coherent structure. One can of course assume the presence of supra currents but outside the organism the flux sheet should fuse to form very long flux sheets.
- (c) Suppose that the magnetic flux flows in head to tail direction so that the magnetic flux arrives to the human body through a layer of cortical neurons. Assume that the flux sheets traverse through the uppermost layer of neurons and also lower layers and that DNA of each neuronal nuclei define a transversal sections organized along flux sheet like text lines of a book page. The total length of DNA in single human cell is about one meter. It seems that single organism cannot provide the needed total length of DNA if DNA dominates the contribution. This if of course not at all necessarily since supra currents are possible and outside the organism the flux sheets can fuse together. This implies however correlations between genomes of different cells and even different organisms.

These observations inspire the notion of super- and hyper genes. As a matter fact, entire hierarchy of genomes is predicted. Super genes consist of genes in different cell nuclei arranged to threads along magnetic flux sheets like text lines on the page of book whereas hyper genes

traverse through genomes of different organisms. Super and hyper genes provide an enormous representative capacity and together with the dark matter hierarchy allows to resolve the paradox created by the observation that human genome does not differ appreciably in size from that of wheat.

Quantum Model for Bio-Superconductivity: II

The models for EEG and its variants and for nerve pulse rely on a general model of high T_c superconductivity. The general vision behind model of cell membrane as super-conductor inspired by the identification of dark matter in terms of hierarchy of Planck constants and the notion of magnetic body was considered in the previous chapter. In this chapter the vision is tested by applying it to various anomalous findings about the behavior of the cell membrane.

The topics discussed are following.

- (a) There are several findings challenging the standard thermodynamical view about cell membrane. TGD suggests a model in which various transmembrane proteins (receptors, channels, pumps) act as Josephson junction between superconductors assignable to the interior and exterior of cell membrane.

The most feasible model for cell membrane and charge transfer found hitherto relies on Pollack's observations about fourth gel like phase of water. The model for the findings leads to a generalization of the cell membrane as Josephson junction obtained by adding to Josephson energy the difference of the cyclotron energies of dark ion at two sides of the cell membrane. Cyclotron energy difference replaces chemical potential difference in the generalization of the thermodynamical model inspired by Zero Energy Ontology, and replacing thermodynamical distributions with their quantal "square roots". Charge transfer would be induced by a phase transition changing the value of Planck constant at either or both sides of the membrane. This would induce the change of the equilibrium concentrations of ions and also charge transfer.

- (b) Water memory, chiral selection of biomolecules, burning of water by radiowaves represent further intriguing effects whose understanding seems to require new physics. Dark matter identified in term of hierarchy of Planck constants and the notion of magnetic body define an attractive candidate in this respect. Scaled up variants of weak physics defined by the hierarchy of Planck constants and p-adic length scale hierarchy could explain chiral selection.
- (c) Hafedh Abdelmelek and collaborators have found evidence for effective super-conductivity in the sciatic nerves of both endotherms (rabbit) and poikilotherms (frog). The TGD based explanation would be in terms of dark supra currents.
- (d) DC currents of Becker have been known for a long time. An attractive interpretation is as supra currents. The basic prediction is that the resistance should not depend on the length of the conduction pathway. One can also construct a quantum model for the current.
- (e) TGD inspires two views about cell membrane which need not be contradictory. For the first model cell is far from vacuum extremal, for the second model nearly vacuum extremal. There are several constraints on the model coming from the TGD based identification of bio-photons, the new view about metabolism. It seems that the first model might be enough when generalized along lines inspired by Pollack's findings about the fourth phase of water.

Physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity.

Tajmar et al have proposed the gravimagnetic effect as an explanation of an anomaly related to the superconductors. The measured value of the mass of the Cooper pair is slightly larger

than the sum of masses whereas theory predicts that it should be smaller. The explanation would be that actual Thomson field is larger than it should be because of gravimagnetic contribution to quantization rule used to deduce the value of Thomson field. The required value of gravimagnetic Thomson field is however 28 orders of magnitude larger than General Relativity suggests. TGD inspired proposal is based on the notion of gravitational Planck constant assignable to the flux tubes connecting to massive objects. It turns out that the TGD estimate for the Thomson field has correct order of magnitude. The identification $h_{eff} = h_{gr}$ at particle physics and atomic length scales emerges naturally.

A vision about the fundamental role of quantum gravitation in living matter emerges. The earlier hypothesis that dark EEG photons decay to biophotons with energies in visible and ultraviolet range receives strong quantitative support. Also a mechanism for how magnetic bodies couple bio-chemistry emerges. The vision conforms with Penrose's intuitions about the role of quantum gravity in biology.

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.

- (a) 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.

- (b) 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 imbedding 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.
- (c) At the orbits of wormhole throats, which can have even macroscopic M^4 projections, one has $1 \rightarrow n_a$ correspondence and at the space-like ends of the space-time surface at light-like boundaries of causal diamond one has $1 \rightarrow n_b$ correspondence. This implies that at partonic 2-surfaces defined as the intersections of these two kinds of 3-surfaces one has $1 \rightarrow n_a \times n_b$ correspondence. This correspondence can be described by using a local singular n -fold covering of the imbedding space. Unlike in the original approach, the covering space is only a convenient auxiliary tool rather than fundamental notion.
- (d) 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 states of these states with several delocalized electrons: in this case one obtains more general charge fractionalization: $q = \nu e$.

- (e) 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.
- (f) 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 correspond to that of 4-fold covering space of imbedding 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 $\hbar_{eff}$ 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.

Part I

THE MOST RECENT WORK RELATED TO CONDENSED MATTER PHYSICS

Chapter 2

TGD Towards the End of 2021

2.1 Introduction

The purpose of this article is to give a rough overall view about Topological Geometro-dynamics (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 [L66] gives an overview of various aspects of TGD and is warmly recommended.

- (a) "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. 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 [L40, L48](see **Fig. 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. 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.

- (b) 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. 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 correlates for massless particles. World as a set of 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. 10**).

- (c) 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. 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. 9**).

$M^8 - H$ duality provides two complementary visions about physics (see **Fig. 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).

- (d) 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. A.2** and **Fig. 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. 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.

- (a) 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.

- (b) 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 .
- (c) 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.

- (d) 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.

2.2 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 [L66].

2.2.1 Space-time as 4-surface in $H = M^4 \times CP_2$

- (a) The energy problem of GRT means that since space-time is curved, one cannot define Poincare charges as Noether charges (see **Fig. 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 $M^4 \subset H$.
- (b) 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.
- (c) 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 [K11]: 3 fermion families are predicted.
- (d) 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.
- (e) 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 [K94, L48].
- (f) 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 [L57, L71]. 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. 3**).

- (a) 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 [L89]. 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.

- (b) Massless extremals (MEs)/topological light rays are counterparts for massless modes. They allow superposition of modes with single direction of light-like momentum. Ideal laser beam is a convenient analogy here.
- (c) 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.

- (a) 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.
- (b) 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. 3**).

2.2.2 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.

- (a) "World of classical worlds" (WCW) can be identified as the space of 3-surfaces endowed with a metric and spinor structure (see **Fig. 7**). Hermitian conjugation must have a geometrization. This requires Kähler structure requiring also complex structure. WCW has Kähler form and metric.
- (b) WCW spinors are Fock states created by fermionic oscillator operators assignable to spinor modes of H basically [L64]. 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 expressible 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 [L56]: 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 [K19] (see **Fig. 7**).

- (a) 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 [L89].
- (b) $X^4(X^3)$ 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.

- (c) Twistor lift [L40, L48] 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 $X^4(X^3)$.

- (d) 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 [L79].
- (e) Soap film analogy is extremely useful [L89]: 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.

- (a) Dan Freed [A7] 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 [K12, K57].
- (b) Twistor lift of TGD [L40, L48] 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 [A15]. 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.

- (a) 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 $X_L^3 \subset X^4$ 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.
- (b) $\delta M_+^4 \times CP_2$ 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 [K12].
- (c) 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 [L60, L61]. 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 and 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 [K45]. 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.

- (a) $M^2(x)$ 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.

- (b) 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.

- (a) For the ordinary symplectic transformations, the closedness of the symplectic for J is essential ($dJ = 0$ corresponds to topological half of Maxwell's equations).
- (b) Second essential element is that symplectic transformation is generated as a flow for some Hamiltonian H : $j_H = i_{dH}J$ or more explicitly: $j_H^l = J^{kl}\partial_l H$. It is essential that one has $i_{j_H}J = -dH$: having a vanishing exterior derivative. In other words, $J_{kl}j_H^l = -\partial_k H$ 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 ?

- (a) 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 $J^2 = g(X^2) - g(Y^2)$.
- (b) 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 $J_{kl}j_H^l = dH$ 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.

- (c) 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 $M^2(x)$.
- (d) 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:

$$L_{j_H}[P(X^2)P(Y^2)] = L_{j_H}(P(X^2))P(Y^2) + P(X^2)L_{j_H}(P(Y^2)) = 0 \quad (2.2.1)$$

The projector $P_{mn}(X^2)$ can be expressed as

$$P^{mn} = g^{\alpha\beta}\partial_\alpha m^k\partial_\beta m^l \quad (2.2.2)$$

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

$$L_j P^{mn} = L_j(g^{\alpha\beta})\partial_\alpha m^k \partial_\beta m^l + g^{\alpha\beta}(\partial_r j^k \partial_\alpha m^r \partial_\beta m^l + \partial_r j^l k \partial_\alpha m^r \partial_\beta m^k) . \quad (2.2.3)$$

The Lie derivative of the induced metric is

$$\begin{aligned} L_j g^{\alpha\beta} &= g^{\alpha\mu} g^{\beta\nu} L_j g_{\mu\nu} , \\ L_j g_{\alpha\beta} &= m_{kl}(\partial_\alpha j^k \partial_\beta m^l + \partial_\alpha m^k \partial_\beta j^l) . \end{aligned} \quad (2.2.4)$$

Although the existence of symplectic transformations in the general case seems implausible, one can construct special slicings for which symplectic transformations are possible.

- (a) 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.
- (b) Second example is provided by the slicing of the light-like 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.

2.2.3 About Dirac equation in TGD framework

Three Dirac equations

In TGD spinors appear at 3 levels:

- (a) At the level of imbedding space $H = M^4 \times CP_2$ the spinor field imbedding 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.
- (b) 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.
- (c) 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 [K57] [L66].

- (d) 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 .

- (a) 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.
- (b) 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?

- (c) 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.

- (a) 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

$$\Gamma_k T^{\alpha k} \partial_\alpha h^k D_k \Psi = \Gamma^k D_k \Psi . \quad (2.2.5)$$

Not surprisingly, it turns out that this condition is too strong.

- (b) 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

$$\Gamma_A T^{A\alpha} \partial_\alpha h^k D_k \Psi = \Gamma_A j_A^k D_k \Psi . \quad (2.2.6)$$

Here $T^{A\alpha}$ is the conserved isometry current associated with the Killing vector j_A^k . Is it possible to satisfy the condition

$$T^{A\alpha} \partial_\alpha h^k = j_A^k \quad (2.2.7)$$

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.

- (c) 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 $\Lambda(x)$:

$$\begin{aligned} T^{A\alpha} &= \Lambda(x) j_A^\alpha \\ j_A^\alpha &= j_A^k \partial_\alpha h_k = j_A^k h_{kl} g^{\alpha\beta} \partial_\beta h^l . \end{aligned} \quad (2.2.8)$$

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.

- (d) 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 $J^{\alpha\beta} J_{kl} \partial_\beta h^k j_A^l$ 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.

- (e) The vanishing of the divergence of $T^{A\alpha}$ using the Killing property $D_l j_{Ak} + D_k j_{Al} = 0$ gives

$$j^{A\alpha} \partial_\alpha \Lambda = 0 . \quad (2.2.9)$$

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.

- (f) 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.
- (g) 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 $H_{\alpha\beta}^k = D_\alpha h^k$, 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 $H_{\alpha\beta}^k = 0$.

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.

- (a) 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.
- (b) 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.
- (c) 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.

- (d) 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 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 $h_{eff} > h$ [K86].

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.

- (e) 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.
- i. 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.
 - ii. 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.
 - iii. 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.

2.2.4 Different manners 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.

- (a) 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 [L53] meaning a decomposition of M^4 to orthogonal slicings by string world sheets and orthogonal partonic 2-surfaces would realize this structure.

- (b) Generalized Beltrami property [L72] 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.

- (c) 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 super-symplectic 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 -tuples 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.

2.3 Physics as number theory

Number theoretic physics involves the combination of real and various p-adic physics to adelic physics [L39, L38], and classical number fields [K93].

2.3.1 p-Adic physics

Motivation for p-adicization came from p-adic mass calculations [K24, K11].

- (a) 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.
- (b) $\exp(-E/T) \rightarrow p^{L_0/T_p}$, $T_p = 1/n$. Partition function p^{L_0/T_p} . p-Adic valued mass squared mapped to 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.
- (c) 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 power of 2: $p \simeq 2^k$. For instance, for 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 μ m).

- (d) p-Adic physics [K54] is interpreted as a correlate for cognition (see **Fig. 10**). Motivation comes from the observation that piecewise constant functions depending a finite number of pinary digits have 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.

2.3.2 Adelic physics

Adelic physics fuses real and various p-adic physics to a single structure [L38].

- (a) 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.
- (b) 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.
- (c) This leads to an evolutionary hierarchy (see **Fig. 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.
- (d) 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 [L92].

$h_{eff} = nh_0$ 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 [L79]. 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 $\sqrt{h/h_0}L_P$.

2.3.3 Adelic physics and quantum measurement theory

Adelic physics [L38] 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.

- (a) 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 .
- (b) 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.
- (c) 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.

- (a) 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.

- (b) 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 $O \times S$ [L75]. 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.
- (c) 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.
- (d) 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 [L62, L74].

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 [?]

- (a) 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.
- (b) 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.

2.3.4 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 [D12] 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?

- (a) 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.
- (b) Number theoretical physics implies that the Galois group becomes the symmetry group of physics and quantum states are representations of the Galois group [L67, L70]. 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.

- (a) 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.

- (b) 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.

2.4 $M^8 - H$ duality

There are several observations motivating $M^8 - H$ duality (see **Fig. 8**).

- (a) 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.
- (b) 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. 8**)?

- (a) Actually a complexification $M_c^8 \equiv E_c^8$ 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_c^8 fails to be a field since $1/o$ does not exist if the complex valued octonionic norm squared $\sum o_i^2$ vanishes.
- (b) The four-surfaces $X^4 \subset M^8$ are identified as "real" parts of 8-D complexified 4-surfaces X_c^4 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.
- (c) 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_c^8 would provide a number theoretic description: no partial differential equations, no Riemannian metric, no connections...
 M_c^8 has only the number theoretic norm squared and bilinear form, which are real only if M_c^8 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.
- (d) 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.

- (e) 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 [L60, L61]. 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_c^8 to the twistor spaces of the space-time surface as 6-surfaces in 12-D $T(M^4) \times T(CP_2)$?

- (f) 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.

- (g) 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 only 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.

2.4.1 Associative dynamics in M_c^8

How to realize the associative dynamics in M_c^8 [L60, L61]?

- (a) 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.
- (b) Algebraic physics suggests that X^4 is in some sense a root of a M_c^8 valued polynomial. One can continue polynomials P with rational coefficients to M_c^8 by replacing the real argument with a complexified octonion.
- (c) The algebraic conditions should imply that the normal space of X^4 is quaternionic/associative. One can decompose octonions to sums $q_1 + I_4 q_2$, 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 octonionic 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.
- (d) $M^8 - H$ 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^2 s 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 discretization 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 $X = \text{Re}_Q(P)$ and imaginary part $Y = \text{Im}_Q(P)$ in quaternionic sense, yielded a series of positive and negative surprises and demonstrated the failure of the naive arguments based on dimension counting.

- (a) 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.
- (b) 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.
- (c) The conjecture based on naive dimensional counting, which was not correct, was that the polynomials P determine these 4-D surfaces as roots of $\text{Re}_Q(P)$. 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.

- (d) 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 $\text{Re}_Q(P) = 0$ ($\text{Im}_Q(P) = 0$) 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 expectations, the solutions of the vanishing conditions for the $\text{Re}_Q(P)$ ($\text{Im}_Q(P)$) (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 [?]) 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.

- (a) 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_c^4 is determined if P does not determine it.

Here holography, considered already earlier, suggests itself: the complex 3-D mass shells belonging to X_c^4 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_R^4 . Bohr orbit property at the level of H suggests that the polynomial P defines the 4-surface more or less uniquely.

- (b) Let us take the holographic interpretation as a starting point. In order to obtain an X_c^4 mass shell from a complex 7-D light-cone, 4 complex degrees of freedom must be eliminated. $M^8 - H$ duality requires that X_c^4 allows M_c^4 coordinates.

Note that if one has $X_c^4 = M_c^4$, 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_c^4 should have interpretation as a non-trivial deformation of M_c^4 in M^8 .

- (c) 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 $p \in M_c^4$ is determined essentially by a point $s(p)$ of the coset space $SU(3)/U(2)$. This is achieved if M_c^4 is deformed by a local $SU(3)$ transformation $p \rightarrow g(p)$ in such a manner 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.

- (d) 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.

- (a) 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!
- (b) 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 [L89]. 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 .
- (c) Do we really know that X_r^4 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 [A3]. In any case, $M^8 - H$ duality is well-defined even without this condition.

- (d) 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 [L52]. The new picture is Lorenz invariant.

Octonionic Dirac equation as analog of momentum space variant of ordinary Dirac equation forces the interpretation of M^8 as an analog of momentum space and Uncertainty Principle forces to modify the map $M^4 \subset M^8 \rightarrow M^4 \subset H$ from identification to inversion. The equations for $Re_Q(P) = 0$ reduce to simultaneous roots of the real polynomials defined by the odd and even parts of P having interpretation as complex values of mass squared mapped to light-cone proper time constant surfaces in H . This leads to the idea that the formulation of scattering amplitudes at M^8 levels provides the counterpart of momentum space description of scattering whereas the formulation at the level of H provides the counterpart of space-time description.

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 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.

2.4.2 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 [L60, L61] 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.

- (a) 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.

- (b) 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 $CD(m, h_{eff})$:

$$m^k = h_{eff} X \frac{p^k}{m^2} \quad , \quad X = \frac{1}{1+p_3/p_0} \quad . \quad (2.4.1)$$

Here p_3 is the length of 3-momentum.

The map is non-linear. At the non-relativistic limit ($X \rightarrow 1$), 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 $cd \subset M^4 \subset H$.

- (c) 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 h_{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 $T = 2h_{eff}/p_0$ between its tips so that the geometric definition gives $p^k = h_{eff} p^k / p_0^2$ as the point at the 2-sphere defining the corner of CD. p-Adic thermodynamics [K24]) 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.
- (d) 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 $L(m, h_{eff}) = h_{eff}/m$ 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.

- (e) 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 $m_{Pl} = \hbar_0/R$, $\hbar_0$ is the minimal value of $h_{eff} = \hbar_0$ 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.
- (f) 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.
- (g) 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.
- (h) 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.

- (a) 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 .
- (b) 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.

- (a) 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.

- (b) 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.

- (a) 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 $M^k = nXh_{eff}P_{tot}^k / \cdot P_{tot}^2$, $X = 1/(1 + P_3/P_0)$, 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.

- (b) 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 $P^k = \sum_i p_i^k$, $p_i^2 = m^2$ 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 , $M^k = nh_{eff}XP_{tot}^k / \cdot P_{tot}^2$ 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.

- (c) 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.

2.4.3 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 $p^0 = E = \text{constant}$ hyperplane. These quantized 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 $P(x) = x^n + p_{n-1}x^{n-1} + \dots$.

The TGD inspired theory of consciousness motivated the interpretation of these hyperplanes as "very special moments in the life of self": this interpretation [L52] 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.

- (a) 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_G^2 of CP_2 carrying Kähler magnetic charge.
- (b) The first thing to notice about the H -image of the 3-D $E = \text{constant}$ 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 $E = \text{constant}$ means that energy does not depend on the momentum: plasmons provide the condensed matter analogy.

- (c) 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.

- (d) 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.

- (a) 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.

- (b) 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 worm-hole 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.
- (c) 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.

- i. 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.
- ii. 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.
- iii. 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.
- iv. 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.

- i. 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.
- ii. 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.

2.4.4 Generalizations of $M^8 - H$ duality

It has become clear that $M^8 - H$ duality generalizes and there is a connection with the twistorialization at the level of H .

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 [L60, L61]. 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 [A15] 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_c^8 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 $X^6 \subset M_c^8$ 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_c^8 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 represent a 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

Consider first the twistorial generalization of $M^8 - H$ correspondence.

- (a) The complex 6-D surface $X_c^6 \subset M_c^8$ has commutative normal space and thus corresponds to complexified octonionic complex numbers $(z_1 + z_2 I)$. X_c^6 has real dimension 12 just as the product $T(M^4) \times T(CP_2)$ of 6-D twistor spaces of M^4 and CP_2 . It has a bundle structure with a complex 4-D base space which is mapped $M^4 \times CP_2$ by $M^8 H$ duality. The fiber has complex dimension 2 and corresponds to the dimension for the product of twistor spheres of the twistor spaces of M^4 and CP_2 .
- (b) This suggests that $M^8 - H$ duality generalizes so that it maps $X_c^6 \subset M_c^8$ to $T(M^4) \times T(CP_2)$. It would map the point of X_c^6 to its real projection identified as a point of $T(M^4)$. "Real" means here that the complex continuation of the number theoretical norm squared for octonions is real so that the components of M^8 point are either real or imaginary with respect to the commuting imaginary unit i . The complex 6-D tangent space of X_c^6 would be mapped to a point of $T(CP_2)$.

The beauty of this picture would be that the entire complex 6-D surface would carry physical information mapped directly to the twistor space.

One can try to guess the form of the map of X_c^6 to the product $T(M^4) \times T(CP_2)$.

The surfaces X^6 have local normal space basis $1 \oplus e_7$. The problem is that this space is invariant under $SU(3)$ for $M^8 - H$ for CP_2 . Could one choose the 2-D normal space to be something else without losing the duality. If e_7 and e_1 are permuted, the tangent space basis vector transforms by a phase factor under $U(1) \times U(1)$. The 4-D sub-basis of normal space would be now $(1, e_1, e_7, e_2)$. This does not affect the $M^8 - H$ -duality map to CP_2 . The 6-D space of normal spaces would be the flag manifold $SU(2)/U(1) \times U(1)$, which is nothing but the twistor space $T(CP_2)$.

What about the twistorial counterpart for the map of $M^4 \subset M^8 \rightarrow M^4 \subset M^8$? One can consider several options.

- (a) At the level of M^8 , M^4 is replaced by M^6 at least locally in the sense that one can use M^6 coordinates for the point of X^6 . Can one identify the M^6 image of this space 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 .
- (b) If $M^8 - H$ duality generalizes as such, the points of M^6 could be mapped to the 6-D analog of cd_4 such that the image point is defined as the intersection of a geodesic line with direction given by the 6-D momentum with the 5-D light-like boundary of 6-D counterpart cd_6 of cd ? Does the slicing of M^6 by 5-D light-boundaries of cd_6 for various values of 6-D mass squared have interpretation as CP_3 ? Note that the boundary of cd_6 does not contain origin and the same applies to $CP_3 = C^4/C_\times$.
- (c) Or could one 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 $o \rightarrow gog^{-1}$, where g is an element of the commutative subalgebra in question?

What about the physical interpretation at the level of M_c^8 .

- (a) The first thing to notice is that in the twistor Grassmann 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_c^8 .

- (b) Consider first the real part of $X_c^6 \subset M_c^8$. 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.

- (c) For the 6-D tangent space of X_c^6 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.

- (d) The points of $X_c^6 \subset M_c^8$ 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.

- (e) 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.

7-surfaces with real normal space and generalization of the notion of twistor space

It would seem that twistorialization could correspond to the introduction of 6-surfaces of M^8 , which have commutative normal 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.

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?

- (a) 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.
- (b) $SU(3)/U(1) \times U(1)$ 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 additional dimension in the S^2 fiber of the twistor spaces of M^4 and CP_2 and of X^4 ? What could the interpretation of the fiber be? S^3 isomorphic to $SU(2)$ and having $SO(4)$ as isometries is the obvious candidate.
- (c) 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 of or 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,

- (d) Twistorialization takes care of spin and electroweak spin. The remaining standard model quantum numbers are quark number and em charge. Could the additional dimension allow their geometrization as partial waves in the 3-D fiber. Could this fiber be $SU(2)$ locally? This would mean that charge and quark number are correlated for a given space-time surface (region) (U or D quark or charged or neutral lepton).

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 .

- (a) Projective space is FP_{n-1} the Grassmannian $F_1(F^n)$ 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 $U(n)/U(n-1) \times U(1) = CP_{n-1}$.
- (b) 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 $d_0 = 0 < d_1 < d_2 \dots d_k = n$. Defining integers $n_i = d_i - d_{i-1}$, this space can in the complex case be expressed as $U(n)/U(n_1) \times \dots U(n_k)$. The real dimension of this space is $d_R = n^2 - \sum_i n_i^2$.
- (c) For $n = 4$ and $F = C$, one has the following important Grassmannians.
 - i. 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 $d_R = 6$.
 - ii. $M = F_2$ 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 $D_C = 4$.

- iii. 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 $U(3) \rightarrow U(2) \times U(1)$ 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 $U(2) \times U(2) \rightarrow U(1) \times U(1)$ 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.

- (a) 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 $R \times R$.
- (b) 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 $R \rightarrow C \rightarrow Q$ brings in some new elements.

- (a) It is natural to define also the quaternionic projective space $Q_c/Q = Q^2/Q$ <https://cutt.ly/LE3vM0G>, 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 $q \rightarrow hqh^{-1}$ 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_R^4 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 Hamilton-Jacobi structures.

- (b) 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. $M^8 - H$ 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.

- (a) 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 [L60, L61] 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.
- (b) 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 $m_{c,odd}^2$ resp. $m_{c,even}^2$ with complex mass squared equal to a root of the odd resp. even part of the polynomial P defining the 4-surface [L60]. 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_c^2 can vanish: 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.

- (c) 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.

- (a) 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 .

- (b) 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.

2.4.5 Hierarchies of extensions for rationals and of inclusions of hyperfinite factors

TGD suggests 3 different views of finite measurement resolution.

- (a) 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.
- (b) 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 [L74, L70]. The HFF in question would be infinite-D group algebra of infinite Galois group for a polynomial R obtained as a composite $R = P_{infy} \circ Q$ of an infinite iterate P_{infy} 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.

- (c) The inclusions $N \subset M$ of hyperfinite factors of type II_1 (HFFs) [K99, K79] 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 supersymplectic 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 identity 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 [K99, K79].

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 $q = r\exp(i2\pi/m)$ 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.

2.4.6 Galois confinement

The notion of Galois confinement emerged in TGD inspired biology [L92, L65, L70, L76]. 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.

- (a) 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 [L65, L76, L75]. 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.
- (b) The idea generalizes also to nuclear physics and suggests an interpretation for the findings claimed by Eric Reiter [L84] 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 [L84]. 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.

- (a) 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 [L55, L63, L30].
- (b) 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.
- (c) 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^8_c with coordinates, which are algebraic integers for the extension.

Momenta as points of M^8_c 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.

- (d) 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.

- (a) 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.
- (b) 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 [L60] are necessary.

- (a) 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.
- (b) This surface can be co-associative but would be also co-commutative. 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.

- (a) 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).
- (b) 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 .
- (c) 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

$$Re(p_i) \cdot Im(p_j) = 0 \quad . \quad (2.4.2)$$

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.

- (d) 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.
- (e) 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 $\bar{e}_k$ plus $n - 2m - 1$ real but algebraically trivial elements r_k besides the real unit 1. The sums $E_k = e_k + \bar{e}_k$ are algebraic integers and give m real basis elements. Note that $F_k = e_k - \bar{e}_k$ 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.
- (f) 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

$$p \cdot Im(p_i) = \sum_k p^i n_{i,k} F_k = 0 \quad . \quad (2.4.3)$$

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.

2.4.7 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 [A20, A1, A9, A8], which I have tried to understand several times [K81] [L1, L7, L27] relates in an interesting manner to $M^8 - H$ duality and Galois confinement.

- (a) Global Langlands correspondence (GLC) states that there is connection between representations of continuous groups and Galois groups of extensions of rationals.
- (b) 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.

- (a) In adelic physics real numbers and p-adic number fields define the adèle. 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.
 - i. Sensory world, "real" world corresponds to representation of continuous groups/Galois groups of rationals. GLC.
 - ii. "p-Adic" worlds correspond to cognition and representations of p-adic variants of continuous groups and Galois groups over p-adics. Local LLC.
 - iii. 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 sub-groups 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 [L31, L58, L59]. The representation of real continuous groups assignable to the real numbers as a piece of adèle [L39, L38] 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 what 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"?

- (a) In momentum space Fermi statistics does not allow fermions to get through the boundary of Fermi ball. This is a good guideline.
- (b) 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.
- (c) 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.

- (a) 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 $x^n + \dots$. 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 be closely related to the "sensory emergence".
- (b) $X^4 \subset M^8$ 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.

- (a) 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".
- (b) 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 [L70].
- (c) 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.

2.5 Neutrinos and TGD

Neutrinos are problematic from the point of view of the standard model. It has become clear that neutrinos experience an analog of CKM mixing for quarks but there are anomalous findings related to the mixing. MiniBoone collaboration published 2018 findings [C2] (see <https://arxiv.org/abs/1805.12028>) related to the mixing between muon and electron neutrinos for incoming muon beam.

The transformation of electron neutrino to electron via charged current reaction was used as a signature for the electron neutrinos and the findings forced the conclusion that the number of electrons produced is too high to be consistent with the neutrino CKM matrix deduced from other experiments. The sterile neutrino was one of the many proposed explanations (see <https://cutt.ly/DRKPZYz>).

The recent experiment of Micro-Boone collaboration however shows no evidence for sterile neutrinos (<https://cutt.ly/QRKDsUA> and <https://cutt.ly/oRKS77W>). The only remaining anomaly is associated with the channel producing an electron but no hadrons in the final state. If this finding is taken seriously, it is difficult to avoid the conclusion that some new physics, which is not caught by the standard model, is involved. Could the transformation of neutrino to an electron occur in some unknown way?

As it often happens, this rather specific question led to a thorough reconsideration of the TGD view about particles and their massivation: what is really understood and what is really certain? The basic idea of the TGD based solution described at the end of the article, would not have required these considerations so that an impatient reader can directly skip to the last section.

2.5.1 Two problems related to neutrinos

The following considerations were motivated by two problems related to neutrinos.

What is the role of right handed neutrinos in TGD?

The new view led to the conclusion that the right-handed neutrino predicted by TGD and analogous to the inert neutrino solves some long-standing problems of TGD.

- (a) TGD in its recent form predicts an entire tower of color excitations as modes of second quantized $H = M^4 \times CP_2$ spinor field identified as a quark field. The mass scale determined by CP_2 length scale and these give rise to bound states of 3 antiquarks having quantum numbers of leptons if TGD view about color symmetry is accepted [L71]. In particular, covariantly constant right-handed neutrino ν_R in some respects analogous to a sterile neutrino is predicted.

It is intuitively clear that ν_R must have a very special physical role. The naive proposal that ν_R and $\bar{\nu}_R$ could generate the analog $N = 2$ SUSY [L57] has not led to a breakthrough. Sparticles would have been created by adding zero momentum right-handed neutrinos and antineutrinos to the state: the problem is that the norm of these states vanishes if the only CP_2 Kähler form is present as in the formulation of TGD before the discovery of the twistor lift of TGD.

- (b) The twistor lift of TGD [L40] predicts that also M^4 has Kähler structure. This implies a breaking of Lorentz symmetry within causal diamond CD to $M^2 \subset M^4$ emerging also in the the dual M^8 picture based on number theoretical view about physics [L60, L61, L83] as a prerequisite of $M^8 - H$ duality.

M^4 mass squared m^2 is replaced with M^2 mass squared as in the quark model of hadrons, in string models, and also in p-adic mass calculations [K24]. The M^2 mass squared spectrum for $H = M^4 \times CP_2$ spinor modes is very much like in conformal field theories and the two integers (n_1, n_2) characterizing analogs of cyclotron states are analogous to conformal weights.

The key point is that the massless ν_R transforms to a tachyon. This is due to the presence of spin term $J^{kl}(M^4)\Sigma_{kl}$ in $D^2(H)$ vanishing for left-handed leptons. On the other hand, p-adic mass calculations [K24] require a tachyon-like ground state: otherwise massless states are impossible. The origin of tachyonicity has remained a mystery. The tachyonic right-handed neutrinos could provide the long sought-for mechanism allowing to reduce the conformal weight of a given many-quark state to obtain a massless state.

- (c) The hard problem is that neutrinos are massive but only the left-handed neutrinos are observed. The problem is that the left-handed neutrinos mix with the right-handed ones if H Dirac operator $D(H)$ determines the time evolution operator. This should be seen in neutrino mixing experiments.

The proposed solution of the problem is based on the TGD view about time evolution in zero energy ontology (ZEO). It has become clear that the time evolution between "small" state function reductions (SSFRs) corresponds to a scaling rather than time translation, and is induced by Virasoro generator L_0 - essentially mass squared operator - rather than by Hamiltonian.

This suggests that for the spinor modes of H , the mass squared operator, that is the square $D^2(H)$ of Dirac operator $D(H)$ - or rather, its longitudinal M^2 part - should determine the time evolution operator rather than $D(H)$. Different M^4 chiralities would *not* mix.

- (d) This alone does not explain why only left-handed neutrinos are observed since different M^4 chiralities for leptons can appear as superpositions if left and right M^4 chiralities have the same value of $m^2(M^2)$. However, the $J^{kl}(M^4)\Sigma_{kl}$ term in $D^2(H)$ implies L-R splitting of mass squared eigenvalues. Degeneracy is possible if different values of $n_1 + n_2$ can compensate for this splitting.

Empirical facts require that R-L mixing is possible for charged leptons but not for neutrino states. Right-handed neutrinos would not mix with left-handed ones and would couple only to M^4 Kähler form but not to electroweak interactions. This could explain why they are not detected but also suggests that their detection might be possible.

Mini-Boone-Micro-Boone conflict and the TGD view about dark matter

This picture looks nice but does not explain the conflict between Mini-Boone and Micro-Boone experiments. Because Micro-Boone observes the anomaly for single electron final states only, it seems that neutrinos must scatter from some new form of matter.

TGD indeed predicts $h_{eff} > h$ phases of ordinary particles behaving like dark matter. The anomalous production of electrons by charged currents could be understood by the presence of dark protons or nuclei in the detector and having large enough h_{eff} . This could scale up weak interaction Compton length by h_{eff}/h above nuclear or even atomic length scale so that weak bosons would be effectively massless particles and the scattering cross section could be of the same order of magnitude as electroweak scattering cross section.

2.5.2 Some background about TGD

Some background about TGD is necessary in order to tackle the problems related to neutrinos.

Spinor fields in TGD

Spinor fields appear in TGD at three levels. At the level of embedding space $H = M^4 \times CP_2$, at the level of space-time surface $X^4 \subset H$, and at the level of "world of classical worlds" (WCW).

1. Spinor fields in H

Consider first spinor fields and their quantization at the level of H , which actually induces the spinor structure at the level of X^4 and WCW.

- (a) In the TGD Universe space-times are 4-surfaces X^4 in 8-D $H = M^4 \times CP_2$. The only fundamental fermions are quarks and the TGD view about color allows us to identify leptons as composites of 3 antiquarks in the scale of CP_2 : this is not possible in QCD [L57, L71]. In what follows a key assumption is that leptons behave effectively like H spinor field having a chirality opposite to that for quarks and have the same electroweak quantum numbers apart from em charge. Therefore the Dirac equation in H applies to them.
- (b) The quantization of spinors is carried out at the level of H and quantized quark fields in X^4 are induced, that is restricted, to X^4 so that one avoids all problems related to second quantization in curved background. One of them is the difficulty in defining what positive and negative energy solutions to the Dirac equation do really mean.
- (c) If the Kähler form of $J(M^4)$ of M^4 vanishes (the more general case will be discussed later on), the square $D^2(H)$ of the H Dirac operator $D(H) = D(M^4) + D(CP_2)$ allows solutions satisfying $D^2(H)\Psi = 0$ that is massless modes in 8-D sense. The solutions of $D(H)\Psi = 0$ are of form $D(M^4)\Psi_1 \otimes \Psi_2 + \Psi_1 \otimes D(CP_2)\Psi_2$. Ψ_1 is a plane wave and Ψ_2 is an eigenstate of $D^2(CP_2)$ with a quantized mass squared eigenvalue m^2 . Note that chiralities are mixed in accordance with the massivation in H .

Covariantly constant right-handed neutrino is the only massless solution of $D(H)\Psi = 0$ in the M^4 sense. Since it does not have electroweak couplings it satisfies $D(CP_2)\nu_R = 0$ and is covariantly constant in CP_2 . One can say that masslessness in 4-D sense is replaced with masslessness in 8-D sense and this is crucial also for why the twistor lift of TGD applies also to massive particles.

One can say that $D(CP_2)$ is the analog of $D(M^4) = \gamma^k p^k$ in M^4 degrees of freedom. However, it cannot be algebraized. One could also say that it acts as an analog of the Higgs field which is not a H scalar but a CP_2 vector.

2. Spinor fields in X^4

Consider next the spinor fields at the level of X^4 .

- (a) One can define modified Dirac operator [L83] at the level of X^4 in terms of the modified Gamma matrices determined as contractions of H gamma matrices Γ^k and the canonical momentum currents T_k^α determined by the action, which for twistor lift involves volume term (length scale dependent cosmological constant) and Kähler action analogous to Maxwell action. Preferred extremals are actually minimal surfaces which are also extremals of the Kähler action in the interior of X^4 [L89].
- (b) Modified Dirac equation cannot be satisfied generally as an operator equation. It could be however satisfied at the boundaries of causal diamond (CD) (one might say for external free quarks there) or possibly even in the interior of X^4 for the physical states but not generally. In any case the oscillator operator algebra for quarks in H would be used to construct quantum states.

The intuitive guess is that the inverse of D can appear as a propagator. Its construction looks however a horrible problem. Fortunately, the problem disappears since $D(H)$ naturally defines a propagator between points restricted to the space-time surface.

What is remarkable is that quite generally, the propagation between points with light-like distance is essentially like massless propagation. Particle-like entities are light-like orbits of partonic 2-surfaces so that the geometric character of particles forces massive modes effectively masslessness. A more precise formulation is discussed in [L83].

The induction procedure generalizes to the level of the isometry algebra (IA) and even supersymplectic algebra (SSA) [K57] [L66, L83].

- (a) One can construct the representations of IA and SSA in H for the Dirac action associated with $D(H)$ and construct the Noether currents of super symplectic algebra and project the currents to the space-time surface. A natural condition would be that these currents are equal to the corresponding currents assigned to the modified Dirac action for the physical states defined at the boundaries of CD.
- (b) An analogous condition for classical currents was proposed in [L83] and stated that the the conserved classical current for given isometry with Killing vector j_A^k is proportional to its projection to the space-time surface.

$$\begin{aligned} T_B^{A\alpha} &= \Lambda(x) j_A^\alpha , \\ j_A^\alpha &= j_A^k \partial^\alpha h_k \equiv j_A^k h_{kl} g^{\alpha\beta} \partial_\beta h^l , \\ \partial_\alpha \Lambda j^{A\alpha} &= 0 . \end{aligned} \tag{2.5.1}$$

This condition could be true for the entire space-time surface or at the ends of X^4 at the boundaries of CD. The conserved bosonic current in H corresponds to j_A^k satisfying $D_k j_A^k = 0$. The conservation condition requires that Λ is constant along the flow lines of j_A^k .

Quantum classical correspondence suggests that the condition can be true only for Cartan algebra. For the volume part of the action the condition is identically true and $\Lambda(x)$ corresponds to length scale dependent cosmological constant in this case. For Kähler action, the condition is non-trivial.

- (c) In the fermionic case, the condition would state that the conserved second quantized quark current at the level of H projected to the space-time surface is equal to the conserved fermionic current for the Dirac action in X^4 . In the general case, this could hold true for the Cartan algebra and in the case of H isometries at the entire space-time surface. For the symplectic currents it could hold true at the 3-D ends of the space-time surface at boundaries of CD. The condition reads as

$$T_F^{A\alpha} = \bar{\Psi} \Gamma_k \partial_\alpha h^k \delta_A \Psi = k(x) \bar{\Psi} \Gamma_k T_B^{k\alpha} \delta_A \Psi . \tag{2.5.2}$$

If the bosonic condition for $T_B^{k\alpha}$ holds true, this condition and the conservation condition are trivially satisfied for $k(x) = \Lambda(x)$ as also the conservation condition. The condition also generalizes to super-currents obtained by replacing $\bar{\Psi}$ or Ψ by a mode of H spinor field in the expression of the fermionic current.

3. WCW spinors

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. WCW spinors are Fock states of quarks. 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 operator [K57] [L66, L83] as a non-hermitian super-Virasoro generator G which however carries fermion number.

Bosonic conditions and the fermionic condition implied by them have been already discussed and would dramatically simplify the construction of the quantum states as super-symplectic representations.

WCW gamma matrices would be simply SSA super charges for the induced spinor fields obtained by integrating the 3-D SSA super currents over 3-surfaces X^3 defining the ends of X^4 at the boundaries of CD. That they are projections of 8-D conserved currents in H would make life simple.

One could construct also WCW Kähler metric and in principle all related geometric entities in terms of SSA.

- (a) The matrix element of the WCW Kähler metric would be obtained as anticommutators

$$g_{\bar{A},B} = \frac{1}{2} \{Q_A^\dagger, Q_B\} \quad (2.5.3)$$

of the super symplectic charges. Super charge Q_A is obtained as a 3-D integral of super current J_A carrying quark number over the 3-surface X^3 :

$$Q_A = \int_{X^3} d^3x J_A \quad (2.5.4)$$

The anticommutators of the fermionic oscillator operators for H spinors give Kronecker deltas for both momenta and color quantum numbers.

- (b) The localization at 3-surface implies that $g_{\bar{A}B}$ is given by an integral of form

$$\int_{X^3 \times X^3} d^3x_1 d^3x_2 \sum_{p,n} \bar{T}_{A_1}(p, n, x_1) T_{A_2}(p, n, x_2) \quad (2.5.5)$$

The plane waves in the product give a factor $\exp(ip \cdot (m(x_1) - m(x_2)))$ giving rise to interference. CP_2 spinor harmonics give a product of $\bar{\Psi}_n(s(x_1))\Psi_n(s(x_2))$. The products of factors at different points give rise to interference effects and could save from infinities.

The replacement of point-like particles with 3-surfaces is essential since the 7-D equal-time anti-commutation relations for quark oscillator operators give a 7-D delta function in H . Indeed, for a point-like particle instead of a 3-surface, one would obtain a sum over terms $\bar{\Psi}_n(s(x_1))\Psi_n(s(x_1))$ multiplied by the volume of the corresponding mass shell.

- (c) More generally, the double 3-D integral over a particle like n -surface should compensate for the 7-D delta function divergence so that for $2n > 7$ divergences would be absent. For 3-D objects one has $2n = 6$, so that one cannot exclude logarithmic divergences typically present also in gauge theories. Does this mean that the divergence cancellation cannot rely on mere non-locality.

- (d) Could the preferred extremal property be crucial? As a matter of fact, the condition guaranteeing that SSA currents for the action are equal to the projections of SSA currents for H spinors (at least at boundary CD) has been already assumed.

Number theoretic holography fixes the space-time region in terms of roots of a polynomial with rational coefficients and is an extremely powerful condition also on 3-surfaces at the boundary of CD.

Also the geometry of $\delta CD = \delta cd \times CP_2$ might be relevant as also the precise definition of the integral. One has a 6-D integral over $\delta cd \times \delta cd$. It seems that this is the correct intuition.

The following argument indeed shows that the geometry of CD (and thus ZEO) is highly relevant.

- (a) For $m_1 - m_2 = 0$, the CP_2 anticommutator gives a 4-D delta function in CP_2 as a singularity for $s(m_1) = s(m_2)$. For $m_1 = m_2$, one also has a 3-D delta function corresponding to equal time anticommutation relations. This would give 7-D delta function and the integral would diverge and be ill-defined. This is the source of troubles and raises the question whether one should one define the integral as a limit in which the ill-defined 7-D delta function contribution is avoided.

- (b) Denote by D the diagonal set $Diag(\delta cd \times \delta cd)$ of points $m_1 = m_2$ of $\delta cd \times \delta cd$. Assign to D a thin 3-D layer $D \times L$ with L having a thickness l and define the integral over the volume $cd \times cd \setminus D \times L$ and take the limit $l \rightarrow 0$. This removes the problematic 7-D delta function singularity and leaves only the 1-D light-ray singularity at δcd [L69, L68] under consideration so that the anticommutator is well-defined and finite.
- (c) Irrespective of mass, fermion anticommutator has 1-D delta function type singularity as a 1-D delta function $\delta(a)$, $a^2 = (m_1 - m_2)^2$. Now both m_1 and m_2 are points at δcd , and the delta function defines light-like geodesic rays from origin connecting m_1 and m_2 . This delta function eliminates 1 integration variable from 6 integration variables in the integration measure $dV = d^3 m_1 d^3 m_2$ associated with $\delta cd \times \delta cd$.
 $d^3 m$ is determined by the the determinant of the induced metric and if the CP_2 coordinates are not constant, the determinant is manifestly non-trivial even if one uses radial light-like coordinate r and angle coordinates Ω of $R_+ \times S^2$ as coordinates. This leaves a 5-D integration volume $X^5 \subset \delta cd \times \delta cd$. Note that for canonically embedded M^4 as a minimal surface extremal the integration measure is trivial so that the 3-surfaces do not belong to WCW.
- (d) The geometry of δcd would be highly relevant. If one had E^3 as time= constant slice instead of M^4 , the same definition of the integral would give a vanishing result since light-like radial rays as singularities would be lost. This picture supports the importance of light-cone boundary as a basic notion but strictly speaking does not force CD.

One could worry for the somewhat ad hoc elimination of 7-D delta function singularity and perhaps take it as a signal telling that something important is still missing. There indeed exists a variant of gamma matrices with which I ended up from the cancellation of fermionic divergences in ZEO. This option is inspired by the multi-locality of the Yangian variants of the super symplectic algebra and isometry algebra for H .

- (a) The fermionic creation and annihilation operators appearing as building bricks of super symplectic (SSA) charges defining the gamma matrices would be at the opposite boundaries of CD and 3-D states at the opposite boundaries would relate like bras and kets. Annihilation operators would act like creation operators at the opposite boundary of CD.

The conserved isometry currents in H would be replaced by bilocals with Ψ and $\bar{\Psi}$ and opposite boundaries of CD and remain conserved currents thanks to the (covariant) constancy of M^4 gamma matrices. Note that although SSA currents are not conserved, the Noether charges at the boundaries of CD are well-defined.

- (b) Can one apply this recipe to the WCW gamma matrices as bi-local entities having 3-surfaces at opposite boundaries as arguments? For supersymmetry generators associated with H isometries, the conservation laws hold and one can calculate the anticommutators. They are non-vanishing and the dominating contributions come from pairs of points with light-like separations. One can use the same CP_2 and S^2 coordinates at both light-like boundaries and only the radial light-like coordinates are different. The 3-D delta function singularity does not appear at all. This would justify the notion of CD rather than only light-cone boundary.
- (c) The commutators of SSA charges associated with 3-surfaces at different boundaries of CDs or even at boundaries of different CDs generate a poly-local algebra, which could have an interpretation as the Yangian algebra of SSA acting as isometries for WCW.

Twistor lift predicts M^4 Kähler force

The twistor lift of TGD suggests also a modification of the neutral weak forces.

- (a) The twistor lift of TGD requires that there is a covariantly constant self-dual Kähler form also in M^4 . This would contribute to the electromagnetic and Z^0 fields an additional coupling analogous to that of electroweak hypercharge to U(1) gauge potential.

- (b) M^4 Kähler form contributes to the Kähler action an additional term. The M^4 contribution is fixed by the condition that the M^4 metric is the square of the Kähler form. Also H -spinors couple to M^4 Kähler gauge potential defining a self-dual Abelian field: essentially constant electric and magnetic fields, which are orthogonal and have the same strength, is in question.

The scale of the M^4 metric defines the normalization of $J(M^4)$. Here one however encounters a problem since M^4 does not have any inherent scale in its geometry. The size scale L causal diamond ($CD = cd \times CP_2$), where cd is the intersection of light-cones with opposite direction, serves as a natural scale allowing to identify dimensionless coordinates for M^4 in such a manner that the range of variation for the dimensionless coordinates does not depend on the size of CD .

In these coordinates the self-dual Kähler form scales $E = B = k/L^2$, k a constant near unity. At the limit of long length scales $E = B$ would approach zero. The identification of L as a length scale determined by the cosmological constant is attractive. The breaking of Lorentz symmetry to that of M^4 for the Dirac operator $D(H)$ would be small in long length scales. In very short length scales associated with quarks, the breaking would be large.

Remark: One cannot completely exclude the alternative option $E = B = k/R^2$, where R is CP_2 scale for which the breaking of Lorentz invariance would be large in all scales.

The presence of M^4 Kähler structure has non-trivial implications also at the level of particle physics.

- (a) In particular, M^4 Kähler gauge potential $A(M^4)$ couples also to neutrinos unlike $A(CP_2)$, where the net coupling vanishes. The effects are expected to be small in the TGD view about space-time sheets at particle level.
- (b) The prediction is that all particles have an additional M^4 contribution in their Z^0 and em force and also right-handed neutrinos couple to M^4 Kähler gauge potential.

Remark: The Kähler gauge potential A does not correspond to a genuine gauge invariance and each choice defines a different physics. The proposal is that the so-called Hamilton-Jacobi structures could correspond to different choices of A .

- (c) At the level of H the square $D^2(H)$ of the modified Dirac operator would allow spinors to be eigen states of energy and single momentum component. Self duality and co-variant constancy imply that $D^2(H)$ contains a term proportional to charge matrix $J^{kl}(M^4)\Sigma_{kl} \propto (\sigma_{03} + \Sigma_{12})$, which vanishes for the second M^4 chirality.
- (d) 2 components of the 3-momentum would correspond to harmonic oscillator states so that the states would be confined to a finite transversal volume to a harmonic oscillator state characterized by transversal momenta of order magnetic length $\sqrt{B_K}$.

Suppose that for the transversal degrees of freedom in E^2 with signature $(-1,-1)$, Kähler gauge potential can be chosen to be $A_x = B_K y$. For an eigenstate of p_x , one obtains for the square of the E^2 part of the square D^2 of the Dirac operator,

$$D^2(E^2) = -(\partial_x - B_K y)^2 - \partial_y^2 = p_x^2 + \partial_y^2 - B_K y^2 - 2ip_x B_K y .$$

The sign of the harmonic oscillator term is correct and the complex shift does not produce problems if the notion of hermiticity is generalized so that PT replaces complex conjugation. Eigenvalues of $p_y^2 + ..$ are essentially the eigenvalues of energy in harmonic oscillator potential and proportional to $2nB_K$ with $n = 1$ assignable to the ground state.

- (e) In the longitudinal degrees of freedom M^2 , the signature of the metric is $(1,-1)$. If A is given by $A_t = B_K z$, the M^2 part of the square of the Dirac operator for an energy eigenstate reduces to $D^2(M^2) = (iE - iB_K z)^2 - \partial_z^2 = -E^2 - \partial_z^2 - B_K^2 z^2 - 2EB_K z$. One obtains a harmonic oscillator potential with a wrong sign and has suffered a complex shift by $z \rightarrow z + iE/B_K$. Harmonic oscillator Gaussian would be replaced with an imaginary exponential - this is of course familiar from free quantum field theories based on path integral defined by Gaussian. The size scale of CD would bring to the theory an arbitrarily long p-adic length scale as a fundamental level scale but expressible in terms of CP_2 radius.

Some physics inspired comments are in order.

- (a) This picture brings strongly in mind the parton model of hadrons. If cosmological constant Λ characterizes the size scale L , it must correspond to the scale which is essentially geometric mean of Planck length and the p-adic length scaled defining the length scale dependent cosmological constant Λ (of order Hubble scale). In the TGD framework, cosmological constant is length scale dependent, and the value of Λ assignable to cosmology would correspond to length L of order 10^{-4} meters assignable to a large neuron.
- (b) The spectrum of the M^2 mass squared operator is integer valued using B as a unit. The mass squared spectrum is similar to the spectrum in string models. This picture also conforms with the idea that the transversal Kac-Moody modes in $M^2 \times E^2$ are dynamical. Also transversality of polarizations in gauge theories conforms with this picture. Also the properties of "massless externals" support this picture.
- (c) What comes to mind is that the values of integers n_i characterizing harmonic oscillator states are analogous to fermionic conformal weights. One has conformal weight for both the light-like radial coordinate of super symplectic representations and for the Kac-Moody type representations associated with light-like orbits of partons: the light-likeness of the partonic 2-surfaces and of light-cone boundary make them metrically 2-D and implies a generalization of conformal invariance.

This conforms with the notion of induction. The fermion super symplectic charges should be constructible in terms of the quark oscillator operators for the second quantized quark fields of H .

How can massless particles exist at all and how do they become massive?

One must understand why there are light particles at all and what makes them massive.

- (a) The mass scale for CP_2 is about 10^{-4} Planck masses and the only massless particle is a right-handed neutrino of only $J(CP_2)$ is present. Also the color quantum numbers depend on the em charge. Therefore physical elementary particles cannot correspond to the quarks as such. The situation remains essentially the same if $J(M^4)$ is present. The proposal has been that H spinor modes define ground states for super-symplectic representations and operators carrying conformal weight contribute to mass squared additively create the physical states. The lowest states have vanishing mass squared. The introduction of $J(M^4)$ suggests that the quark oscillator operators labelled by two integers could actually be interpreted as conformal weights and that M^2 momentum would take the role of M^4 momentum. The number of ground states of super-symplectic representations could be much smaller.
- (b) p-Adic thermodynamics however mixes these states with states of higher conformal weight and this gives rise to the mass of the light particles. One must assume that there is a negative tachyonic contribution to the ground state conformal weight since only the right-handed neutrino is massless in 4-D sense. The origin of this negative conformal weight has remained a mystery.
- (c) $M^8 - H$ duality provides a possible insight to the mystery of the tachyonic conformal weight. The map of 4-surfaces in M_c^8 (complexified octonions) by $M^8 - H$ duality involves selection of M^4 as a 4-D linear subspace in M^8 . This choice is not unique. Momenta and color quantum numbers in H correspond to 8-momenta in M^8 such that 8-D mass squared vanishes at both sides and M^4 momenta are identical. For a suitable choice of $M^4 \subset M^8$, the 8-momentum is parallel to M^4 and the state is massless!

Could the introduction of negative tachyonic conformal weight provide an alternative description of this choice? This choice can be made only for a single, naturally dominant contribution of the state, and the remaining contributions to mass squared coming from higher conformal weights give rise to massivation described by p-adic thermodynamics.

- (d) Here the twistor lift comes to rescue. Twistor lift of TGD requires that also M^4 has Kähler structure defined by a self-dual Kähler form $J_{kl}(M^4)$ (constant E and B with $\text{vert}B = |E|$ orthogonal to each other). Depending on the selected correlation between M^4 and CP_2 chiralities guaranteeing that quarks correspond to a fixed H chirality, $D^2(H)$ contains for either left- or right-handed M^4 modes a nonvanishing spin term $J^{kl}(M^4)\Sigma_{kl}$. The reason is that for left-/right-handed mode the eigenvalues of Σ_{03} and Σ_{12} have the same/opposite sign or vice versa.

This would give a mass splitting between left- and right-handed modes and also spin splitting for left- or right-handed modes. The spin-splitting could give rise to a negative contribution to the mass squared in the case of right-handed neutrinos. Could the tachyonic state of the right-handed neutrino give rise to the mysterious tachyonic ground states required by p-adic mass calculations? Could a suitable number of tachyonic right-handed neutrinos allow to nullify arbitrarily high conformal weight of ground state?

How to describe the unitary time evolution of quantum states in the TGD Universe?

The first question is how to describe the time evolution of quantum states in general. The time evolution at the single particle level is involved with the mixing of neutrinos.

Remark: One must remember that physical particles are multiquark composites: even leptons are local composites of 3 antiquarks). Therefore the description in terms of H -spinors applied in the sequel can be criticized.

- (a) In the TGD framework the standard 4-D approach based on the Hamiltonian picture can be only an approximate description since it neglects masslessness in the 8-D sense and is not relativistically invariant.
- (b) The empirical fact is that neutrinos are massive but always left-handed. The trivial explanation could be that right-handed neutrinos have only gravitational interaction so that their detection is not possible. The mixing of left-handed neutrinos with right-handed ones should however be visible in neutrino mixing experiments.

In the TGD framework Dirac equation in H forces the mixing of quark chiralities for the modes of H -spinors. The covariantly constant right-handed neutrino is an exception. Induction as a mere restriction to the space-time surface respects this property! This implies that left-handed neutrino modes mix with right-handed ones and this could make itself visible in the neutrino beam experiments like Mini-Boone and Micro-Boone. The problem can be avoided if it is possible to have massive neutrinos with well-defined M^4 chirality and a time evolution which does not mix the chiralities. Could this kind of time evolution allow a realization?

- (c) Certainly, if the Dirac operator in H , or equivalently, the modified Dirac operator in X^4 defines the phenomenological Hamiltonian operator, the chirality mixing seems unavoidable. There is however no deep reason why $D(H)$ or $D(X^4)$ should define the propagation.
- (d) To get some guidance, one can also consider the level of "world of classical worlds" (WCW). The gamma matrices of WCW are constructed in terms of anticommuting oscillator operators of H -spinors and at that level the analog of the Dirac operator is a generator G of super-conformal algebra whereas the scaling generator L_0 is essentially $GG^\dagger$. However, G carries a quark number and therefore it does not make sense to talk about a propagator defined by G or an analog of Hamiltonian.

The only reasonable unitary time evolution operator at WCW level is defined by the exponent of L_0 , which is essentially mass squared operator obtained as "square" of WCW Dirac operator and has at the level of H counterpart of mass squared operator $D^2(H)$.

In fact, in superstring models, the time evolution operator for the string world sheet is defined by L_0 so that this idea is not new. Also p-adic thermodynamics is defined by

the exponent of L_0 , at this time real, and its existence in the p-adic sense is responsible for the predictive power of p-adic thermodynamics.

Here one must be more precise. Entire L_0 cannot be in question if it annihilates the physical states. In p-adic mass calculations L_0 is identified as the vibrational part $L_{0,vib}$ and for physical states in the string model satisfy $L_0\Psi = (p^2 - kL_{0,vib})\Psi = 0$. One could say that one has thermodynamics for states with different values of mass squared but satisfying the Virasoro condition. p^2 could also correspond to the longitudinal M^2 momentum and transversal momentum would be absorbed to $L_{0,vib}$. Both p-adic mass calculations and M^4 Kähler form favor this option and this picture conforms also with the stringy picture with M^2 effectively replacing the string world sheet.

Also the TGD based quantum measurement theory [L56] [K101] leads to the conclusion that the unitary time evolutions between "small" state function reductions (SSFRs) correspond to the exponential of L_0 . Unitary time evolution as a time translation is replaced with a scaling which is a Lorenz invariant notion and better suited for relativistic purposes.

- (e) L_0 does not mix chiralities! If the initial state of a neutrino is left-handed, it remains left-handed. But how can the initial state of a neutrino be left-handed if spinor modes at the level of H are mixtures of left and right-handed modes as $D(H)\Psi = 0$ demands? Massless Dirac equation cannot be satisfied at the level of X^4 and at the level of WCW it does not make sense. Could one consider the radical possibility of giving it up altogether so that at the level of H one would require only that $D^2(H)\Psi = 0$ is satisfied and $D^2(H)$ would define counterpart of fermionic L_0 and time evolution.

If so, the number of modes is doubled except for the right-handed neutrino. This implies mirror neutrinos. Could left and right-handed charged leptons and quarks be interpreted in terms of the mirror modes? Mirror neutrino hypothesis does not however have empirical support at available energies. One explanation is that the right-handed neutrino modes are very massive or somehow special.

- (f) If $J(M^4)$ is present, the masses of the left-handed mode and corresponding right-handed mode differ by the $S = J^{kl}(M^4)\Sigma_{kl}$ whose eigenvalues define the vacuum conformal weight $\pm h_{vac}$. Assume that S is non-vanishing for the right-handed mode. The number of right-handed modes with tachyonic mass squared would be the number of CP_2 modes with mass squared smaller than h_{vac} . Covariantly constant neutrino 0 would certainly define this kind of state.

If the mass is identified as the longitudinal M^2 mass, it might be possible to select the values of the conformal weights n_1 and n_2 for the modes in such a manner that the masses are identical for the left- and right-handed modes and they can superpose. This should happen for charged modes. If this is not possible for neutrinos, the mixing of chiralities could not occur. This does not work.

The masses of modes related by multiplication with Dirac operator have always identical mass squared values as follows from the commutativity of D and D^2 . However, the covariantly constant right-handed neutrino does not have a left-handed companion. Both mixed states as modes of D and unmixed states satisfy $D^2\Psi = 0$. Why would neutrinos always have a definite handedness? Does the absence of standard model interactions for ν_R imply that the state preparation and reduction involving weak interactions creates only purely left-handed neutrinos?

In the TGD Universe, even covariantly constant right-handed neutrino mode couples to M^4 Kähler form. Could this make it possible to project from mostly left-handed neutrino the non-covariantly constant right-handed part? Could their large mass make their creation impossible?

2.5.3 Problems related to neutrinos

In what follows, the problem of missing right-handed neutrinos and the problem created by apparently contradictory findings of Mini-Boone and Micro-Boone about neutrino mixing

are discussed. Also the topological model for neutrino and D-quark CKM mixing is briefly considered.

Why only left-handed neutrinos are observed?

A basic theoretical motivation for the sterile neutrinos is the difficulty posed by the fact that the neutrinos behave like massive particles. This is not consistent with their left-handedness, which is an experimental fact.

As a matter of fact, the sterile neutrinos would be analogous to the covariantly constant right-handed neutrinos in TGD if only $J(cP_2)$ would be present.

Remark: As already stated, in the sequel it is assumed that leptons as bound states of 3 antiquarks can be described using spinors of H with chirality opposite to that for quarks. They have colored modes and the action of super-symplectic algebra is assumed to neutralize the color and also give rise to a massless state getting its small mass by p-adic thermodynamics.

How could one understand the fact that only left-handed neutrinos are observed although neutrinos are massive? One can consider two approaches leading to the same conclusion.

Is it possible to have time evolution respecting M^4 chirality and neutrinos with fixed chirality possible despite their mass?

- (a) All spinor modes in CP_2 are of the form Φ_L or $D(CP_2)\Phi_L$ and therefore generated from left-handed spinors Φ_L .

If one assumes $D(H)\Psi = 0$, the spinor modes of H are of the form $D(M^4)\Psi_R \otimes \Phi_L + \Psi_R \otimes D(CP_2)\Phi_L$. The modes of form $D(M^4)\Psi_L \otimes \Phi_R + \Psi_L \otimes D(CP_2)\Phi_R$ are therefore of the form $D(M^4)\Psi_L \otimes D\Phi_L + \Psi_L \otimes D^2(CP_2)\Phi_L$. The mixing of chiralities is unavoidable.

- (b) However, if one assumes only the condition $D^2(H)\Psi = 0$, one can obtain both left- and right-handed modes without mixing of M^4 chiralities and M^4 Kähler structure could make the lowest mass second right-handed neutrino (covariantly constant in CP_2) tachyonic. The time evolution generated by the exponent of L_0 would respect M^4 chirality.

This does not prevent superpositions of right- and left-handed fermions if their masses are the same. If only charged leptons can satisfy this condition, one can understand why right-handed neutrinos are not observed.

An alternative approach would rely on quantum measurement theory but leads to the same conclusion.

- (a) Suppose that neutrinos can appear as superpositions of both right- and left-handed components. To detect a right-handed neutrino, one must have a measurement interaction, which entangles both left- and right-handed components of the neutrino with the states of the measuring system. Measurement would project out the right-handed neutrino. If only the $J(CP_2)$ form is present, the right-handed neutrino has only gravitational interactions, and this kind of measurement interaction does not seem to be realizable.
- (b) Putting it more explicitly, the reduction probability should be determined by a matrix element of a neutral (charged) weak current between a massive neutrino (charged lepton) spinor with a massless right-handed neutrino spinor. This matrix element should have the form $\bar{\Psi}_R O \Psi_L$, where O transforms like a Dirac operator. If it is proportional to $D(H)$, the matrix element vanishes by the properties of the massless right-handed neutrino.
- (c) There is however a loophole: the transformation of left- to right-handed neutrinos analogous to the transformation to sterile neutrino in the neutrino beam experiments could demonstrate the existence of ν_R just like it was thought to demonstrate the existence of the inert neutrino in Mini-Boone experiment. Time evolution should thus respect M^4 chirality.

If $J(M^4)$ is present, one might understand why right- and left-handed neutrinos have different masses.

- (a) Also the right-handed neutrino interacts with Kähler gauge potential $A(M^4)$ and one can consider an entanglement distinguishing between right- and left-handed components and the measurement would project out the right-handed component. How could this proposal fail?

Could it be that right- and left-handed neutrinos cannot have modes with the same mass so that these superpositions are not possible as mass eigen states? Why charged modes could have the same mass squared but not the neutral ones?

- (b) The modes with right-handed CP_2 chirality are constructed from the left-handed ones by applying the CP_2 Dirac operator to them and they have the same CP_2 contribution to mass squared. However, for the right-handed modes the $J^{kl}(M^4)\Sigma_{kl}$ term splits the masses. Could it be that for right- and left-handed charged leptons the same value of mass is possible.

The presence of $J(M^4)$ breaks the Poincare symmetry to that for M^2 which corresponds to a Lagrangian manifold. This suggests that the physical mass is actually M^2 mass and the QCD picture is consistent with this. Also the p-adic mass calculations strongly support this view. The E^2 degrees of freedom would be analogous to Kac-Moody vibrational degrees of freedom of string. This would allow right- and left-handed modes to have different values of "cyclotron" quantum numbers n_1 and n_2 analogous to conformal weights. This could allow identical masses for left- and right-handed modes. For a Lagrangian manifold M^2 , one would have $n_1 = n_2 = 0$, which could correspond to ground states of super-symplectic representation.

- (c) Why identical masses would be impossible for right- and left-handed neutrinos? Something distinguishing between right- and left-handed neutrinos should explain this. Could the reason be that Z^0 couples to left-handed neutrinos only? Could the fact that charged leptons and neutrinos correspond to different representations of color group explain why only charged states can have right and left chiralities with the same mass?

Perhaps it is of interest to notice that the presence of $J^{kl}(M^4)\Sigma_{kl}$ for right-handed modes makes possible the existence of a mode for which mass can vanish for a suitable selection of B .

Mini-Boone and Micro-Boone anomalies and TGD

After these preliminaries we are ready to tackle the anomalies associated with the neutrino mixing experiments. The incoming beam consists of muonic neutrinos mixing with electron neutrinos. The neutrinos are detected as they transform to electrons by an exchange of W boson with nuclei of the target and the photon shower generated by the electron serves as the experimental signature.

The basic findings are as follows.

- (a) Mini-Boone collaboration reported 2018 [C2] an anomalously large number of electrons generated in the charged weak interaction assumed to occur between neutrino and a nucleus in the detector. "Anomalous" meant that the fit of the analog of the CKM matrix of neutrinos could not explain the finding. Various explanations including also inert neutrinos were proposed. Muonic inert neutrino would transform to inert neutrino and then to electron neutrino increasing the electron neutrino excess in the beam.
- (b) The recently published findings of Micro-Boone experiment [C1] studied several channels denoted by $1eNpM\pi$ where $N = 0, 1$ is the number of protons and $M = 0, 1$ is the number of pions. Also the channel $1eX$, where "X" denotes all possible final states was studied.

It turned out that the rate for the production of electrons is below or consistent with the predictions for channels $1e1p$, $1eNp0\pi$ and $1eX$. Only one channel was an exception and corresponds to $1e0p0\pi$.

If one takes the finding seriously, it seems that a neutrino might be able to transform to an electron by exchanging the W boson with a nucleus or hadron, which does not belong to the target.

In TGD, the only imaginable candidate for this interaction could be charged current interaction with a dark nucleus or with a nucleon with $h_{eff} > h$. This could explain the absence of ordinary hadrons in the final state for 1e events.

- (a) Dark particles are identified as $h_{eff} > h$ phases of the ordinary matter because they are relatively dark with respect to phases with a different value of h_{eff} . Dark protons and ions play a key role in the TGD inspired quantum biology [L92] and even in the chemistry of valence bonds [L36]. Dark nuclei play a key role in the model for "cold fusion" [L16, L63] and also in the description of nuclear reactions with nuclear tunnelling interpreted as a formation of dark intermediate state [L55].
- (b) I have proposed that dark protons are also involved with the lifetime anomaly of the neutron [L42] [L42]. The explanation relies on the transformation of some protons produced in the decay of neutrons to dark protons so that the measured life time would appear to be longer than real lifetime. In this case, roughly 1 percent of protons from the decay of n had to transform to dark protons.
- (c) If dark protons have a high enough value of h_{eff} and weak bosons interacting with them have also the same value of h_{eff} , their Compton length is scaled up and dark W bosons behave effectively like massless particles below this length scale. The minimum scale seems to be nuclear or atomic scale. This would dramatically enhance the dark rate for $\nu p \rightarrow e + n$ so that it would have the same order of magnitude as the rates for electromagnetic interactions. Even a small fraction of dark nucleons or nuclei could explain the effect.

CKM mixing as topological mixing and unitary time evolution as a scaling

The scaling generator L_0 describes basically the unitary time evolution between SSFRs [L56] [K101] involving also the deterministic time evolutions of space-time surfaces as analogs of Bohr orbits appearing in the superposition defining the zero energy state. How can one understand the neutrino mixing and more generally quark and lepton mixing in this picture?

- (a) In the TGD framework, quarks are associated with partonic 2-surfaces as boundaries of wormhole contacts, which connect two Minkowskian space-time sheets and have an Euclidean signature of induced metric and light-like projection to M^4 [K11, K24].
- (b) For some space-time surfaces in their superposition defining a zero energy state, the topology of the partonic 2-surfaces can change in these time evolutions. The mixing of boundary topologies would explain the mixing of quarks and leptons. The CKM matrix would describe the difference of the mixings for U and D type quarks and for charged and neutral leptons. The topology of a partonic 2-surface is characterized by the genus g as the number of handles attached to a sphere to obtain the topology.

The 3 lowest genera with $g \leq 2$ have the special property that they always allow Z_2 as a conformal symmetry [K11, K24]. The proposal is that handles behave like particles and thanks to Z_2 symmetry $g = 2$ the handles form a bound state. For $g > 2$ one expects a quasi-continuous spectrum of mass eigenvalues. These states could correspond to so-called unparticles introduced by Howard Georgi (<https://cutt.ly/sRZKSfM>).

- (c) The time evolution operator defined by L_0 induces mixing of the partonic topologies and in a reasonable idealization one can say that L_0 has matrix elements between different genera. The dependence of the time evolution operator on mass squared differences is natural in this framework. In standard description it follows from the approximation of relativistic energies as $p_0 \simeq p + m^2/2p$. Also the model of hadronic CKM relies on mass squared as a basic notion and involves therefore L_0 rather than Hamiltonian.

2.6 Zero energy ontology (ZEO)

ZEO [K101] 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.

2.6.1 The basic view about ZEO and causal diamonds

The following list those ideas and concepts behind ZEO that seem to be rather stable.

- (a) GCI in WCW implies holography, Bohr orbitology and ZEO [L56] [K101].
- (b) X^3 is more or less equivalent with Bohr orbit/preferred extremal $X^4(X^3)$. Finite failure of determinism is however possible [L89]. Zero energy states are superpositions of $X^4(X^3)$. Quantum jump is consistent with causality of field equations.
- (c) 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. A.2 Fig. 13**).
- (d) 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 .

- (e) 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.

- (f) 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 [L50] as observed by Mineev et al [L50].
- (g) h_{eff} hierarchy [K71, K72, K73, K74] implied by the number theoretic vision [L60, L61] 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.
- (h) 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 [L54]: dissipation with reversed arrow of time looks like self-organization [L92].

2.6.2 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.

- (a) 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).
- (b) Mental mentals (say after images) are in kind of Karma's cycle: they are born and die roughly periodically.
- (c) I do not experience directly mental images with the opposite arrow of time.
- (d) 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.

- (a) After images appear and disappear roughly periodically. Also I fall asleep and wake up with a standard arrow of time roughly periodically.
 - i. 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?
 - ii. 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.
- (b) 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?

Suppose that the sub-CDs within a bigger CD "follow the flow". How the dynamics of the bigger CD could induce this flow?

- (a) 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 ageing in their personal Karma's cycle, and the paradox would disappear.
- (b) 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.

- (c) 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".

2.6.3 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

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 number theoretic point of view.

- (a) 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 [L67]. I have proposed that this occurs in all particle reactions. For instance, nuclear reactions involving tunnelling 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 [L55] and also the TGD based model for "cold fusion" relies on this picture [L30, L63]. After the SSFR cascade 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.

- (b) 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 [L70].

The measurement interaction can be also considered from the topological point of view.

- (a) 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.

- (b) 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.

2.6.4 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.

- (a) 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.
- (b) $U(n)$ 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.
- (c) 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.
- (d) 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.

- (e) One can also have flags inside flags inside leading to more complex flag manifolds $F(n_1, n_2, \dots, n_k = M) = U(M)/U(m_1) \times \dots \times U(m_k)$, $m_k = n_k - n_{k-1}$ 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.
- (f) The analog of flags inside flags is what happens in what I call number theoretic measurement cascades for wavefunctions [L67] 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 discrete 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 composite polynomial $P_n \circ P_{n-1} \dots \circ P_1$ has the roots of $P_1, \dots, P_{n-1}$ as its roots. In this case the inclusion of state spaces are unique so that flag manifolds are not needed.

2.6.5 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP) [L78] is the basic variational principle of TGD based quantum measurement theory giving rise to a theory of consciousness.

- (a) 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.
- (b) 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.
- (c) 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. This picture is consistent with the paradoxical proposal of Jeremy England [I24] [L15] that biological evolution involves an increase of entropy.
- (d) 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.

2.7 Appendix

2.7.1 Comparison of TGD with other theories

Table A.1 compares GRT and TGD and Table A.2 compares standard model and TGD.

	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 identification 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 2.1: 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 symmetry	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 2.2: Differences and similarities between standard model and TGD

2.7.2 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.

Many-sheeted space-time (see **Fig. A.1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by **wormhole contacts** (see **Fig. A.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*** [K54] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- ***Adelic physics*** [L39, L43] 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 [L10].
- ***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 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 Alfvén 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 factor $h_{eff}/h = n$. 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 superconductors 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 [K26] [L78] 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)** (CD, see **Fig. A.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 imbedding 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 [L56] [K101]. 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 also 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 [L56] [K101]. 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 [L56] [K101]. 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 [L54]. 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 Mineev et al [L50] give support for BSFR at atomic level. Together with $\hbar_{eff}$ hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

2.7.3 Figures

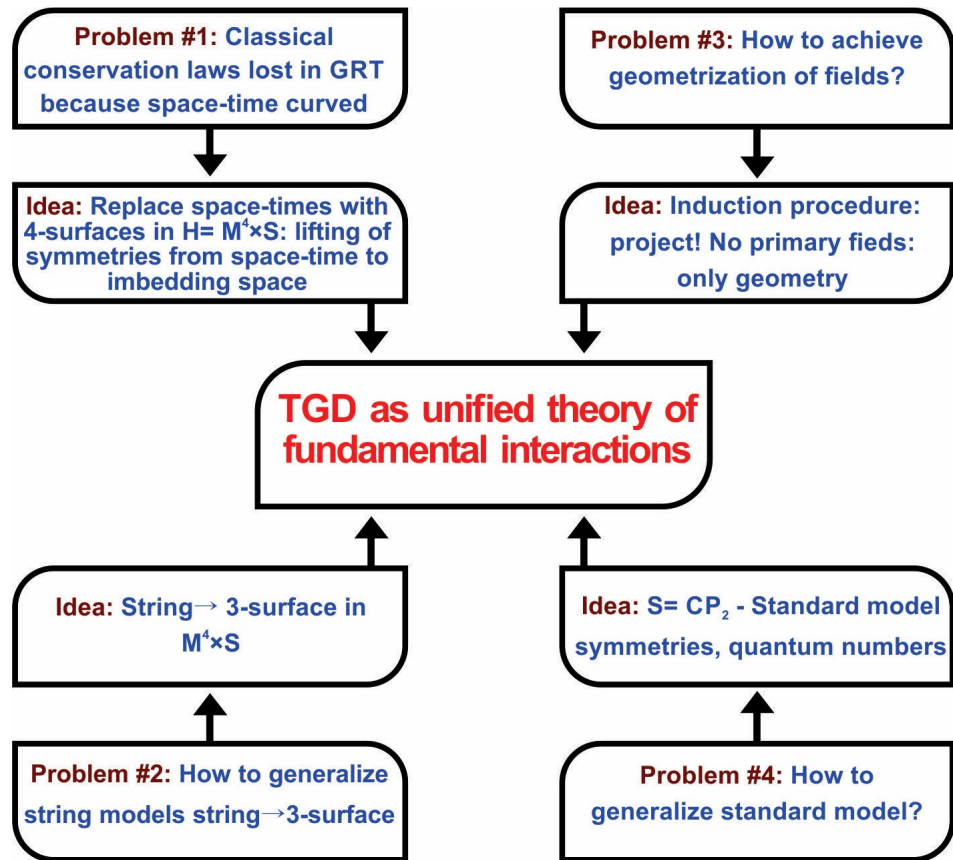


Figure 2.1: The problems leading to TGD as their solution.

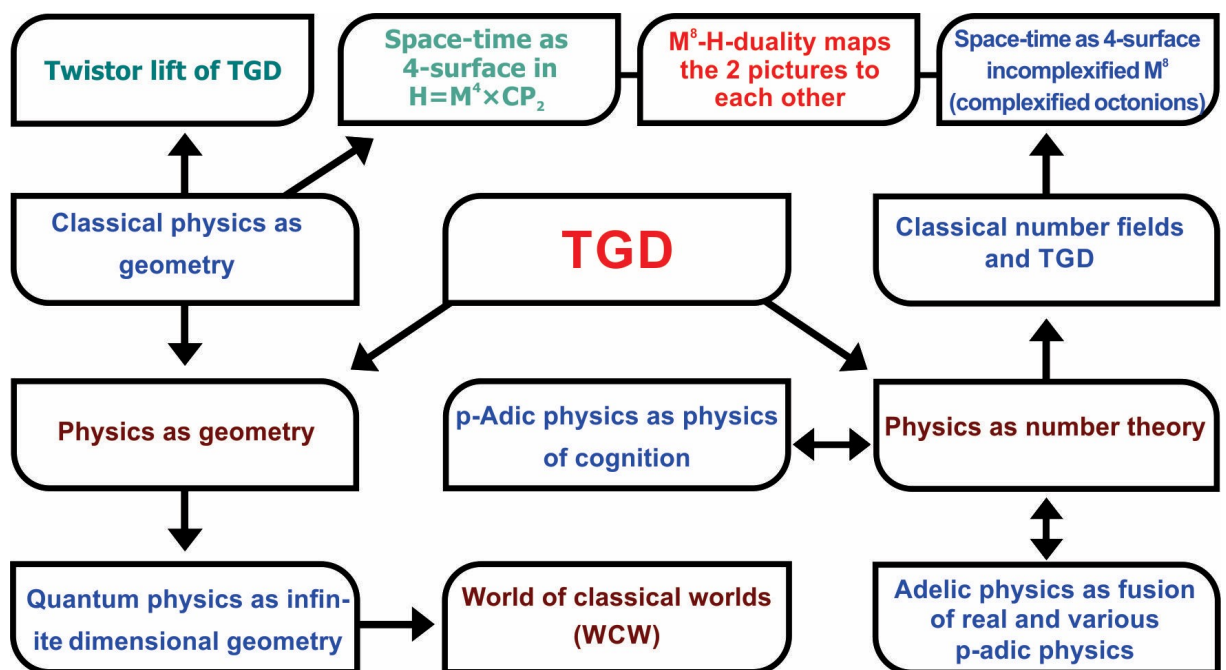


Figure 2.2: TGD is based on two complementary visions: physics as geometry and physics as number theory.

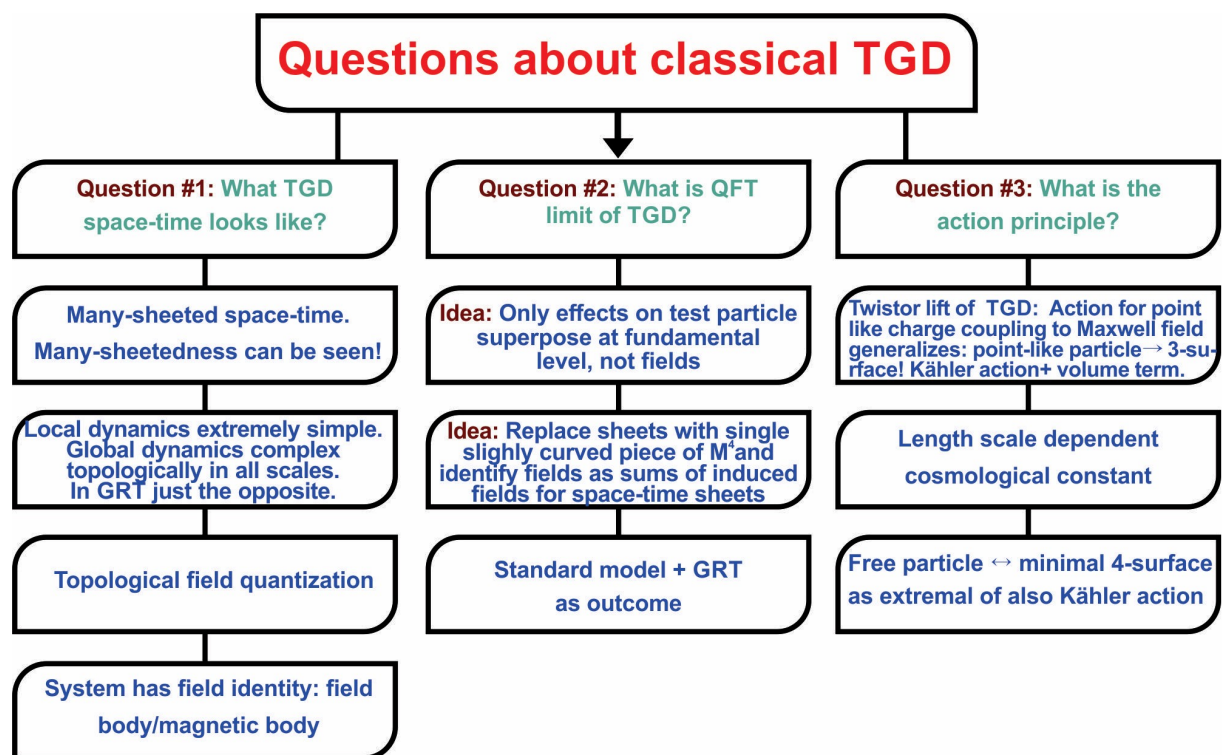


Figure 2.3: Questions about classical TGD.

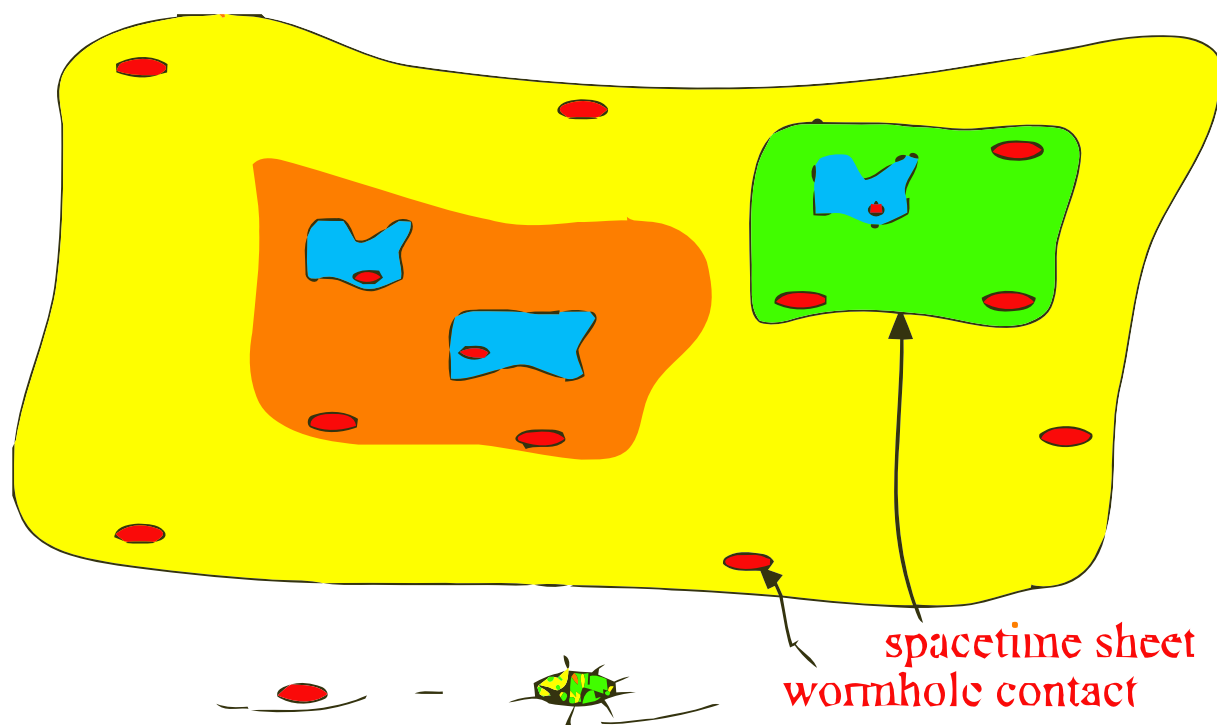


Figure 2.4: Many-sheeted space-time.

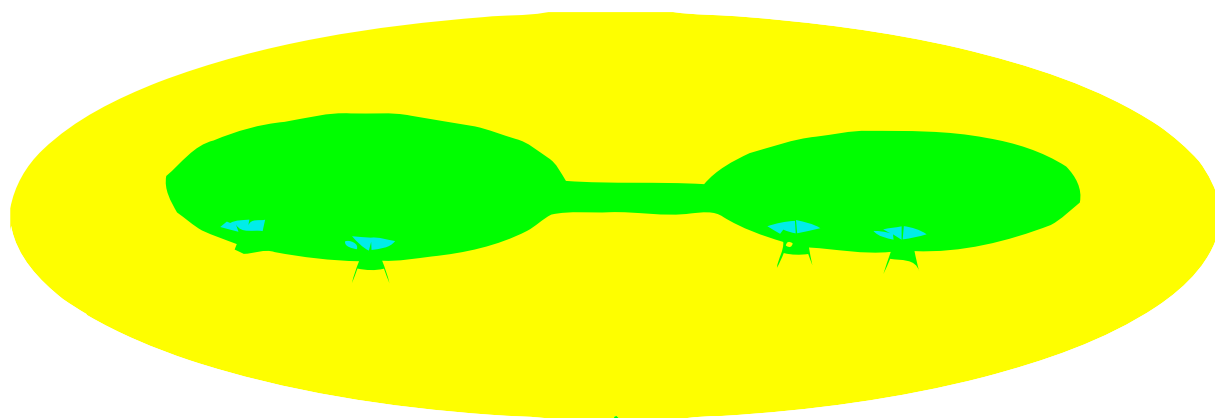


Figure 2.5: Wormhole contacts.

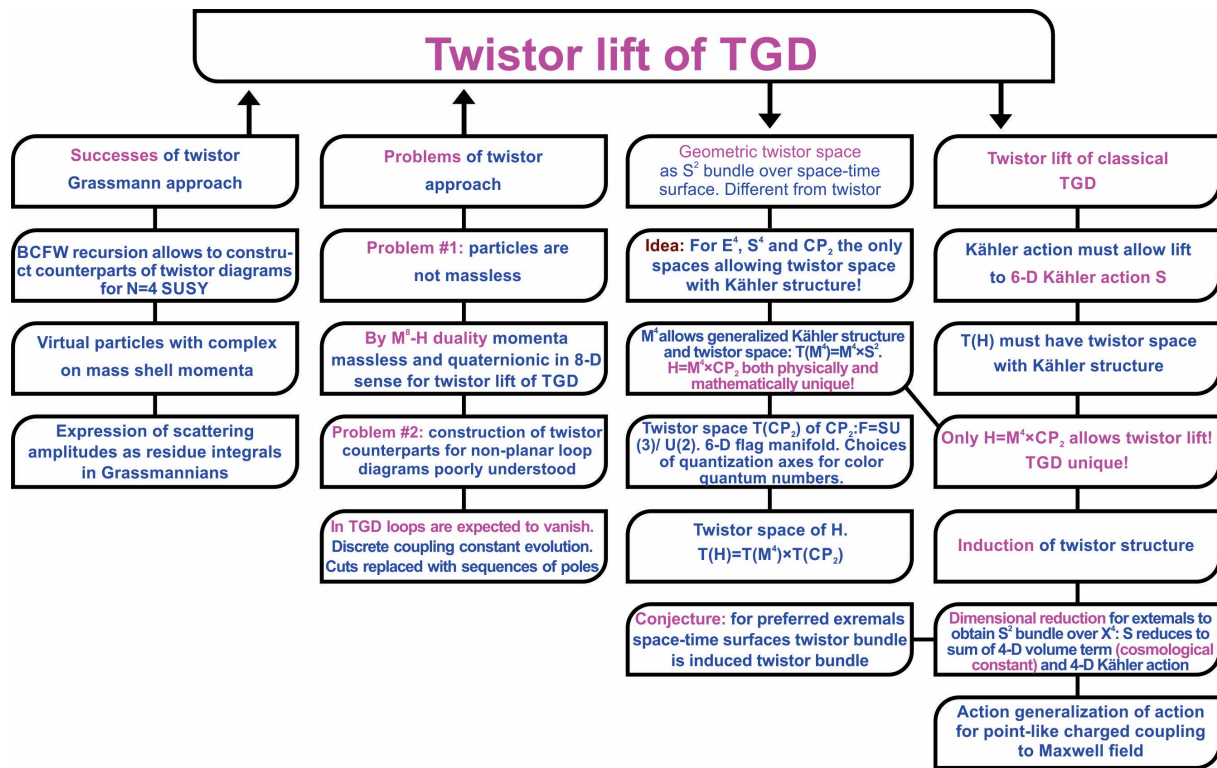


Figure 2.6: Twistor lift

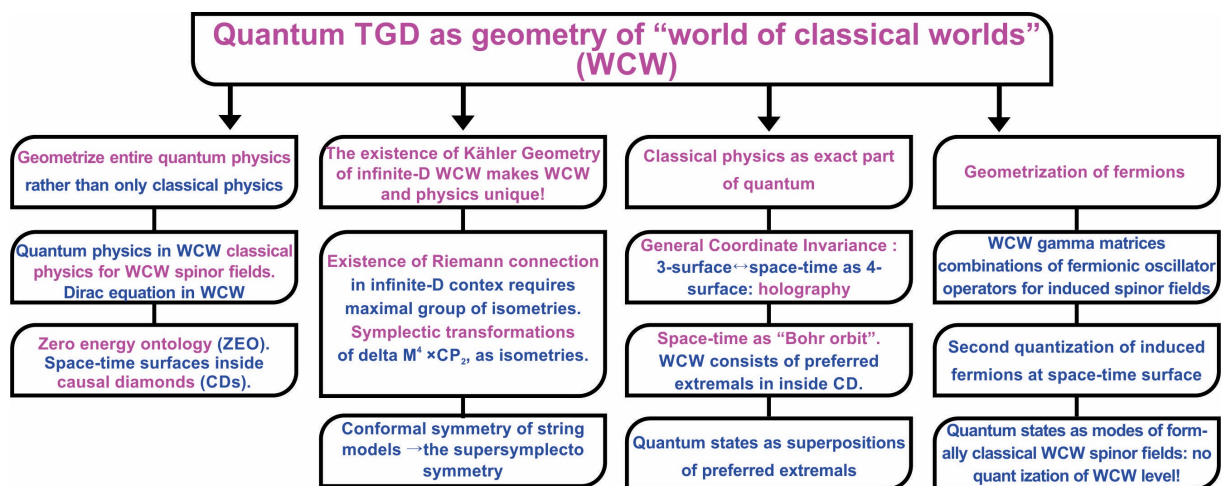
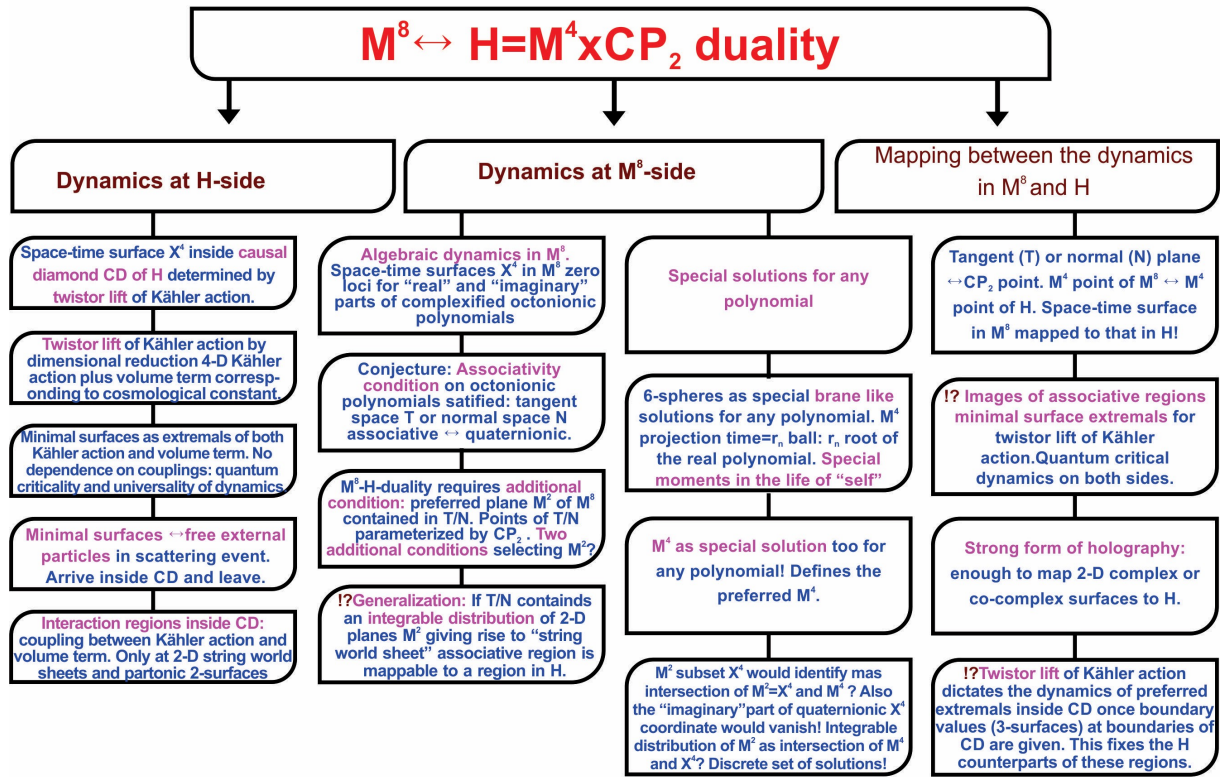


Figure 2.7: Geometrization of quantum physics in terms of WCW

Figure 2.8: $M^8 - H$ duality

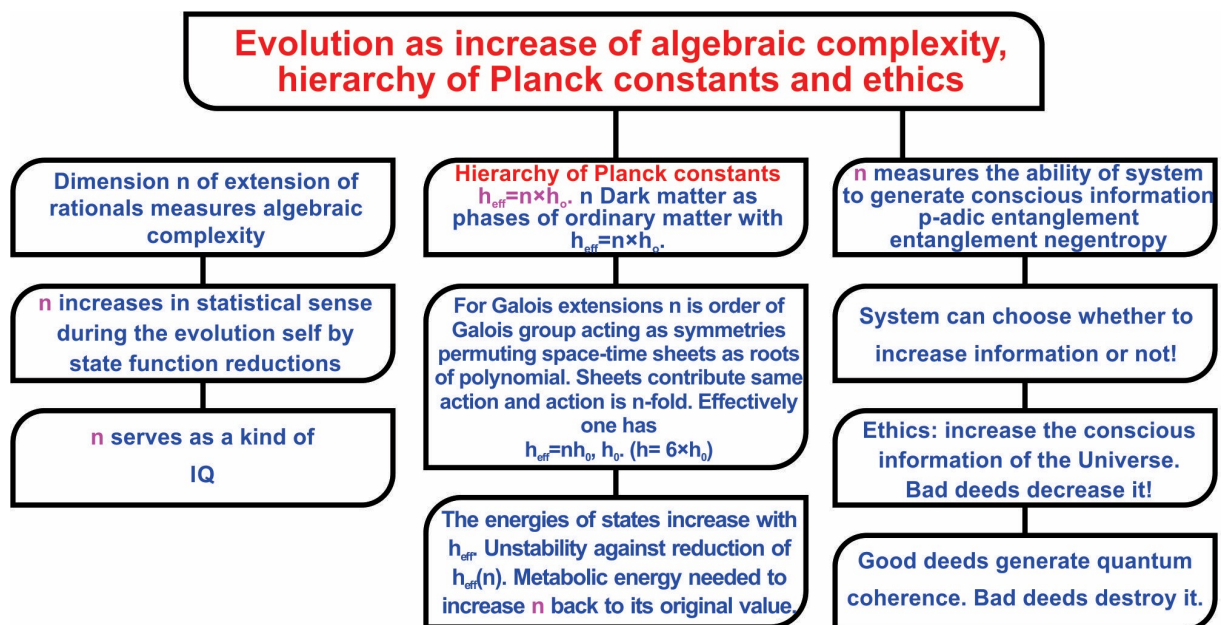


Figure 2.9: Number theoretic view of evolution

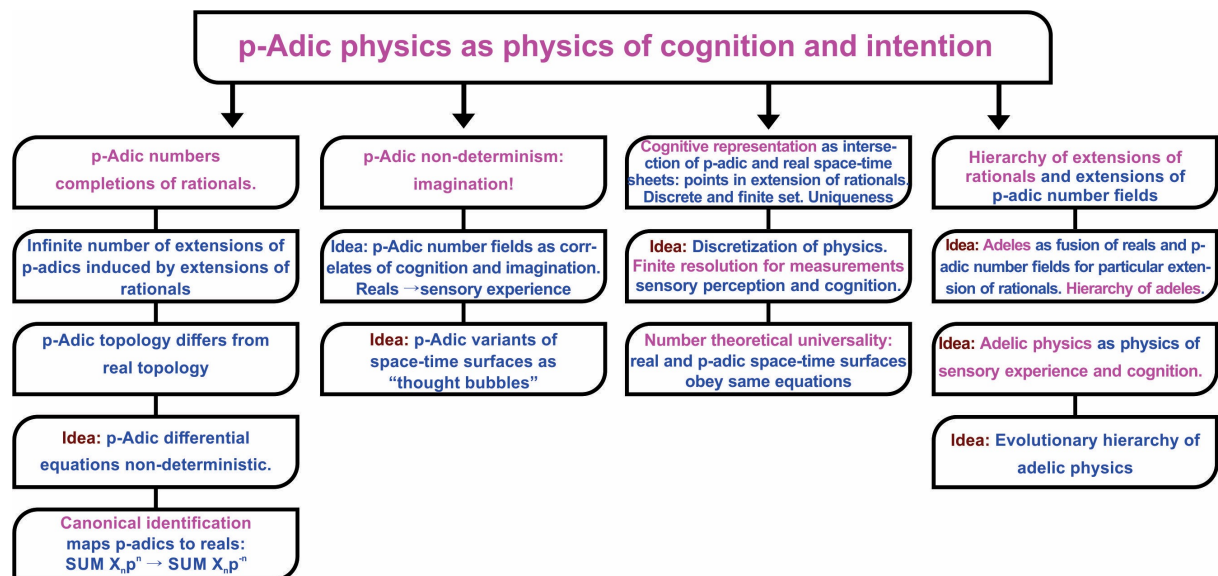


Figure 2.10: p-Adic physics as physics of cognition and imagination.

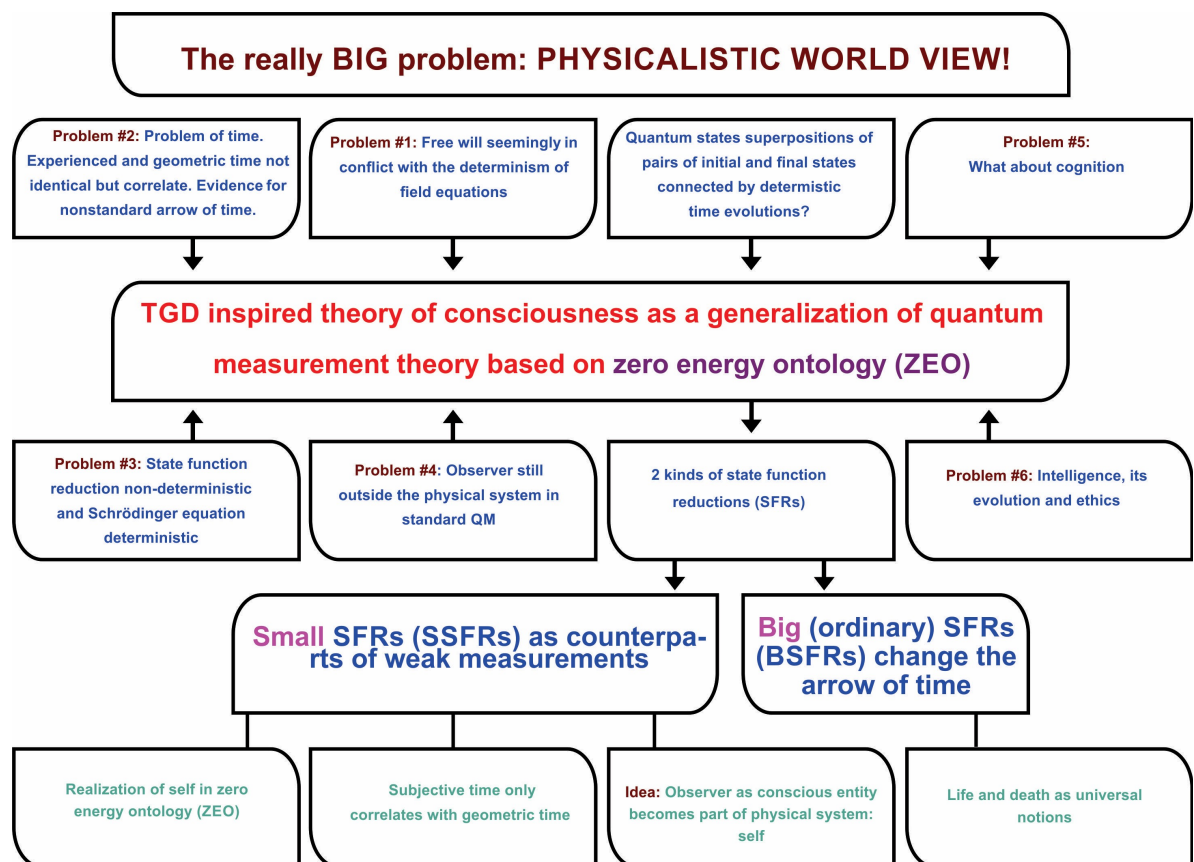


Figure 2.11: Consciousness theory from quantum measurement theory

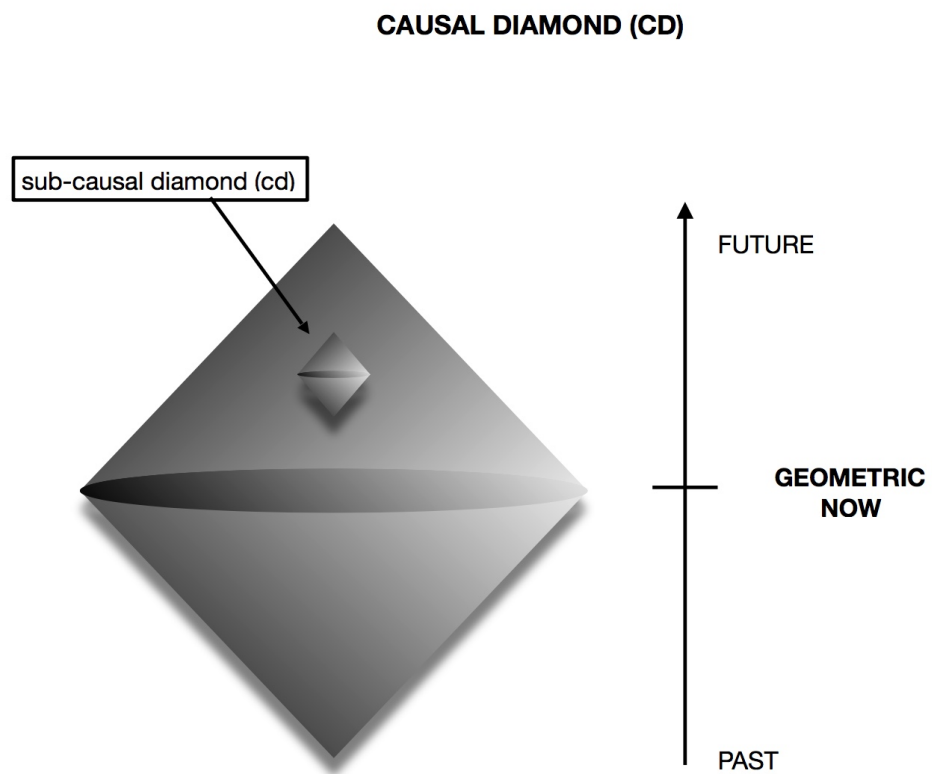


Figure 2.12: Causal diamond

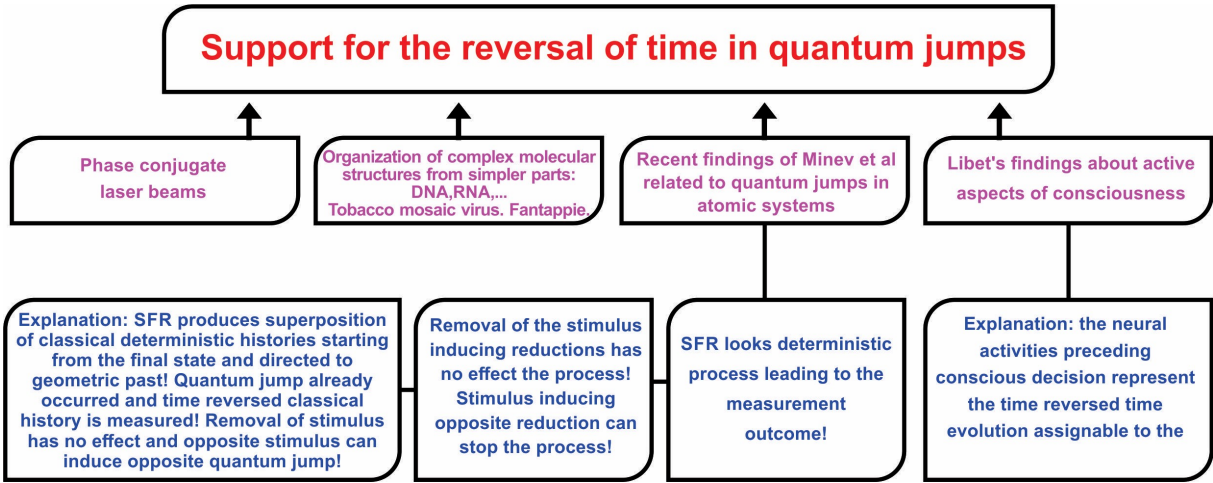


Figure 2.14: Time reversal occurs in BSFR

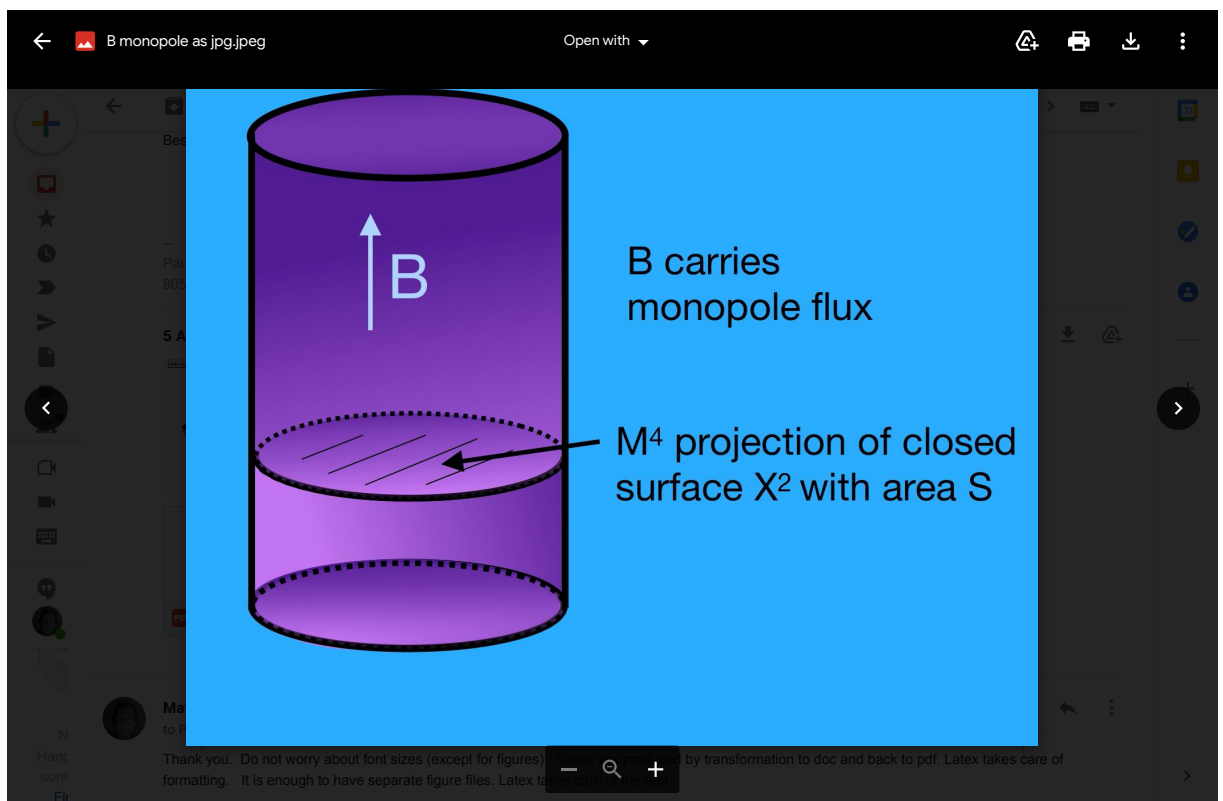


Figure 2.15: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e \oint B \cdot dS = eBS = kh$ at single sheet of n -sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

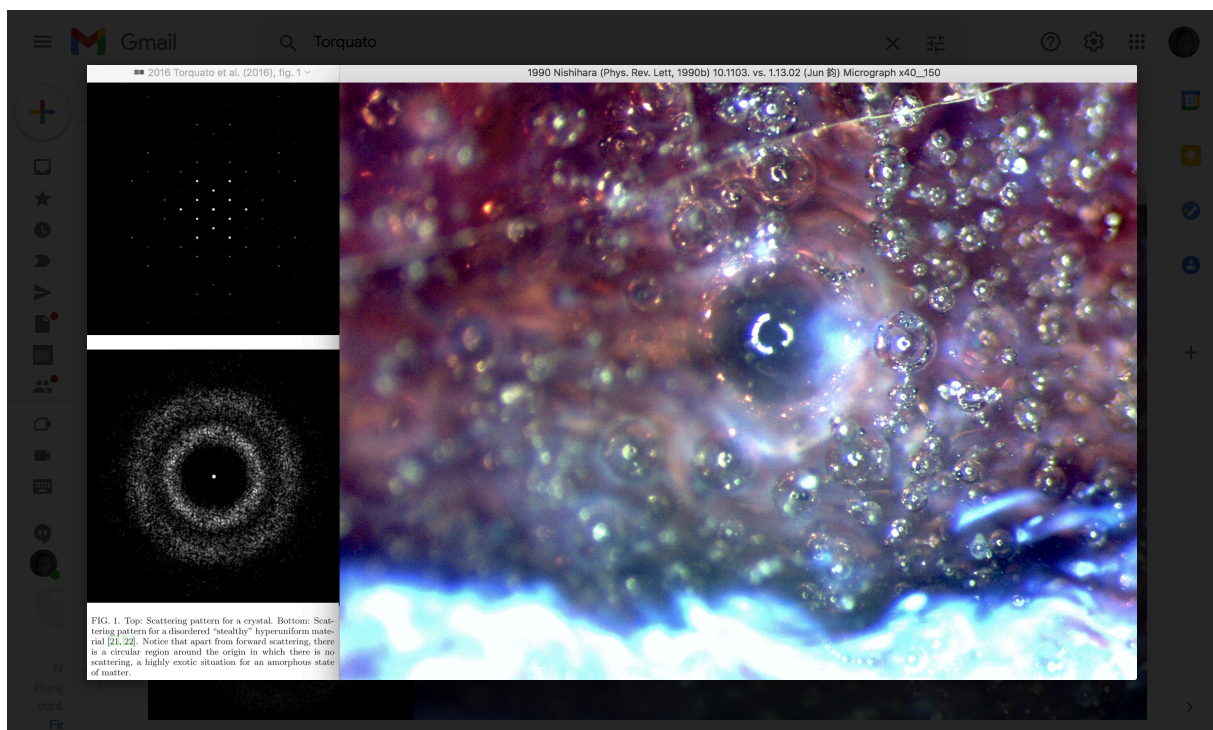


Figure 2.16: The scattering from a hyperuniform amorphous material shows no scattering in small angles apart from the forward peak (<https://cutt.ly/ZWyLgjk>). This is very untypical in amorphous matter and might reflect the diffraction pattern of dark photons at the magnetic body of the system.

Chapter 3

TGD and Condensed Matter Physics

3.1 Introduction

The purpose of this article is to give a rough overall view about Topological Geometro-dynamics (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 [L72] 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 [L66] gives an overview of various aspects of TGD and is warmly recommended.

- (a) "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. 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 [L40, L48](see **Fig. 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. 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.

- (b) 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. 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 correlates for massless particles. World as a set of 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. 10**).

- (c) 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. 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. 9**).

$M^8 - H$ duality provides two complementary visions about physics (see **Fig. 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).

- (d) 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. A.2** and **Fig. 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. 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.

- (a) 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.

- (b) 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 .

- (c) 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.
- (d) 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.

- (a) 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.
- (b) 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.
- (c) 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.
- (d) 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 4th 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.

3.2 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.

3.2.1 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_H^8 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 .

- (a) 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 [L89].
- (b) 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 [L39, L38]) 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.

- (a) The condition that the total 4-momentum is integer-valued poses a strong condition on the bound states.
- (b) 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.
- (c) 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.

- (d) 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 $\hbar_{eff}/m$ 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 icoso-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 [L76].

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.

- (e) 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.

- (a) 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).

- (b) 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.

- (c) 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.

- (d) 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.

- (a) 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.

- (b) 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.

- (c) 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.
- (d) 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.

- (a) 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.
- (b) 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 [L60] are necessary.

- (a) 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 $m_c^2 \equiv m_{Re}^2 - m_{Im}^2 + 2i Re(p) \cdot Im(p) = r_1$, where the real and imaginary masses are defined as $m_{Re}^2 = Re(p)^2$ and $m_{Im}^2 = Im(p)^2$ and r_1 is some root for the odd part of the polynomial P assumed to determine the 4-surface.
- (b) 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.

- (a) 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 .
- (b) 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.
- (c) 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.

- (a) 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.
- (b) 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.

- (a) 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.

- (b) 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 $P_n \circ P_{n-1} \circ \dots \circ P_1$ and these polynomials have roots of $P_1, \dots, P_{n-1}$ 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.

3.2.2 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.

- (a) At H level 4-surfaces as analogous to 4-D complexified momentum space are algebraic surfaces, that is 4-D "roots" of polynomials. These 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.

- (b) These singularities need not however correspond as such to the above listed singularities since the active points of cognitive representation defined by momenta 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.

- (a) 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.

- (b) 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 $\exp(iknL)$ would be roots of unity and therefore number theoretically universal. This requires that $kL = m$ is a rational integer.

- (c) 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.
- (d) 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 $E = \text{constant}$ 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 [D16] 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.

- (a) 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.

- (b) 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.

- (c) 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 [D91] helpful for a newcomer to the field.

Let us summarize the basic physical properties of spin waves.

- (a) 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 [D91] <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.

- (b) 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.
- (c) 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.

- (d) 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-split 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?

- (a) 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.
- (b) In Quantum hydrodynamics (QHD) according to TGD [L82], 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.

- (c) 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 [K1] [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.

- (a) 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 [L60] 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.

- (b) 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 $M^4 \subset M^8$.

- (c) 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.

- (a) 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 $\tau = \theta/2\pi + 4\pi i/g^2$.
- (b) 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.
- (c) In the gauge theory θ is analogous to momentum. The vacuum state is plane-wave like superposition $\sum_N \exp(iN\theta/2\pi) |N\rangle$ 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.

- (a) 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 .

- (b) The non-trivial gauge transformations - $U(1)$ instantons - are clearly possible. The non-trivial gauge transformation could correspond to a topological 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.
- (c) Kähler action generalizes to

$$S_K = \frac{1}{\alpha_K} \int J \wedge *J\sqrt{g} - \frac{i}{2\pi} \theta \int J \wedge J\sqrt{g} . \quad (3.2.1)$$

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.

- (d) $I(CP_2)$ 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.
- (e) 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?
- (f) $J \wedge J$ 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.

- (a) 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.

- (b) 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 extremals since dynamics 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?

- (c) 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 antiquarks 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.
- (d) 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?

3.2.3 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. A.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 accompy 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 of 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 [K36, K13, K37].

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.

3.2.4 About quantum criticality in TGD

In TGD number theoretical vision about physics brings a new view about quantum criticality.

- (a) 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.
- (b) 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 [L79].

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 [K24, K11]. Also this temperature quantization could be seen as a counterpart for the quantum criticality.

- (c) Quantum criticality involves long range correlations and the hierarchy of Planck constants characterizing them [K71, K72, K73, K74]. 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.

3.2.5 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.

- (a) 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.

- (b) 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.

- (c) 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 [L74].

A concrete example is provided by the iteration of a polynomial of finite degree [L74]. 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.

3.2.6 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 [D97] <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?

- (a) WCW is a Kähler manifold [K57, K19]. 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.
- (b) 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.

- (a) 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 $\langle \Psi(\lambda) | \Psi(\lambda + \delta\lambda) \rangle$ 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 or appearance of quantal WCW degrees of freedom as zero modes 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.

- (b) 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.
- (c) 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 $\hbar_{eff}$ 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.

- (a) 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.
- (b) 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?

- (c) 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?
- (d) One can invent objections against this proposal.
 - i. 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.
 - ii. 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 .

- iii. 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?

- (a) 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 [L60, L61], 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.

- (b) Super-symplectic transformations [K12, K57] 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.

- (c) 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.

3.2.7 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/cWy309Ts>).

- (a) Quantum hydrodynamics appears in TGD as an *exact* classical correlate of quantum theory [K62]. 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.

- (b) 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 [L89]. Beltrami flow for classical Kähler field defines an integrable flow [L72]. There is no dissipation classically and this can be interpreted as a correlate for a quantum coherent phase.
- (c) 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.
- (d) 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.
- (e) 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.
- (f) Beltrami conditions make sense also for fermionic conserved currents as purely algebraic linear conditions stating that fermionic current is a gradient of some function bilinear in oscillator operators. Whether they are actually implied by the classical Beltrami conditions, is an interesting question.
- (g) 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 [L89].

3.2.8 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.

3.2.9 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.

- (a) 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 $L = \hbar_{eff}/m$.
- (b) 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.
- (c) 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.
- (d) 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 $\hbar_{eff}I$, 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 [K92] 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 [L65, L76].

Superconductivity and superfluidity in TGD framework

The TGD based view about superconductivity and fluidity [L72] differs in many respects from BCS theory.

- (a) 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 Bogoliubov 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.

- (b) 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.
- (c) 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.

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.

- (a) 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.

- (b) 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.

- (c) 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.
- (d) 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.

3.3 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.

3.3.1 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 [D71] (<https://cutt.ly/MWy3S5J>). Their universal appearance suggests that they could appear at fundamental level.

What TGD view would be following.

- (a) 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.

- (b) Skyrmion in as a map $B^3 \rightarrow S^3 \subset E^4 \subset M^8 = M^4 \times E^4$ is mapped to a map $B^3 \rightarrow S^3 \subset CP_2 \subset H$ by $M^8 - H$ duality. The map $B_3 \rightarrow B^3$ 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 $D \leq 3$ 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).

- (c) 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 [D89] (<https://arxiv.org/abs/1812.07974>). Could this relate to the speculated emergence of $SO(3)$ as a synthetic gauge group [D32])(<https://cutt.ly/qWy3H9M>?

3.3.2 Dark matter and condensed matter physics

Could one make dark matter visible?

Dark matter in TGD sense could make itself visible in many manners.

- (a) 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 visible 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 [K59, K58, K97].
- (b) 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 [L92].

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 [D93] (<https://cutt.ly/ZWyLgjk>) for a hyperuniform amorphous material is very different and is called highly exotic (see **Fig. 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.

- (a) 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?
- (b) 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 [D61](<https://cutt.ly/4Wy8zi9>). Could one think of polariton vortex lattices [D52] (<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.

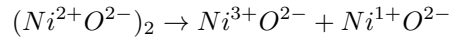
Mott insulators learn like living organisms

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 [K34] briefly considered transition metals, Mott insulators, and anti-ferromagnets from the point of view of TGD inspired theory of high Tc superconductivity.

- (a) 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 $[\text{Ar}] 3d^8 4s^2$ or $[\text{Ar}] 3d^9 4s^1$. 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.
- (b) Mott developed a model for NiO as an insulator: the expected conduction was based on the transition for neighboring $Ni^{2+}O^{2-}$ molecules



In the latter configuration, the number of valence electrons of Ni is odd for both neighbors.

- (c) 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.
- (d) 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.
- (e) 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 [K33, ?] [L72] 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 $\hbar_{eff} \geq \hbar$, 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.

3. 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 [L37] [L37] [K73]. The TGD proposal is that the electrons become dark in the TGD sense.
4. 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 [L81, L83].
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 [L81]) 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 [L76].
5. 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 $h_{eff} \geq nh_0 > h$ 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.
6. Above T_c , 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 [?].

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" [L72].

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 $\hbar_{eff}$. 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 $\hbar_{eff}$ 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 $\hbar_{eff} > \hbar$ 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 $\hbar_{eff} > \hbar$ phase and the value of $\hbar_{eff}$ 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 [K86]. 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 [L83].

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.

3. 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 [K86].
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 [L92, L75].

Braid statistics could also relate to the problem created by Bose-Einstein and Fermi statistics.

1. The problem is that many-boson and many-fermion states are maximally entangled so that state function reduction is in the QFT framework possible only for the entanglement between fermions and bosons.

In the TGD framework the situation is even more difficult since all elementary particles can be constructed from quarks. The replacement of point-like particles with 3-surfaces however forces us to re-consider the notion of particle identity. Number theoretic definition of identity applying to cognitive representations is attractive.

2. The intuitive proposal is that Galois representations can entangle and that the reduction of entanglement is possible. In particular, the decomposition of extension to a hierarchy of extensions with Galois groups forming a hierarchy of normal subgroups allows the notions of cognitive measurement cascade [L67].
3. A more rigorous basis for the intuition emerges from the TGD view about braiding. The Galois group can be always represented as a subgroup of a suitable symmetric group S_n . S_n allows braidings and therefore induces a braiding of the Galois group. The discrete subgroups of symmetry groups of TGD could allow representation as a Galois group of the space-time surface. They could also allow braiding defined by the lift of the continuous isometry flow to the space-time surface. This suggests that the notion of a quantum group could allow a geometric interpretation in terms of the braiding based on the many-sheeted sub-manifold geometry.
4. The Galois group is in general non-Abelian and the braided Galois group would define braid statistics allowing higher-D representations. This would also make possible a non-maximal entanglement and the reduction of entanglement for the tensor products would be possible..

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 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 [L38, L60, L61, L77]. 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 [K14] [L88]. $M^8 - H$ duality allows us to imagine what this means at M^8 -level [L89]. 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 [K54].
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 [L56, L67, L75]. 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 [L70]. 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 [L75]. 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 [L92, L76].

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_c^8 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 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 Galois singlets and genes in turn would be Galois singlet for a Galois group at larger space-time sheet [L65, L76]. 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/2n65x0k>) as a temporal analog of ordinary crystals in the sense that there is temporal periodicity, was proposed by Frank Wilczek in 2012. Experimental realization was demonstrated in 2016-2017 [D54] but not in the way theorized by Wilczek. Soon also a no-go theorem against the original form of the time crystal emerged [B26] and motivated generalizations of the Wilczek's proposal.

Temporal lattice-like structures defined by 4-D minimal surfaces as preferred extremals of action which sum of volume term and Kähler action [L89] 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 $\hbar_{eff} = n\hbar_0$ is realized at the level of MB. To preserve the values of $\hbar_{eff}$ energy feed is needed since $\hbar_{eff}$ 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 [L56, L80]. The experiments of Mineev et al [L50] [L50] 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 $\hbar_{eff}$ 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 [L54]. 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 $[t_1, \dots, t_k]$ 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" [L91].

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.

3.3.3 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 $\text{Dy}_2\text{Ti}_2\text{O}_7$ and holmium titanate $\text{Ho}_2\text{Ti}_2\text{O}_7$.

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 [D51, D46]. 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 [D13, D88, D51, D46] (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 [D88] 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 [D51]. 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 biew 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 [D88] 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 $\hbar_{eff}$ 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 $\hbar_{gr}(Sun)/\hbar \sim 2 \times 10^{20}$. 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 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 [L40] 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 h_{eff} . In some situations even $h_{eff} = \hbar_{gr}$ 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 [D13, D88, D51, D46] to give rise to a strong enhancement 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 [D13, D88, D51, D46] 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.

3.3.4 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 Bogoliubov 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 [L70]. 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 [D100]. 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?

3.3.5 Condensate of electron quadruplets as a new phase of condensed matter

Formation of fermion quadruplet condensates [D99] (<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 precise 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 [L72].

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 for B implies that Lorentz force vanishes.
2. The proposal of [K65] 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 [K65]: 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 $h_{eff} > h$ [L72]. 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 [L82].
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 [L83, L81] 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 leave Galois singlets invariant.

3.3.6 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 [L92, L76] [K49, K48, K22, K13, K37].

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 spaghetti would provide this degeneracy.

3.4 Testing of the vision

Eventually the basic concepts of TGD applied to condensed matter physics should be tested. The following lists some challenges.

3.4.1 Observation of dark matter

The observation of dark matter as $h_{eff} = nh_0$ phases in condensed matter systems is one basic goal (allbqcritdark1,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 to $3k(n, K)$, 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 extension of 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.

3.4.2 Topological physics at space-time and imbedding 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 .

3.4.3 The new view about gauge fields

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 [L18], 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 [L40, L48] 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 [L57, L71].

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 [D32] (<https://cutt.ly/4Wy39B5>)?

3.4.4 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.

3.4.5 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 [L54]. The findings of Mineev et al discussed in [L50] 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) [L78]. 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.

.1 Appendix

.1.1 Comparison of TGD with other theories

Table A.1 compares GRT and TGD and **Table A.2** compares standard model and TGD.

.1.2 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 identification 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 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 symmetry	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 2: Differences and similarities between standard model and TGD

Many-sheeted space-time (see **Fig. A.1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by *wormhole contacts* (see **Fig. A.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** [K54] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- **Adelic physics** [L39, L43] 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 [L10].
- ***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 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 Alfvén 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 factor $h_{eff}/h = n$. 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 superconductors 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 [K26] [L78] 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. A.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 imbedding 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 [L56] [K101]. 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 also 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 [L56] [K101]. 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 [L56] [K101]. 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 [L54]. 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 Mineev et al [L50] give support for BSFR at atomic level. Together with $\hbar_{eff}$ hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

.1.3 Figures

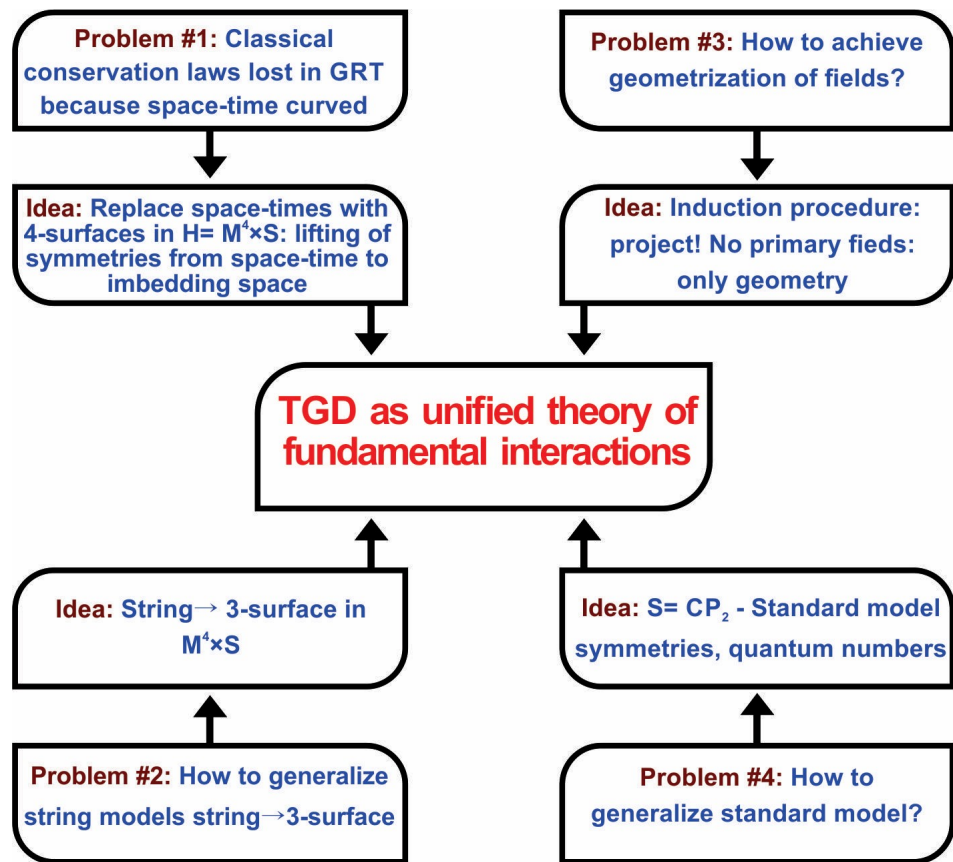


Figure 1: The problems leading to TGD as their solution.

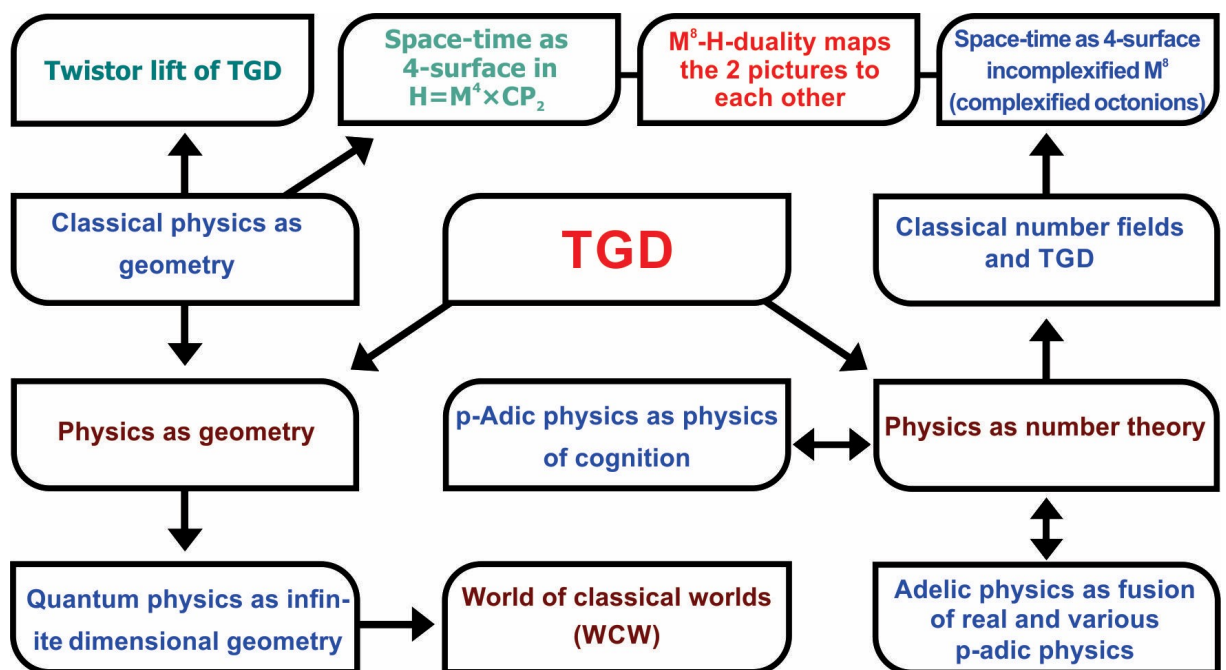


Figure 2: TGD is based on two complementary visions: physics as geometry and physics as number theory.

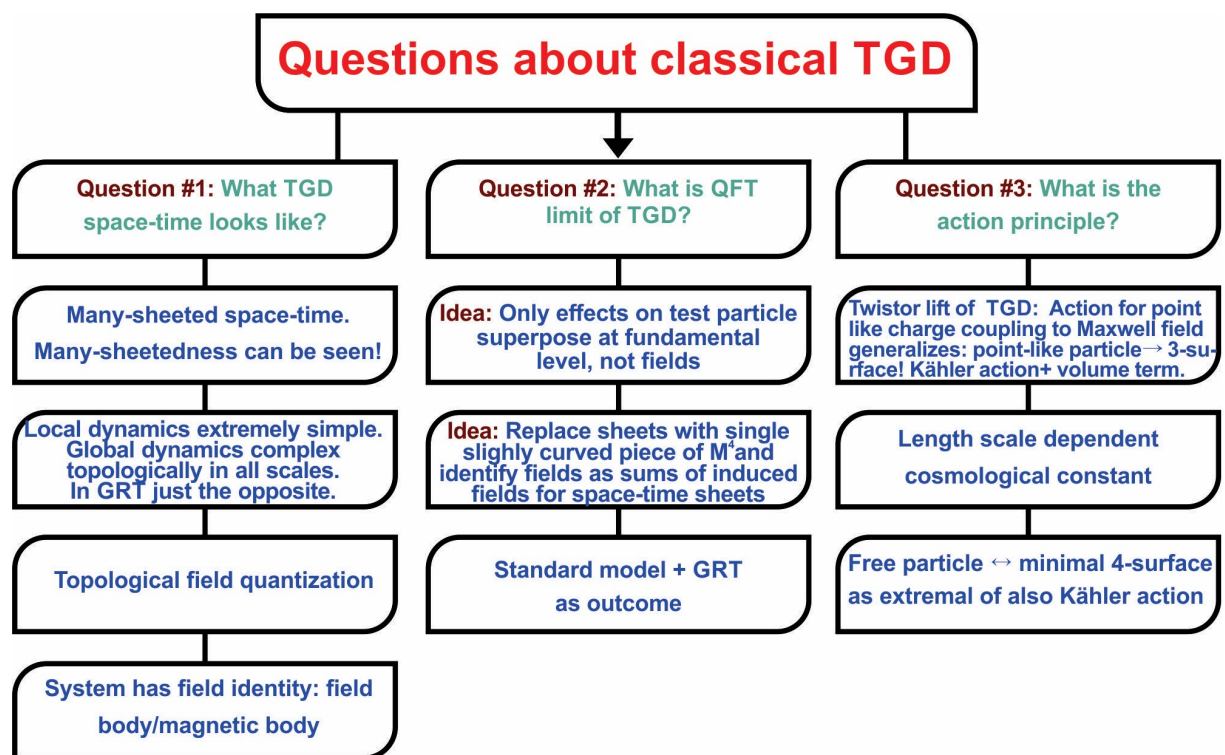


Figure 3: Questions about classical TGD.

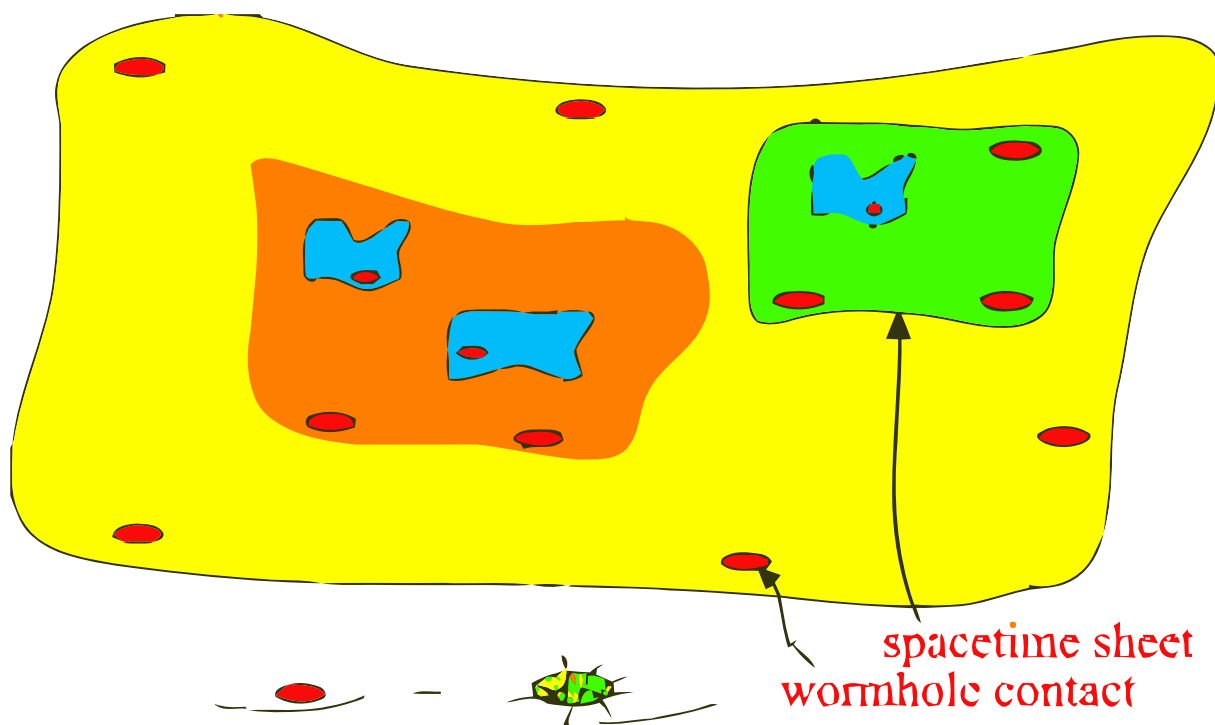


Figure 4: Many-sheeted space-time.

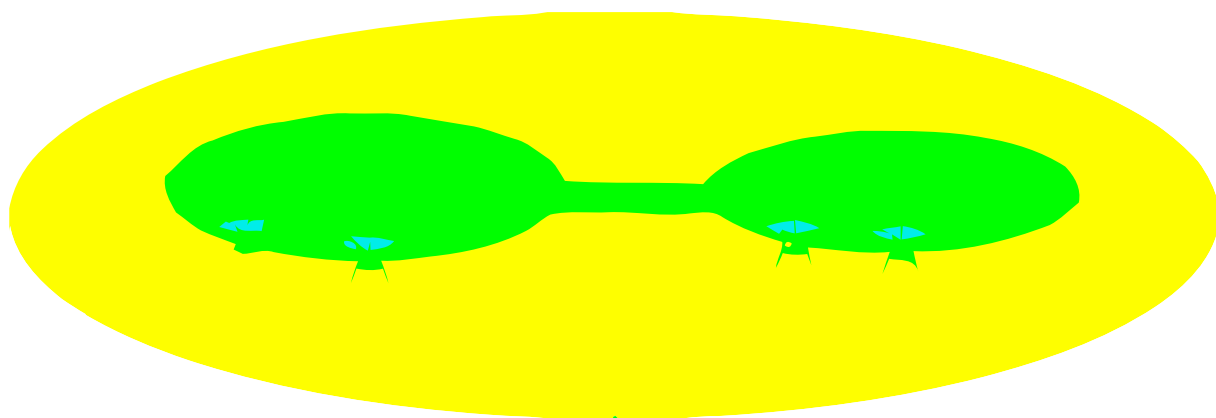


Figure 5: Wormhole contacts.

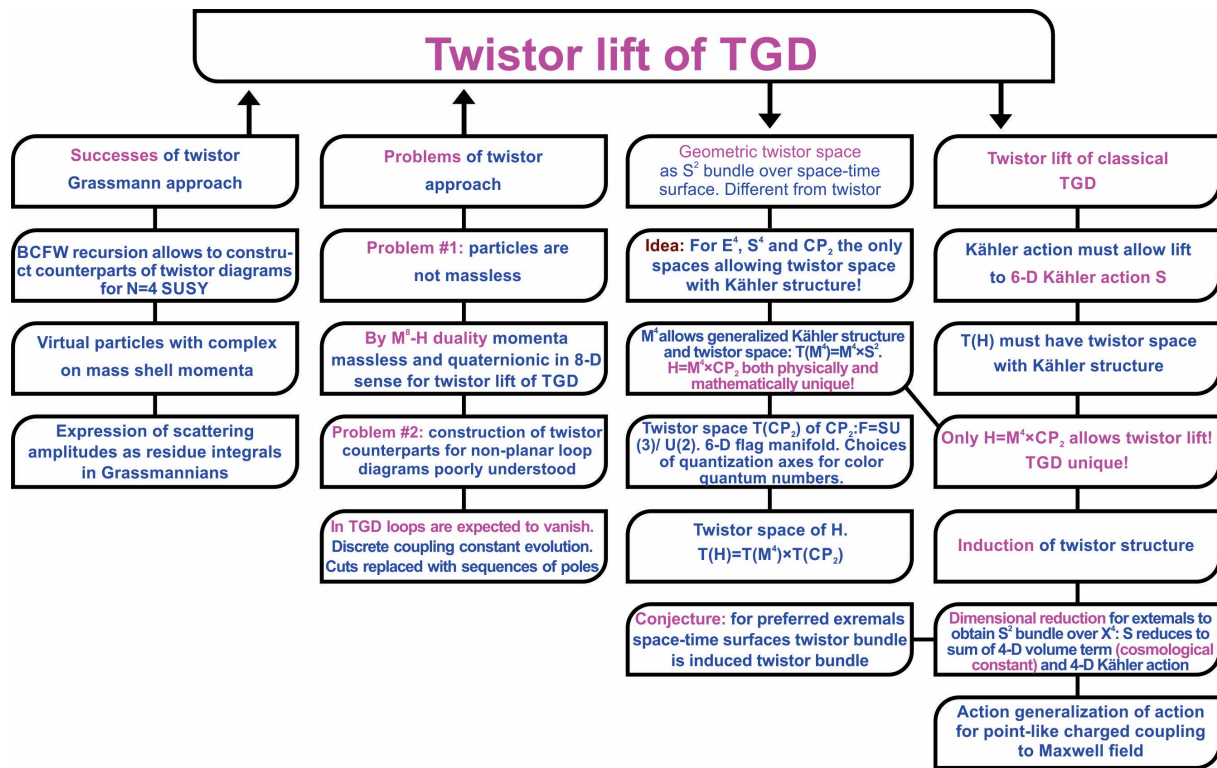


Figure 6: Twistor lift

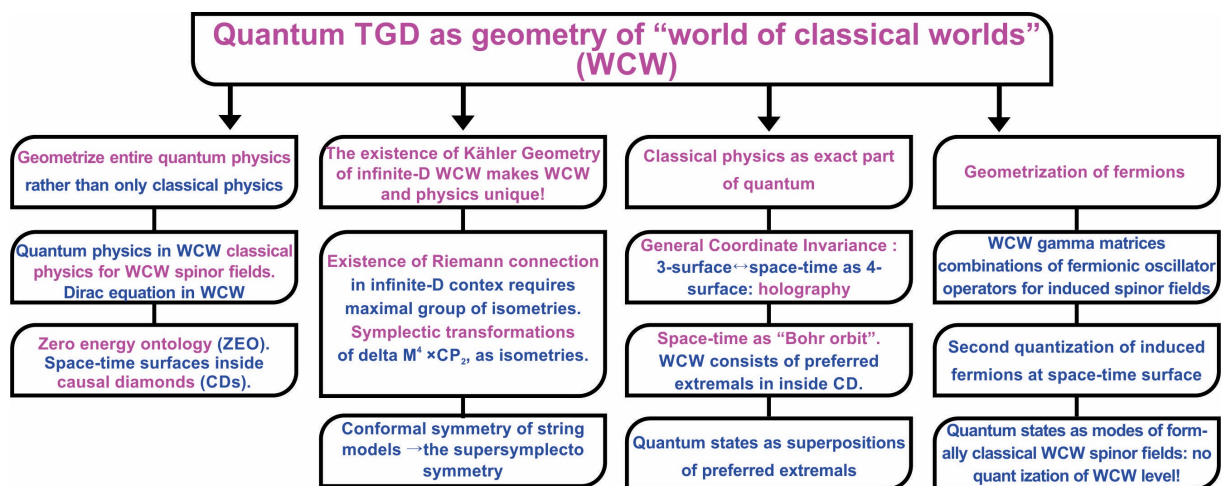
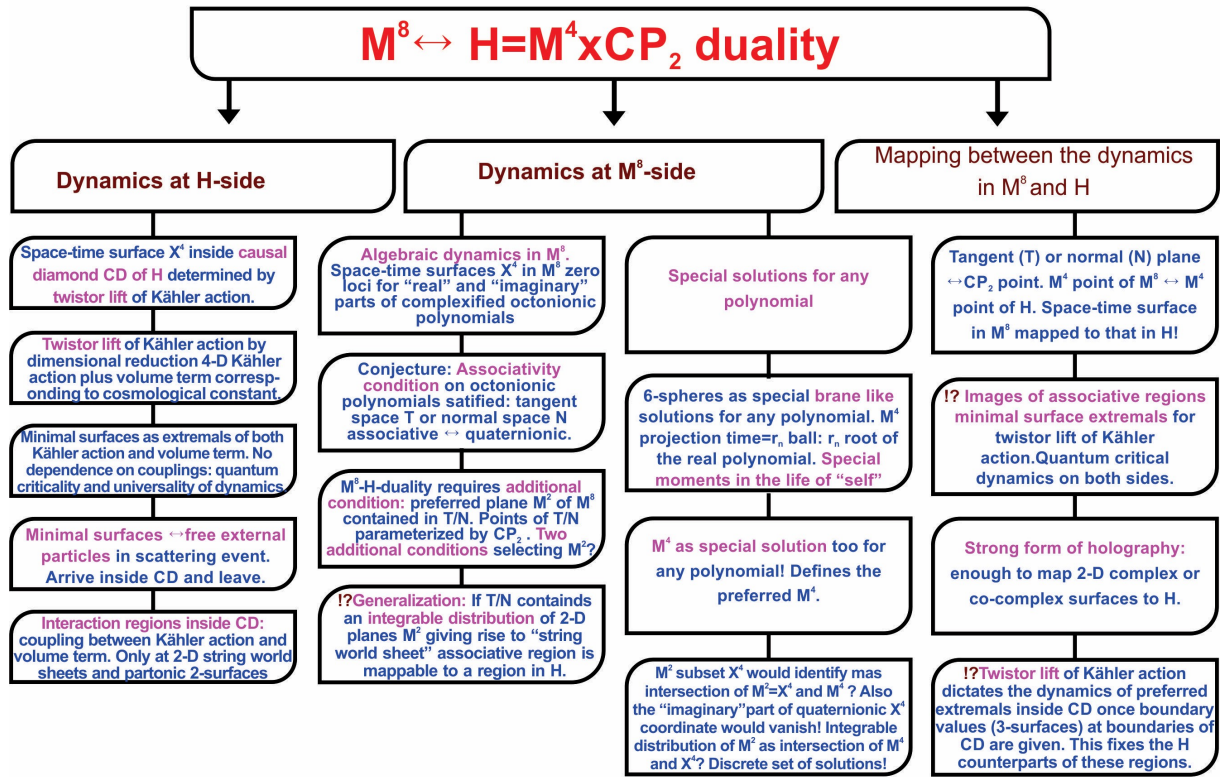


Figure 7: Geometrization of quantum physics in terms of WCW

Figure 8: $M^8 - H$ duality

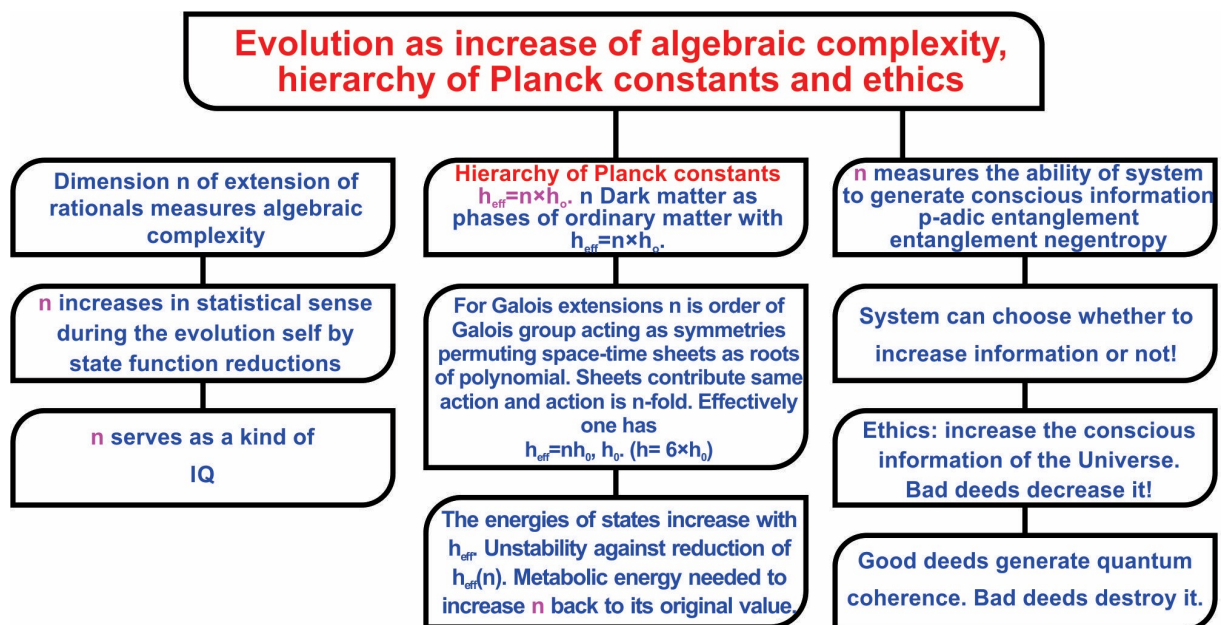


Figure 9: Number theoretic view of evolution

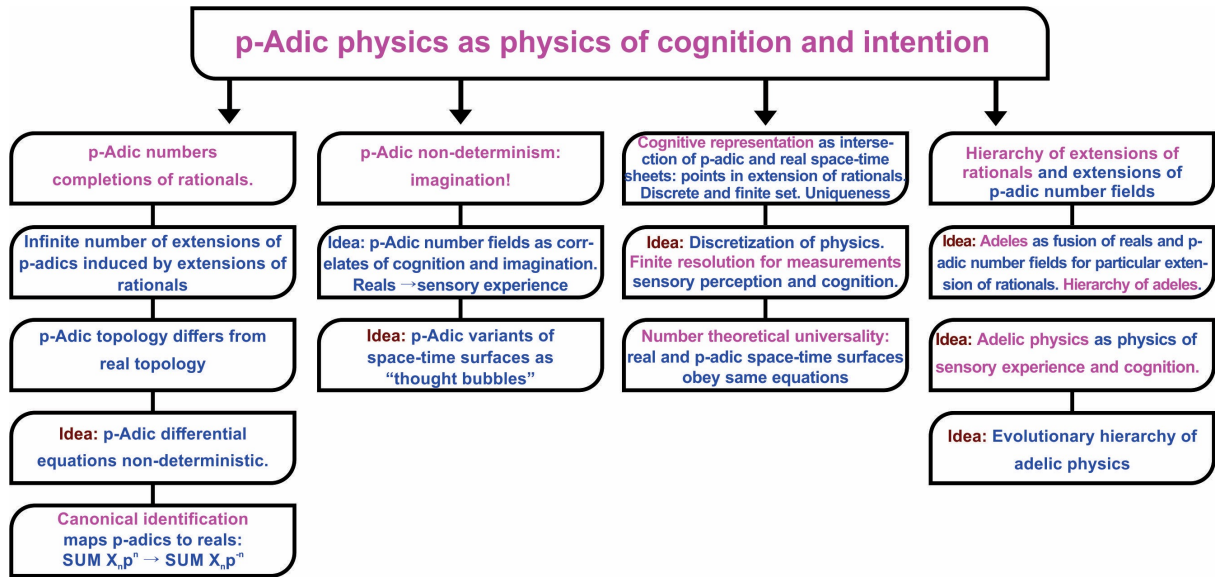


Figure 10: p-Adic physics as physics of cognition and imagination.

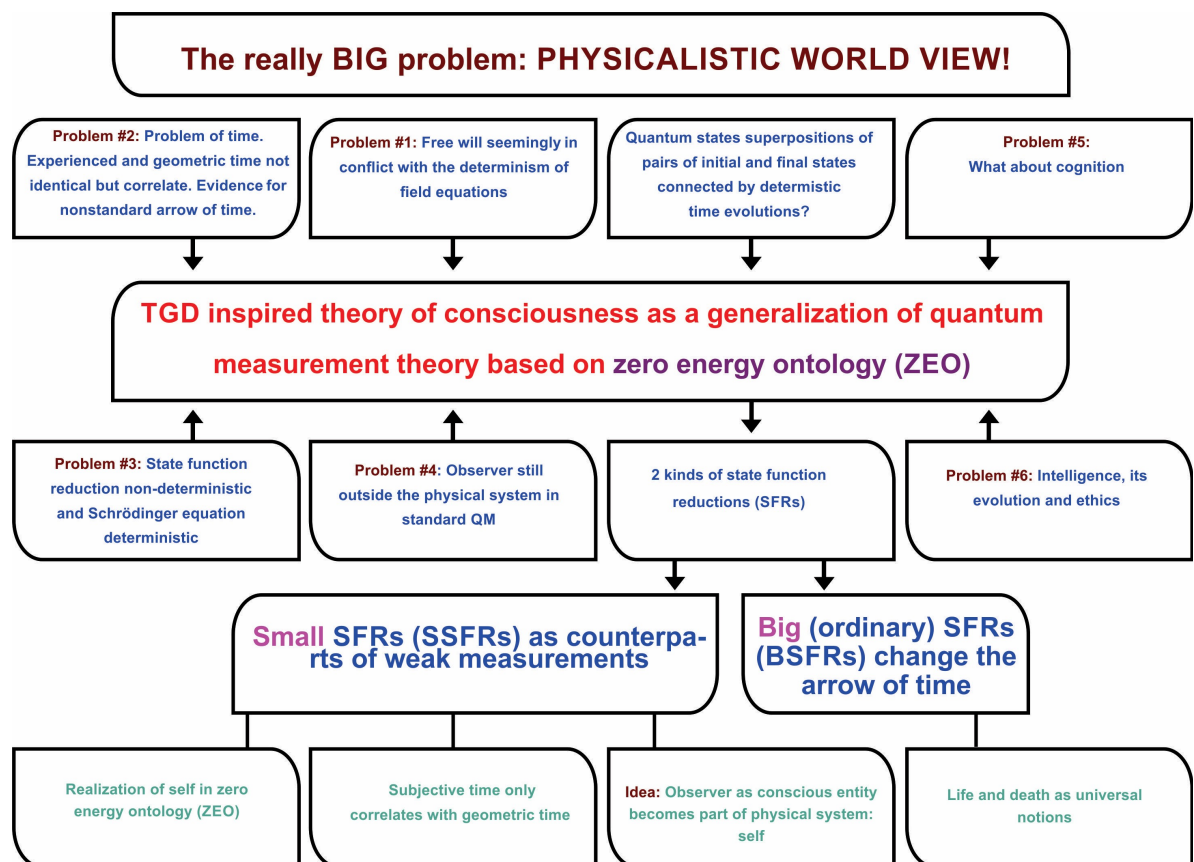


Figure 11: Consciousness theory from quantum measurement theory

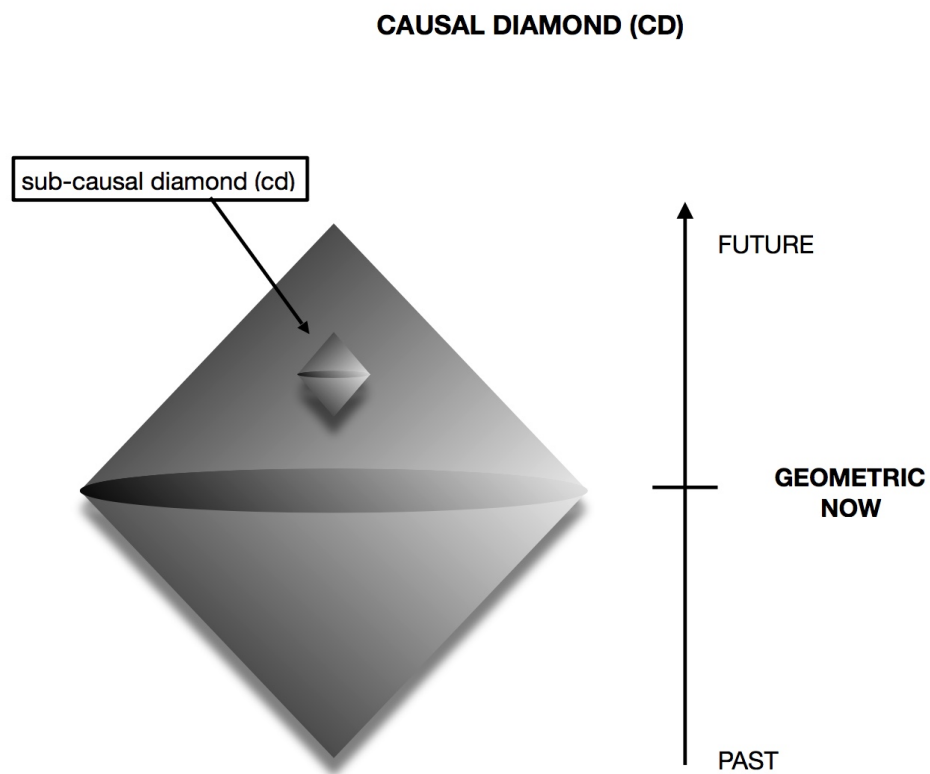


Figure 12: Causal diamond

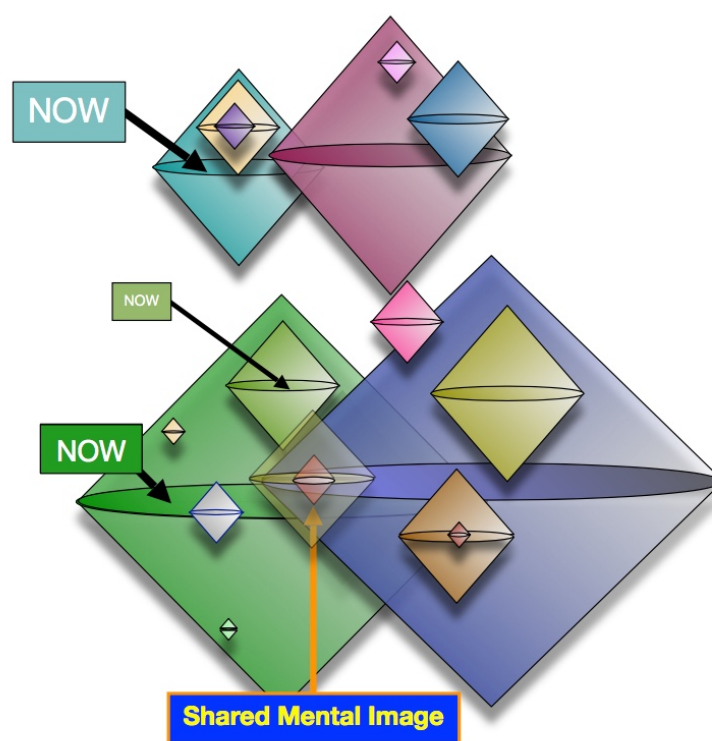


Figure 13: CDs define a fractal “conscious atlas”

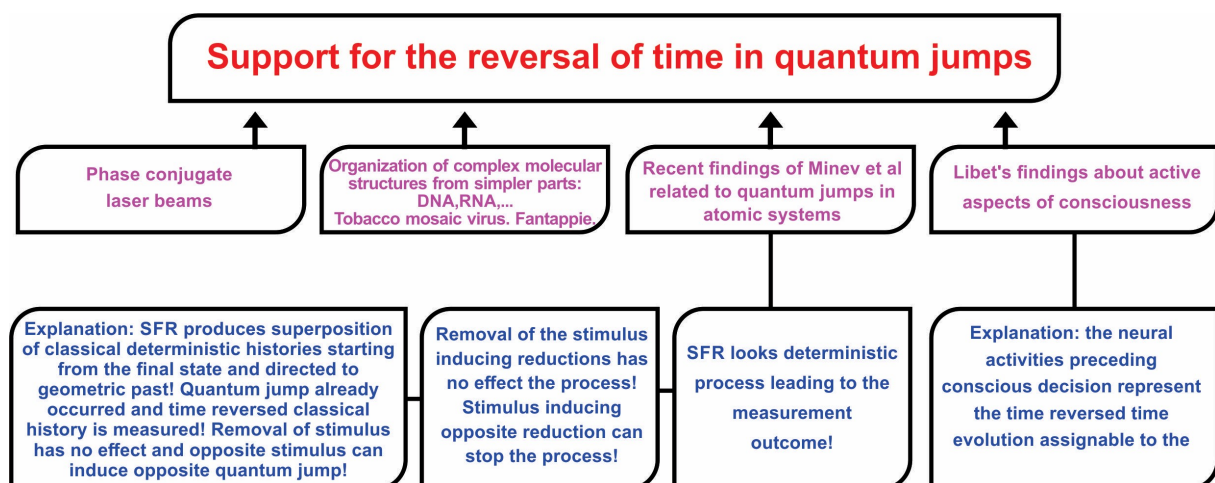


Figure 14: Time reversal occurs in BSFR

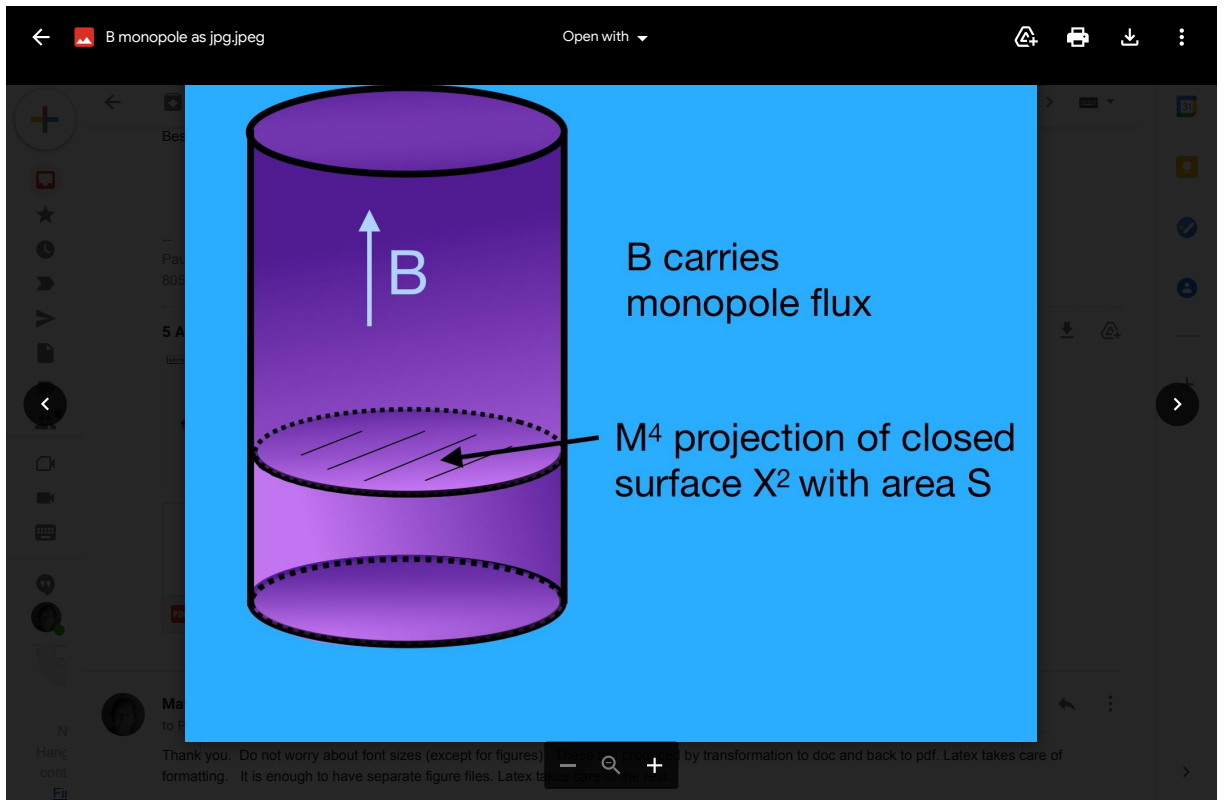


Figure 15: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e \oint B \cdot dS = eBS = kh$ at single sheet of n -sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

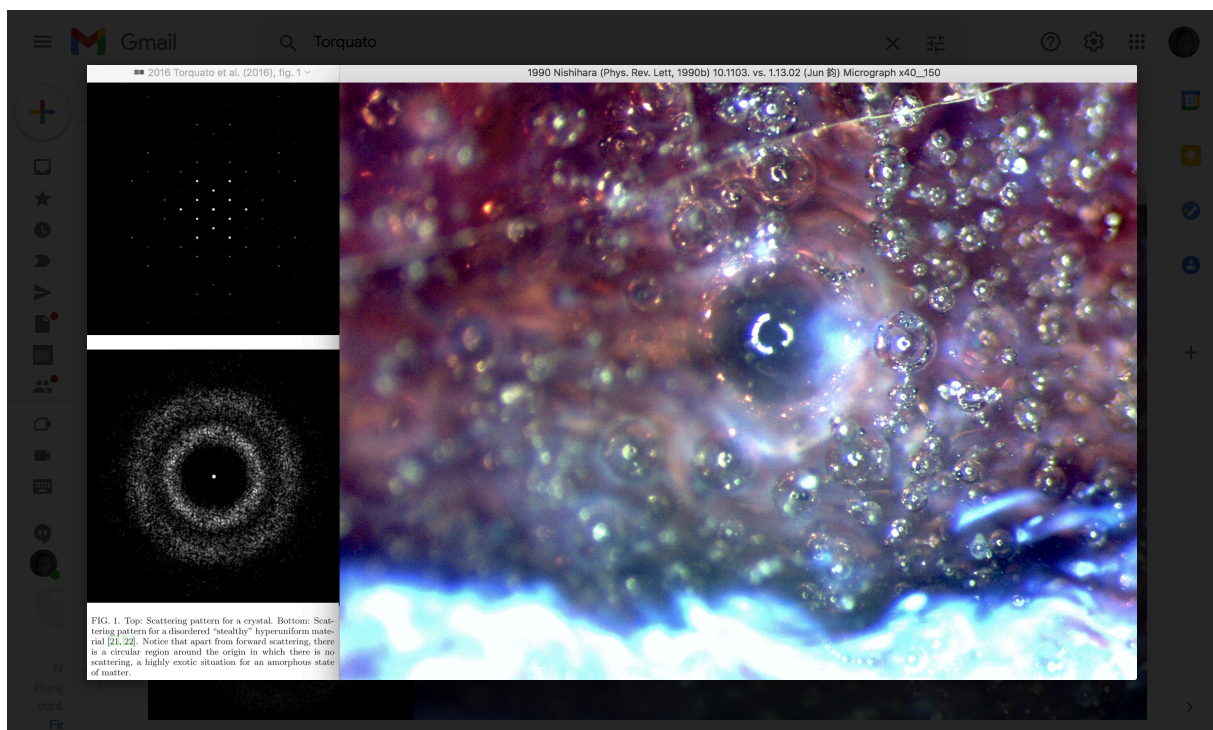


Figure 16: The scattering from a hyperuniform amorphous material shows no scattering in small angles apart from the forward peak (<https://cutt.ly/ZWyLgjk>). This is very untypical in amorphous matter and might reflect the diffraction pattern of dark photons at the magnetic body of the system.

Appendix A

TGD and Quantum Hydrodynamics

A.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 [K62]. 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 [L89]. Beltrami flow for classical Kähler field defines an integrable flow [L72]. 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 bilinear 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 [L83]. This

implies as generalization of the energy conservation along flow lines of hydrodynamical flow ($\rho v^2/2 + p = \text{constant}$).

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 [L89].

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 [D27]. 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 suggest 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 $\hbar_{eff} > \hbar$: 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.

A.2 TGD view about quantum hydrodynamics

In this section the general ideas of quantum hydrodynamics in TGD framework are introduced.

A.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.

A.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 [D14] (<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. A 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 eddies. 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 [D11] (<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 [D14] (<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.

A.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 $\int B dA$ 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 $\exp(iq \oint A dl/\hbar) = \exp(i \oint d\Phi) = 1$ 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 $D^2 A \equiv \nabla^2 A - \nabla(\nabla \cdot A) = j$.

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 $D^2 A$ 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.

A.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 potential $A(CP_2)$ of CP_2 ,
3. or to the sum $A(M^4) + A(CP_2)$, 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 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.

A.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 [K22].

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

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) , \quad (\text{A.2.1})$$

$n_+ = 1$ 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 [L57, L71], 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

$$\begin{aligned} R_{03} &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) , \end{aligned} \quad (\text{A.2.2})$$

in terms of the fields γ and Z^0 (photon and Z - boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - pQ_{em}) \quad p = \sin^2(\theta_W) \quad . \quad (\text{A.2.3})$$

4. Here θ_W is Weinberg angle. Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - pR_{12} \quad , \\ Z^0 &= 2R_{03} \quad . \end{aligned} \quad (\text{A.2.4})$$

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

$$\sum_{sheets} 2(2Y + X) = 0 \quad , \quad Y = e^0 \wedge e^3 \quad , \quad X = e^1 \wedge e^2 \quad . \quad (\text{A.2.5})$$

There is no obvious reason for why this should be the case automatically.

This would give

$$\sum_{sheets} e^1 \wedge e^2 = \sum_{sheets} J_{CP_2} \quad . \quad (\text{A.2.6})$$

This implies

$$\begin{aligned}
\sum_{sheets} e^1 \wedge e^2 &= \sum_{sheets} J_{CP_2} \quad , \\
\sum_{sheets} R_{12} &= \sum_{sheets} 3J_{CP_2} \quad , \\
\sum_{sheets} \gamma &= \sum_{sheets} 3(1-p)J_{CP_2} + 3JM^4 \quad .
\end{aligned}
\tag{A.2.7}$$

The vanishing of $\sum J_{CP_2}$ (Lagrangian surface in CP_2) implies $\sum Z^0 = 0$ and $\sum \gamma = 3JM^4$.

2. The condition $\sum \gamma = 0$ perhaps relevant for ordinary hydrodynamics can be treated in a similar manner. One obtains

This gives

$$\sum_{sheets} 2(2X + Y) = 0 \quad .
\tag{A.2.8}$$

From this one obtains

$$\begin{aligned}
\sum_{sheets} X &= -aY - bJ_{M^4} \quad , \quad a = -\frac{3-p}{3-2p} \quad , \quad b = -\frac{3}{2(3-2p)} \quad . \\
J_{CP_2} &= 2(cY + dJ_{M^4}) \quad c = -\frac{2p}{6-4p} - \frac{6}{6-4p} \quad .
\end{aligned}
\tag{A.2.9}$$

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

$$Z^0 = 2(-Y - J_{M^4}) = 2(-Y + J_{CP_2}) \quad .
\tag{A.2.10}$$

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 $R_{03} = 2(e^0 \wedge e^3 + e^1 \wedge e^2)$ 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 $\sum \gamma = 3(1-p/2) \sum J_{CP_2} + 3JM^4$. 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 $\sum \gamma = -p \sum Z^0 + 3JM^4$. 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.

A.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 A.7.2 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-monopole 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

$$\frac{F}{L} = \rho v \Gamma, \quad \Gamma = \oint v \cdot dl = \int (\nabla \times v) \cdot dA. \quad (\text{A.2.11})$$

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^0 plasma, 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 [K72] [L86], 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 [K24, K11] 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 $\hbar_{eff} = \hbar_{gr}$.

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 $\hbar_{eff}$ 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 $\hbar_{eff}$ 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.

A.3 TGD view about the generation of turbulence

A.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 $\hbar_{eff} > \hbar$ 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 $\hbar_{eff} > \hbar$ 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 [L85] 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 Schwartschild radius r_s . Λ_{gr} for Earth appears in the TGD based model for superconductivity [L72].

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 $h_{eff} = h$ [L85]. 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-monopole 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 [K101] [L56] 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 Mineev et al suggest [L50]. 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 [D50], 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 order micrometer to be compared with 1 Angstrom size in Helium superfluid.

To sum up, although the picture described in this section 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 [K69, K89, K82, L51] could correspond to this phase.

A.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 $v_{in} L = v_{out} \delta$. The ratio $R_{SP} = v_{in}/v_{out} = B_{out}/B_{in}$ is called normalized or dimensionless 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 Alfvén 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 A.7.2 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/fEq5on1>) 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 $\epsilon_r = \epsilon/\epsilon_0$

$$\begin{aligned} \beta &= \sqrt{1/\epsilon_r} = \frac{1}{\sqrt{1+\rho/B^2}} = \frac{\beta_A}{\sqrt{1+\beta_A^2}} , \\ \beta_A &= \sqrt{\frac{B}{\rho}} . \end{aligned} \tag{A.3.1}$$

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.

$$R_{rec} \sim \frac{1}{\tau_{rec}} = \frac{v}{l} . \tag{A.3.2}$$

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:

$$l = \frac{1}{n^{1/2}} . \tag{A.3.3}$$

3. The magnetic flux for monopole flux tubes is conserved and quantized as

$$\Phi_{tube} = \oint_{tube} q_K B_K dS = nm\hbar, \quad \frac{\hbar_{eff}}{\hbar} = m. \quad (A.3.4)$$

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

$$n = \frac{N_{tube}}{L^2}. \quad (A.3.5)$$

5. The number N_{tube} of flux tubes intersecting the plane can be estimated in terms of total magnetic flux as

$$N_{tube} \sim \frac{\Phi_{tot}}{\langle \Phi_{tube} \rangle}. \quad (A.3.6)$$

6. This would give for R_{rec} the expression

$$lR_{rec} = \frac{1}{\tau_{rec}} = v \times n^{1/2} = v \times \frac{N_{tube}^{1/2}}{L} \sim v \times \sqrt{\frac{\Phi_{tot}}{\Phi_{tube}}} \frac{1}{L}. \quad (A.3.7)$$

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.

Alfven waves propagate with the Alfven velocity

$$v = v_A = \frac{B_K}{\sqrt{\rho}}. \quad (A.3.8)$$

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 [D90] 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 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-on collision of two circular vortices. The article of Chen et al [D74] 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. A.5**) and **A.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 flux 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. A.5**) illustrates the complexity of the resulting patterns. **Fig. A.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 that 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. A.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. A.5**).

A.3.3 Breaking of the circulation theorem of Kelvin

This section was motivated by the article of Tobias et al [D18] 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 [D18].

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 citebartGaloisTGD. 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 [L70]. 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 $n\hbar_0$ 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 [L67, L70] occur for extensions of extensions... of rationals Q representable as $Q \rightarrow E_1 \dots \rightarrow E_n$ 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 [L70].
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 in 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 [D18], 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} . $\hbar_{gr} = GMm/v_0$ is suggestive and mass M would be much larger in astrophysical scales: note that gravitational Compton length for particle with mass m is $\Lambda_{gr} = GM/v_0$ [L87, L86].

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 $\nu/\eta \leq 1$ 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 [L73].

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 [L56] [K101]. 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 [L50].

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.

A.3.4 Kelvin-Helmholtz 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 linear. 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/mENp0dq>). 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 $x \rightarrow x - i/2$. 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 [L83].

1. The restriction to imaginary shifts $x \rightarrow x + iy_0$ of real M^4 coordinates implied by the generalized hermiticity condition allows only imaginary shifts for space-like M^4 coordinates in M^8 interpreted as momentum space. The reality of the number theoretic norm requires $\sum x \cdot y_0 = 0$. 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 [L90].

A.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 $h_{eff}/h = n$?

A.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 bouncing 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 macroscopic 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 [D27] 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 [L54] 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 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 [E1] [L79] and also appearing in the TGD based model of superconductivity [L72]. 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 Scwarschild 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 [D27] 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 accelerations. 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 [L89] as SSFRs. In the TGD inspired theory of consciousness, the loci of non-determinism for space-time surfaces as analogs of soap films 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).

A.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

$$\begin{aligned} \frac{d^2 z}{dt^2} + 2\mu \frac{dz}{dt} + \Omega^2(t)z &= 0 \quad , \\ \Omega^2 &= \omega_0^2(1 + \alpha(t)) \quad . \end{aligned} \quad (\text{A.4.1})$$

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

$$g(t) = g + A\omega_0^2 \cos(\omega t) = g(1 + \Gamma \cos(\omega t)) \quad . \quad (\text{A.4.2})$$

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 recent 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

$$\omega_{min} < \omega < \omega_{max}, \quad \Omega_{\pm} = 2\omega_0 \pm \sqrt{\Gamma\omega_0^2 - 4\mu^2} \quad , \quad (\text{A.4.3})$$

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

Floating droplets on vibrating bath were first described by Jearl Walker in Scientific American in 1978. In 2005, bouncing droplets on vibrating 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 a sum 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 $q2m\Omega \int_{\rho_0}^{\rho_n} f(\rho/\rho_0)\rho d\rho 2\pi = n\hbar e f f$. This gives $f(\rho) = \rho_0/\rho$ and

$$\rho_n = n \frac{\hbar e f f}{m 2 Q \Omega \rho_0^2} . \quad (\text{A.4.4})$$

The vector potential qA_ϕ would be of form

$$qA_\phi = 2m\Omega \log\left(\frac{\rho}{\rho_0}\right) . \quad (\text{A.4.5})$$

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 [D27]. 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 $U\lambda_F = U\hbar_{gr}/m$.

A.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 Mineev 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 $\hbar_{eff}$ hierarchy. Of course, also the basic paradox of quantum measurement theory disappears by ZEO.

$\hbar_{eff}$ hierarchy and gravitational Planck constant

$\hbar_{eff}$ 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 $\hbar_{eff}$ at MB is much larger since the scale is dramatically larger. The first guess is that $\hbar_{eff}/\hbar$ 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 to be a more realistic guess!

3. Viscosity and magnetic diffusivity could be proportional to $\hbar_{eff}/m$ as proposed in the 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 $\hbar_{eff}$ 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 droplet 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

$$\hbar_{eff} = \hbar_{gr} = \frac{GMm}{v_0} , \quad (\text{A.4.6})$$

where $\hbar_{gr}$ is the gravitational Planck constant introduced by Nottale [E1] [L79] and also appear in the TGD based model of superconductivity and superfluidity [L72]. This would give

$$\lambda_F = \lambda_{gr} = \frac{GM}{v_0} = \frac{r_s(M)}{2v_0} , \quad (\text{A.4.7})$$

where $r_s(M)$ is Schwarzschild 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 Schwarzschild 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 [D27] 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

$$\frac{2\nu}{\mu} = \left(\frac{GM}{v_0}\right)^2 . \quad (\text{A.4.8})$$

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 $.107M_E$ 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 statistical 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 $\hbar_{eff} = n\hbar_0$ 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 induced 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 [L89] 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 binary 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 [L67, L75]

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 analogous to 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 [L67, L83].

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.

A.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.

A.5.1 The notion of viscosity

Kinematic viscosity (<https://cutt.ly/iRuXTsH>) for liquid can be fitted by using the expression

$$\nu\left(\frac{h}{m}, \frac{T}{T_b}\right) = \frac{h}{m} \times f\left(\frac{T_b}{T}\right) , \quad f\left(\frac{T_b}{T}\right) = \exp(3.6 \frac{T_b}{T}) . \quad (\text{A.5.1})$$

(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} m²/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.

A.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

$$\frac{\delta}{x} = \frac{5}{\sqrt{Re_x}} , \quad Re_x \leq Re_{x_{cr}} \simeq 5 \times 10^5 . \quad (\text{A.5.2})$$

For a turbulent flow past a flat plate of finite length L , the prediction is

$$\frac{\delta}{x} = \frac{.38}{Re_L^{1/5}} , \quad 5 \times 10^5 \leq Re_L < 10^7 , \quad (\text{A.5.3})$$

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

$$L = m\delta \times U , \quad \delta = 5\sqrt{\frac{\nu}{u}}\sqrt{x} . \quad (\text{A.5.4})$$

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

$$L = 5m \times Re_{cr}\nu . \quad (\text{A.5.5})$$

$L = \hbar_{eff}$ would give for the transition

$$Re_{cr} = \frac{\hbar_{eff,f}}{\hbar_{eff,i}} \quad \text{for} \quad \hbar_{eff,i} = 5m\nu . \quad (\text{A.5.6})$$

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

$$Re_V = \frac{U\delta}{\nu} = \frac{\delta}{D} \times Re_{cr} = 5Re_{cr}^{1/2} . \quad (A.5.7)$$

A.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 inertia. 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

$$\frac{f(T/T_b)}{f(1)} = \frac{\hbar_{eff}(T)}{\hbar(T_b)} \times \frac{m(T)}{m_f(T_b)} \geq 1 . \quad (A.5.8)$$

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} .

A.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 $v_0 = \text{time} q 2^{-11}$ in the Nottale's model for 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 [L72] 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 Schwarzschild radius of Sun one has for the gravitational Compton length of Sun $\Lambda_{gr}(\text{Sun}) = GM_{\text{Sun}}/v_0 = 6$ 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. $\Lambda_{gr}(\text{Sun}) = 6 \times 10^3$ 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 for M_{MW} vary in the range $M_{MW}/M_{\text{Sun}} \in [10^{11} - 10^{12}]$ 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 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 $M(M_{MW}/M_{\text{Sun}} = 5.0 \times 10^{10})$ giving for the Schwarzschild 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

$$\frac{D_{pr}}{D_R} = \frac{r_{S,MW}}{D_R} \times \frac{c}{U\beta_0} \simeq 5 \times \frac{c}{U\beta_0} .$$

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 $.012M_E$. 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 $\hbar_{eff} \leq \hbar_{gr}$. $\hbar_{gr}$ 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 $\beta_0 \simeq 1 \rightarrow 2^{-11}$ 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 $M_E \rightarrow M_{Sun}$ and $\beta_0 \simeq 1 \rightarrow 3\beta_0/5$?

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 $\Lambda_{gr} \in \{.1 \text{ m}, 3.2 \text{ km}, 644 \text{ Mm}\}$.

Needless to emphasize, these proposals are only a light-hearted thought game taking seriously the notion of macroscopic quantum gravitational coherence.

A.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 [E1].

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}

$$\nu_{gr} = \Lambda_{gr} c = \frac{GMc}{\beta_0} = \frac{r_s c}{2\beta_0} . \quad (\text{A.5.9})$$

This corresponds for Earth's mass $M = M_E$ and $\beta_0 = 1$ to the Schwarzschild 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} m²/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 variation of β_0 could allow us to understand the dependence on temperature.

Could one understand kinematic viscosity in terms of masses of geological or atmospheric objects?

Could one understand kinematic viscosity in terms of masses of geological or atmospheric 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 $\Lambda_{gr} \simeq 10^6$ m²/s whereas centiStoke as natural unit of η is 10^{-6} m²/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/m³ 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/m³ 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.

A.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 $\hbar_{em}/\hbar > 1$ and $\hbar_Z/\hbar > 1$ and this gives the following criterion for darkness

$$\begin{aligned} Q_Z &\geq \frac{\beta_0}{4\pi\alpha_Z} , \\ Q_{em} &\geq \frac{\beta_0}{4\pi\alpha_{em}} , \end{aligned} \tag{A.5.10}$$

In the electromagnetic case and for $\beta_0 = 1$, the transition would take place for completely ionized atoms with charge $Q_{em} > 10$. Sodium 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 [L92, L76, L75].

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

$$\Lambda_{em} = \frac{\hbar_{em}}{m} , \tag{A.5.11}$$

$$\Lambda_Z = \frac{\hbar_Z}{m} , \tag{A.5.12}$$

$$\tag{A.5.13}$$

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 $\hbar_{gr}/\hbar$ 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 plasma 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 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

$$L_\nu = \frac{\nu}{c} = \frac{\hbar_Z}{m} = \frac{4\pi\alpha_Z q_z^2 N}{\beta_0} \frac{\hbar}{m} . \quad (\text{A.5.14})$$

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

$$N = \frac{1}{4\pi\alpha_Z q_z^2} \times \beta_0 \frac{f(T/T_b)}{f(1)} . \quad (\text{A.5.15})$$

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.

$$\begin{aligned}
\Lambda_{em} &= \Lambda_Z = \lambda_{gr} , \\
\Lambda_{em} &= \frac{\hbar_{em}}{m_e} = \frac{e^2 q^2 N_p}{\beta_0} L_{c,e} \sim \frac{10^{-2} N_p}{\beta_0} \times 2 \times 10^{-12} \text{ m} , \\
\Lambda_Z &= \frac{\hbar_{em}}{m_\nu} = \frac{e^2 q^2 N_n}{\beta_0} L_{c,\nu} \sim \frac{10^{-2} N_n}{\beta_0} \times 10^{-6} \text{ m} \sim \Lambda_{gr} , \\
\Lambda_{gr} &= \frac{GM}{\beta_0} , \\
(M, \beta_0) &\in \{(M_E, \beta \simeq 1), (M_{Sun}, \beta_0 \simeq 1), (M_{Sun}, \beta_0 \simeq 2^{-11})\} .
\end{aligned} \tag{A.5.16}$$

This gives the conditions

$$\begin{aligned}
N_p &= \frac{\beta_0}{e^2 q^2} \frac{\Lambda_{gr}}{L_{c,e}} , \\
N_n &= \frac{\beta_0}{g_Z^2 q_Z^2} \frac{\Lambda_{gr}}{L_{c,\nu}} .
\end{aligned} \tag{A.5.17}$$

This gives for $\Lambda_{gr} \in \{1.0 \text{ cm}, 3.2 \text{ km}, 6.4 \text{ Mm}\}$.

$$\begin{aligned}
N_p &= \frac{4\pi\beta_0}{\alpha e^2} \frac{\Lambda_{gr}}{L_{c,e}} \in \frac{4\pi\beta_0}{\alpha e^2} \times \{.5 \times 10^{10}, 1.6 \times 10^{15}, \\
N_n &= \frac{4\pi\beta_0}{\alpha_Z q_Z^2} \frac{\Lambda_{gr}}{L_{c,\nu}} \in \frac{4\pi\beta_0}{\alpha_Z q_Z^2} \times \{2.5 \times 10^{16}, 8.0 \times 10^{21}, 1.8 \times 10^{25}\} .
\end{aligned}$$

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 [L14] 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 [L92]. 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

$$\Lambda_{gr,dB} = \frac{\hbar_{gr}}{mv} = \frac{GM}{v_0 v} = \frac{r_s c^2}{2\beta_0 \beta} . \quad (\text{A.5.19})$$

The length scale $UD = \Lambda_{gr}/m$ gives $D = \Lambda_{gr,dB}$ for 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 [K54]. $p = 2$ 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 $\beta_0(\text{Sun}) \simeq 2^{-11}$ 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 $\beta_0(\text{out}) = \beta_0(\text{in})/5$. $p = 5 = 2^2 + 1$ 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 $n = 2, 4, 5$ for the inner planets and as $n = 5k$ for $k = 2, \dots, 6$, 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 $\beta_{0,1} = \beta_0(\text{Sun})$.

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 $2^{k+4+1/2}$ $k = 0, 1, \dots, 6$ 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 $\beta_{0,1}(\text{out})$ for solar-planet gravitational flux tubes satisfies $\beta_{0,1}(\text{out}) = 1.1\beta_{0,1}(\text{in})$. 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.

A.6 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.

A.6.1 Cold fusion, nuclear tunnelling, $\hbar_{eff}$, and BSFRs

This model allows us to understand "cold fusion" in an elegant manner [L30, L63, L16]. 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.

A.6.2 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 [L72, L83]. 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 as 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 $\hbar \rightarrow \hbar_{eff}$. 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 $\hbar_{eff} > \hbar$ must be present.

p-Adic length scale hypothesis led to the proposal [K27, K28] 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 [L92, L65, L76] and also to explain the strange findings of Eric Reiter challenging some basic assumptions of nuclear physics if taken at face value [L84].

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 $\hbar_{eff} \rightarrow \hbar$ would take place and yield M^{89} mesons. It would seem that part of the matter of the composite system ends up to a M_{89} hadronic phase with 512 times higher T_H . In the number theoretic picture, these BEC like states would be Galois confined states [L70, L75].

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 do 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 $\hbar_{eff}$ 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 $\hbar_{eff}/\hbar \geq m_H/m_q$. The hadrons containing u, d, and c quarks are very special.
2. Second option is that the value of $\hbar_{eff}$ for quarks is smaller than $\hbar$ 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.

A.7 Appendix

A.7.1 Comparison of TGD with other theories

Table A.1 compares GRT and TGD and Table A.2 compares standard model and TGD.

A.7.2 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. A.1) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by *wormhole contacts* (see Fig. A.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 identification 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 A.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 symmetry	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 A.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** [K54] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.
- **Adelic physics** [L39, L43] 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 [L10].

- ***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 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 Alfvén 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 $E_c = \hbar ZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $\hbar \rightarrow \hbar_{eff}$ E_c is scaled up by a factor $\hbar_{eff}/\hbar = n$. For sufficiently high value of $\hbar_{eff}$ cyclotron energy is above thermal energy $E = \hbar_{eff} ZeB/m$. 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 superconductors 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 [K26] [L78] 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. A.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 imbedding 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 [L56] [K101]. 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 also 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 [L56] [K101]. 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 [L56] [K101]. 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 [L54]. 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 Mineev et al [L50] give support for BSFR at atomic level. Together with $\hbar_{eff}$ hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

A.7.3 Figures

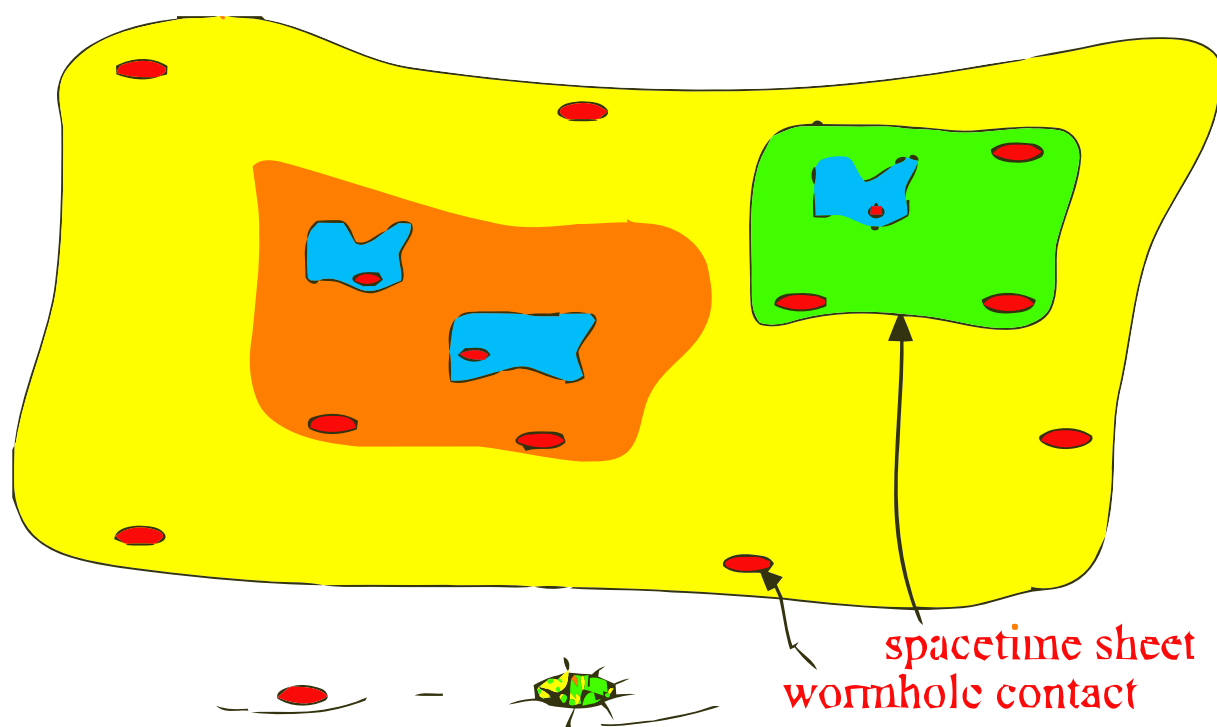


Figure A.1: Many-sheeted space-time.

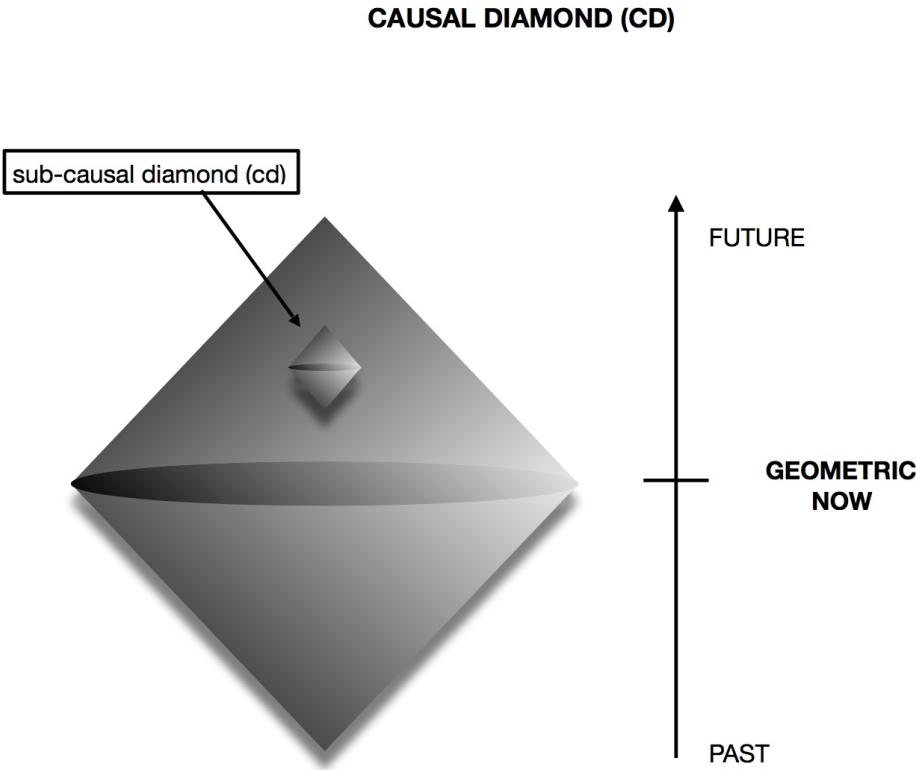


Figure A.2: Causal diamond

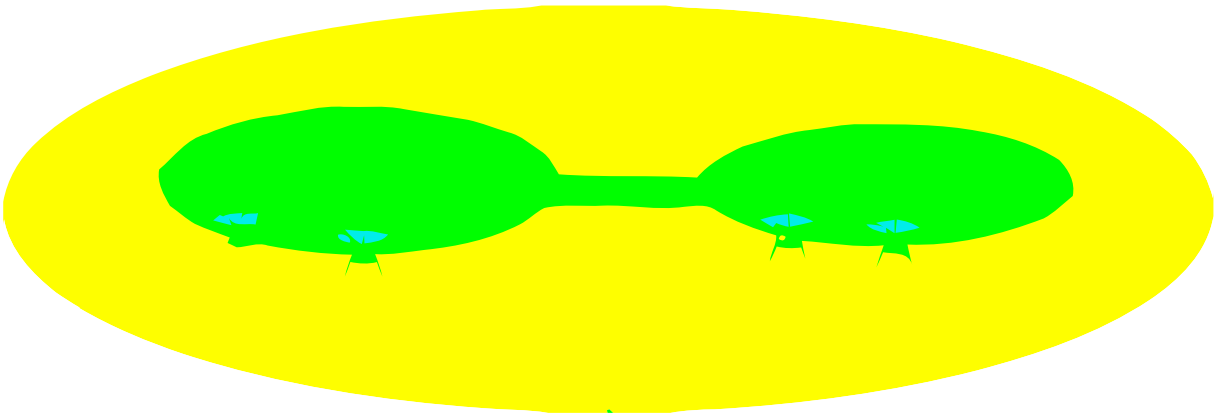


Figure A.3: Wormhole contacts.

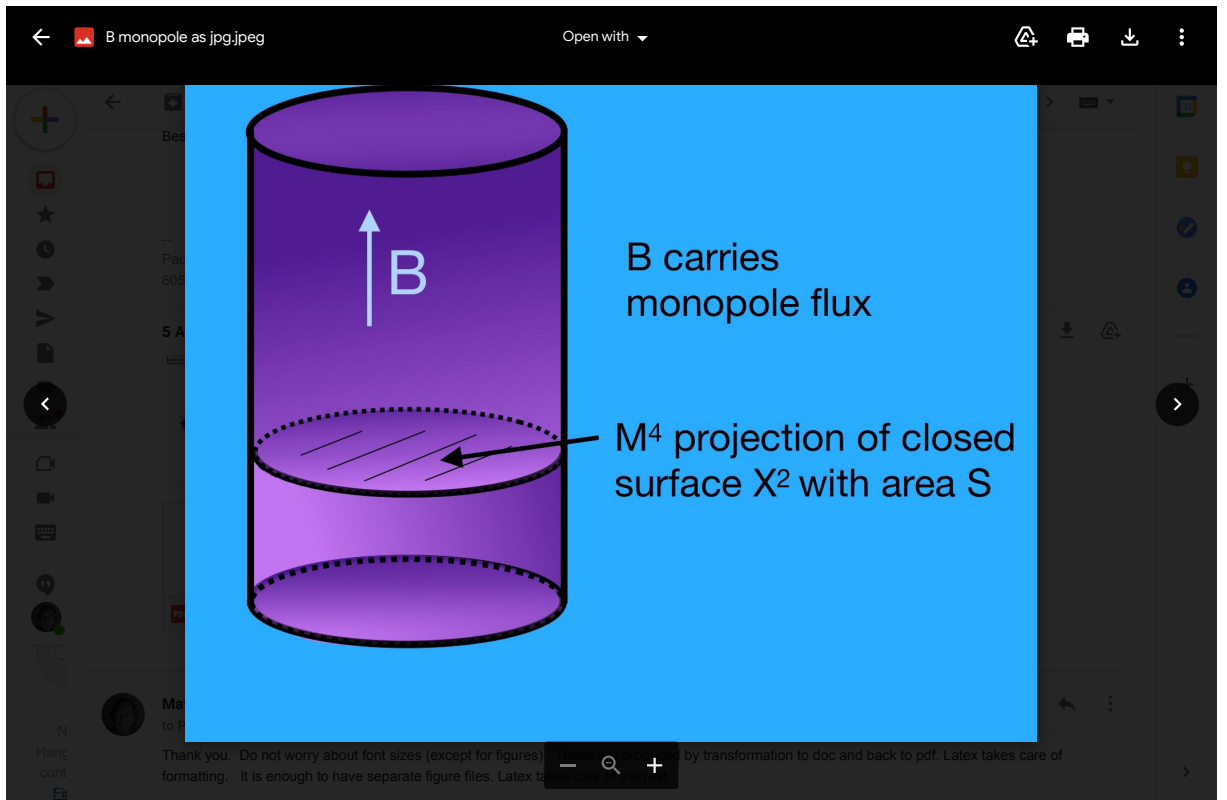


Figure A.4: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e \oint B \cdot dS = eBS = kh$ at single sheet of n -sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

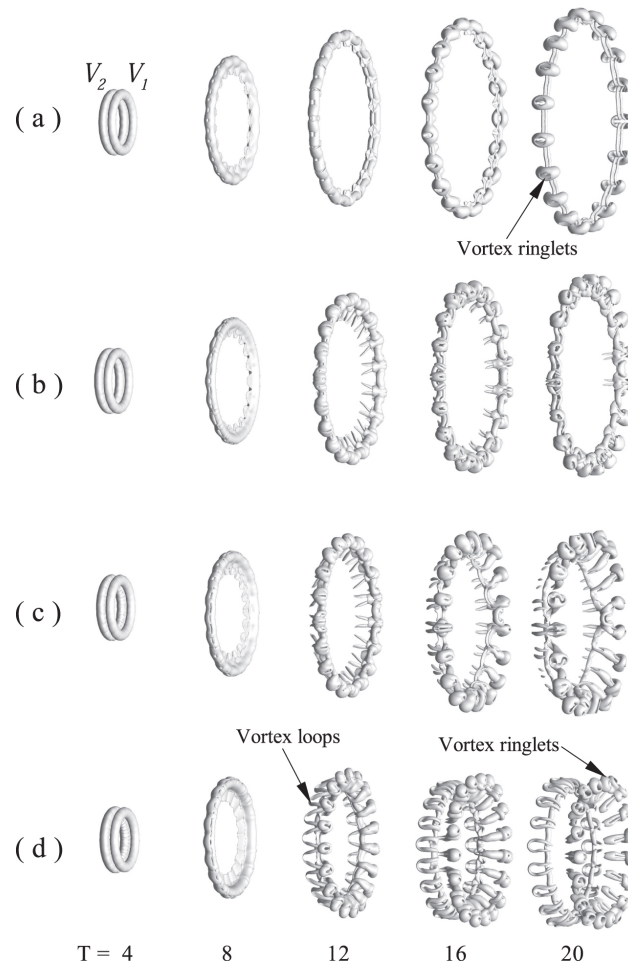


Figure A.5: Illustrations of flow patterns resulting in a numerical simulation of a head-on collision of vortex rings with opposite circulations.

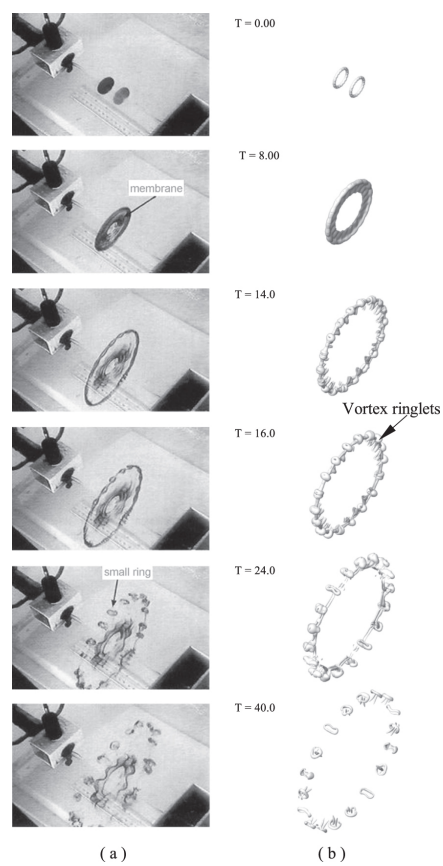


Figure A.6: Illustrations of flow patterns resulting in a real head-on collision of vortex rings with opposite circulations.

Appendix B

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

B.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 adiabatically evolving systems. I learned about the theory from a popular article published in Scitechdaily (<https://cutt.ly/LmS4t0l>).

A more technical description of the model can be found in an article [D69])(<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".

B.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 [D69] is following:

1. In standard model of super-conductivity 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 super-current. 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 [D56] 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 modle 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 supercurrent.

The integrable flow is a 4-D generalization [K33, K34, K3] of the notion of 3-D Beltrami (magnetic) field [B4, B25, 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 [L89]. 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 [L92].
4. The formation of Cooper pairs occurs 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 SCy 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.

B.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 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?

B.2 TGD based model of superconductivity

TGD inspired model of super-conductivity has developed slowly during years [K33, K34] [L19] [L49].

B.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 arbitrarily 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 evolution 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 [L93] assumes that the space-time sheets carrying dark matter slowly approach thermal equilibrium with the space-time sheets carrying ordinary matter [L91]. 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 unnecessary. 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 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 $T_{c1} > T_c$ 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 $\hbar_{eff} > \hbar$ phase.
6. For gravitational flux tubes the generalization of Nottale hypothesis [E1] states that $\hbar_{gr} = GMm/v_0$ 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 [K8, K9, K33, K34] a rough model for high T_c super conductivity [D63, D64, D66, D21, D9, D72]. 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 be 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 $\hbar_{eff}$ 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.

B.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 serve 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 interpretation. 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 definition 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 [L89]. 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 [K3], I have briefly discussed a decades old proposal that the 4-D generalization of so called Beltrami flow [B4, B25, 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 [K65, K62].

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 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

$$j \wedge dj = 0 \quad (\text{B.2.1})$$

of the Beltrami flow states that the flow is of form

$$j = \Psi d\Phi \ , \quad (\text{B.2.2})$$

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

$$j^\alpha = D_\beta J^{\alpha\beta} \quad (\text{B.2.3})$$

with Kähler form $J_{\alpha\beta}$ is absent:

$$j^\beta J_{\alpha\beta} = 0 \ . \quad (\text{B.2.4})$$

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 [K62] [L89], 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 [L89]: the identification of this structure would be as Hamilton-Jacobi structure [K62] 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 $H = M^4 \times CP_2$ [K57]. 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 [K45], whose second quantization is induced by the quantization of free spinor fields of H [L64].

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 the 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 [K65, K3] 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 analog of TGD [L40, L48] 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 [L57, L71].

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 [K62] 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.

B.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 Maxwellian 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 $\bar{\psi}$ with wave vectors $k < 0$.

$$\begin{aligned}\psi &= \int_{k>0} \frac{dk}{2\pi} [\exp(ikx)\alpha(k) + \exp(-ikx)\beta^\dagger(k)] , \\ \bar{\psi} &= \int_{k<0} \frac{dk}{2\pi} [\exp(ikx)\alpha(k) + \exp(-ikx)\beta^\dagger(k)] .\end{aligned}\tag{B.2.5}$$

It should be noticed that the definition of $\bar{\psi}_+$ does not involve hermitian conjugation as usually.

3. ψ is expressed in terms of bosonic field ϕ as

$$\psi =: \exp(i \int_\infty \partial_{++}\phi) : , \quad \bar{\psi} =: \exp(-i \int_\infty \partial_{++}\phi) : .\tag{B.2.6}$$

The subscript $\pm$ refers to either light-like coordinate.

The bosonic and fermionic currents are related by

$$\partial_{++}\phi =: \bar{\psi}\psi : .\tag{B.2.7}$$

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

$$\begin{aligned}\psi_{R,\uparrow}^\dagger &\rightarrow \exp(i\sqrt{2\pi}\theta_c) , & \psi_{R,\downarrow}^\dagger &\rightarrow \exp(-i\sqrt{2\pi}\theta_c) , \\ \psi_{L,\uparrow}^\dagger &\rightarrow \exp(i\sqrt{2\pi}\Phi_s) , & \psi_{L,\downarrow}^\dagger &\rightarrow \exp(-i\sqrt{2\pi}\Phi_s) .\end{aligned}\tag{B.2.8}$$

In the singlet case, these rules give the correspondences

$$O_{SS} = \psi_{R\uparrow}^\dagger \psi_{L\downarrow}^\dagger \rightarrow \exp(i\sqrt{2\pi}\theta_c) \exp(-i\sqrt{2\pi}\Phi_s) .\tag{B.2.9}$$

In the triplet case, one obtains

$$\begin{aligned}O_{TS}^1 &= \psi_{R\uparrow}^\dagger \psi_{R\uparrow}^\dagger \rightarrow \exp(i\sqrt{2\pi}\theta_c) \exp(i\sqrt{2\pi}\phi_s) , \\ O_{TS}^{-1} &= \psi_{R\downarrow}^\dagger \psi_{R\downarrow}^\dagger \rightarrow \exp(-i\sqrt{2\pi}\theta_c) \exp(-i\sqrt{2\pi}\phi_s) .\end{aligned}\tag{B.2.10}$$

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 $\hbar_{eff} = \hbar$.

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 [D56] (<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.

B.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 $H_1 = H_2 + H_2^\dagger$

$$H_2 = C^{Nkl} c_N b_k^\dagger b_l^\dagger . \quad (B.2.11)$$

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

$$H_2 = B_{kl} b_k^\dagger b_l^\dagger , \quad B_{kl} = C^{Nkl} C_N . \quad (B.2.12)$$

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. Bogoliubov 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

$$H_2^\dagger = \overline{C}^{Nkl} c_N^\dagger b_k b_l . \quad (B.2.13)$$

$H_2^\dagger$ 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 $\partial\phi_{++} =: \bar{\psi}\psi$.

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.

B.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>)

$$E_F = \frac{p_F^2}{2m_e} = \frac{\hbar^2}{2m_e} (3\pi^2 n_e)^{2/3} . \quad (B.2.14)$$

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 [L91] 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

$$T_c = 1.134 \times E_D \times \exp(-\frac{1}{N(0)}) \quad , \quad N(0) = n(0)V \quad . \quad (\text{B.2.15})$$

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 [L92, L65], 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 $\hbar_{eff} = h$ can be transformed to dark photons with $\hbar_{eff} = \hbar_{gr}$ satisfying $E = \hbar f_{high} = \hbar_{eff} f_{low}$, 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 [L65]. 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

$$\Delta E(T = 0) = 1.1764 T_c \quad . \quad (\text{B.2.16})$$

As one approaches T_c , the gap energy obeys the formula

$$\Delta E(T) = 3.06 \sqrt{1 - \frac{T}{T_c}} \quad . \quad (\text{B.2.17})$$

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 $\hbar_{eff} > h$ property (the energy of state as function of $\hbar_{eff}$ increases with $\hbar_{eff}$). 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 $h \rightarrow \hbar_{eff}$ transition is possible. The surplus energy can be realized as kinetic energy of supra currents. At T_c ΔE vanishes and above T_c $h \rightarrow \hbar_{eff}$ 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 $p_{max}^{(1)} = 2m_e \Delta E / p_F$ (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 $p_{max}^{(2)} = \sqrt{4m_e \Delta E}$. This gives for the ratio $p_{max}^{(2)} / p_{max}^{(1)}$

$$\frac{p_{max}^{(2)}}{p_{max}^{(1)}} = \sqrt{E_F} \Delta = \sqrt{\frac{E_F}{1.764 T_c}} .$$

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 $\hbar_{eff} q B / m_e$ takes most of the energy.

What could be the values of the monopole flux magnetic field and $\hbar_{eff}$?

In order to say something about the value of B and $\hbar_{eff}$, some assumptions are needed.

1. The generalization of the Nottale hypothesis [E1] to TGD context [K88, K84] 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 [K33, K34] [L92] deduced from the effects of ELF em fields on mammal brain by Blackman and others [J11]. The spectrum of B_{end} is assumed to contain also other values, in particular a representation of 12-note scale [L12, L65, L76] 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

$$E_c(\hbar_{gr}) = \hbar_{gr} \frac{q B_{end}}{m} = \frac{GM}{v_0} q B_{end} = \frac{\hbar_{gr}}{\hbar} E_c(\hbar) \quad (B.2.18)$$

2. are independent of the mass m of the charged particle. This universality reflects Equivalence Principle.

Second consequence is that the gravitational Compton length

$$\lambda_{gr} = \frac{\hbar_{gr}}{m} = \frac{GM}{v_0} \quad (\text{B.2.19})$$

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 Schwarzschild 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 inner planets of the Sun [L87, L86, L79].

4. $v_0 = c/2$ predicts that in the case of electron

$$\frac{\hbar_{gr}(m)}{\hbar} = \frac{2GMm}{v_0\hbar} = \frac{r_S}{L_c(m)} . \quad (\text{B.2.20})$$

From the value $r_S = 9$ mm for the Earth's Schwarzschild radius and the value of electron Compton length $L_c(e) = 2.4 \times 10^{-12}$ m, one obtains

$$\frac{\hbar_{gr}(e)}{\hbar} \simeq .4 \times 10^{10} .$$

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

$$E_c(\hbar_{gr}) \simeq 9.3 \text{ eV} ,$$

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 $\hbar_{eff}$ scaling up also the weak Compton scale. $\hbar_{eff} = \hbar_{gr} = GM_E m/v_0$ 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 Schrödinger 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

$$(\partial_\mu - 2eA_\mu)\psi = 0 \tag{B.2.21}$$

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 in 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 [D69] mentions 4 anomalies of the BCS model (no generally accepted model of high- T_c 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 $\hbar_{eff}$), which are so short that macroscopic super-conductivity is not possible. In the lower transition temperature $\hbar_{eff}$ 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 prediction 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 [L18]. 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.

B.3 Summary and conclusions

B.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 [L51, L55]. 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 T_c 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.

B.3.2 Speculations and questions

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" [L16, L30, L63] led to a reformulation of nuclear physics [L55] 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 [L89] 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 imbedding 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 [D69].

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 [K63]. 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 [L79].

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.

B.4 Appendix: General considerations related to Beltrami flows

The following text is based on the updated view about the material from the appendix of [K3]. More details can be found in [K62, K65, K3].

B.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

$$j_I^\alpha = \epsilon^{\alpha\beta\gamma\delta} A_\beta J_{\gamma\delta} \quad (\text{B.4.1})$$

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 [L89] 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 induced at the level of H by $M^8 - H$ duality [L33, L34, L35, L60, L61, L77].

The twistor twistor lift of TGD [L40, L48] 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.

B.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.

B.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:

$$J = \pm I \quad c . \quad (\text{B.4.2})$$

The condition states that only the left or right handed current chiral defined as

$$J_{L/R} = J \pm I \quad (\text{B.4.3})$$

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 [L40, L48] 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:

$$\begin{aligned} A_K &= A_K(M^4) + A_K(CP_2) , & J_K &= J(M^4) + J_K(CP_2) , \\ K &= K(M^4) + K(CP_2) , & J &= J(M^4) + J(CP_2) . \\ I &= I(M^4) + I(CP_2) . \end{aligned} \quad (\text{B.4.4})$$

Only the divergence of I must vanish:

$$\partial_\alpha I^\alpha = 0 . \quad (\text{B.4.5})$$

A possible interpretation is in terms of the 8-D variant of twistorialization by twistor lift [L40, L48] 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 [L89].

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 [L57, L71].

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.

Part II

SOME EARLIER WORK (BEFORE 2021) RELATED TO CONDENSED MATTER

Appendix C

Quantum Model for Bio-Superconductivity: I

C.1 Introduction

The model for EEG and its variants and nerve pulse relies on a general model of high T_c superconductivity [K8, K9]. In this chapter the general vision behind model of cell membrane as superconductor inspired by the identification of dark matter in terms of hierarchy of Planck constants and the notion of magnetic body is discussed.

C.1.1 General Mechanism Of Bio-Superconductivity

The ideas about high temperature superconductivity have evolved gradually as a reaction to experimental input and evolution in the understanding of TGD.

1. The many-sheeted space-time concept suggests a very general mechanism of superconductivity based on the “dropping” of charged particles from atomic space-time sheets to larger space-time sheets. 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 is that particles topologically condensed to all space-time sheets having non-empty Minkowski space projection to the region where the particle is.
2. The possibility of large $\hbar$ quantum coherent phases makes the assumption about thermal isolation between space-time sheets unnecessary. At larger space-time sheet the interactions of the charged particles with classical em fields generated by various wormhole contacts feeding gauge fluxes to and from the space-time sheet in question give rise to the necessary gap energy. The simplest model for Cooper pair is space-time sheet containing charged particles having attractive Coulombic interaction with the quarks and antiquarks associated with the throats of the wormhole contacts.
3. It became clear quantum criticality predicting a new kind of superconductivity explaining the strange features of high T_c superconductivity is essential. There are two kinds of Cooper pairs, exotic Cooper pairs and counterparts of ordinary BCS type Cooper pairs. Both correspond to a large value of Planck constant. Exotic Cooper pairs are quantum critical meaning that they can decay to ordinary electrons. Below temperature $T_{c1} > T_c$ only exotic Cooper pairs with spin are present and their finite lifetime implies that superconductivity is broken to ordinary conductivity satisfying scaling laws characteristic for criticality. At T_c spinless BCS type Cooper pairs become stable and exotic Cooper pairs can decay to them and vice versa. An open question is whether the BCS type Cooper pairs can be present also in the interior of cell.

These two superconducting phases compete in certain narrow interval around critical temperature for which body temperature of endotherms is a good candidate in the case of living

matter. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

4. Magnetic flux tubes would be carriers of dark particles and according to the findings about high temperature super-conductivity magnetic fields are indeed 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. 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.

This mechanism is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T_c bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability at room temperature and it seems that only electron, neutrino, and proton Cooper pairs are possible at room temperature besides Bose-Einstein condensates of all bosonic ions and their exotic counterparts resulting when some nuclear color bonds become charged.

5. This mechanism of high temperature super-conductivity is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T_c bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability at room temperature. If h_{eff} is proportional to the particle mass, the binding energy of Cooper pairs identifiable as spin-spin interaction energy and does not depend on the mass of the Cooper pair. The binding energy is proportional to h_{eff} and in visible and UV range if bio-photons result when dark photon transforms to ordinary photon. The hypothesis that gravitational Planck constant and h_{eff} are identical ($h_{eff} = h_{gr}$) in microscopic domain, implies the universality.

C.1.2 Hierarchies Of Preferred P-Adic Length Scales And Values Of Planck Constant

All p-adic length scales above electron length scale $L_e(127)$ were identified erratically in all writings about TGD before 2014. This deserves some clarifying comments.

1. The wrong identification was $L(151) \simeq 10$ nm implying wrong identification of other scales above $L(127)$ since I have calculated them by scaling $L(151)$ by an appropriate power of two. What I have denoted by $L(151)$ is actually obtained by scaling the Compton length $L_e(127) = \hbar/m_e$ by $2^{(151-127)/2}$ and therefore electrons Compton scale if it would correspond to $k = 151$. Since the mass of electron from p-adic mass calculations is given by $m_e = \sqrt{5 + X}\hbar/L(127)$, the correct identification of $L(151)$ would be

$$L(151) = 2^{(151-127)/2} L(127) = 2^{(151-127)/2} L_e(151)/\sqrt{5 + X} = 10/\sqrt{5 + X} \text{ nm} , \quad 0 \leq X \leq 1 .$$

Here X denotes the unknown second order contribution of form $X = n/M_{127}$, n integer, to the electron mass, and in the first approximation one can take $X = 0$ - the approximation is excellent unless n is very large. In the sequel I will try to use the shorthand $L_e(k) = \sqrt{5}L(k)$ but cannot guarantee that the subscript "e" is always present when needed: it is rather difficult to identify all places where the earlier erratic definition appears. I can only apologise for possible confusions.

2. This mistake has no fatal consequences for TGD inspired quantum biology. Its detection however provides a further support for the speculated central role of electron in living matter. Since the scales obtained by scaling the electron Compton scale seem to be important biologically (scaled up Compton scale $\sqrt{5}L(151)$ corresponds to cell membrane thickness), the conclusion is that electrons - or perhaps their Cooper pairs - play a fundamental role in living matter. The correct value of $L(151)$ is $L(151) = 4.5$ nm, which is slightly below the p-adic length scale $L_e(149) = 5$ nm assigned with the lipid layer of cell membrane.
3. I have also assigned to electron the time scale $T = .1$ seconds defining a fundamental biorhythm as a secondary p-adic time scale $T_2(127) = \sqrt{M_{127}}T(127)$. The correct assignment of $T = .1$ seconds is as the secondary Compton time $T_{2,e}(127) = \sqrt{M_{127}}T_e(127)$ of electron: secondary p-adic time scale is $T_2(127) = \sqrt{M_{127}}T(127)$ and corresponds to $T_{2,e}(127)/\sqrt{5} = .045$ seconds and to $f(127) = 22.4$ Hz.

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 .

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241, \dots\}$ (the number theoretical miracle is that all the four scale up Compton lengths of electron with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μ m) 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 [K13]. This hypothesis - to be referred to as Mersenne hypothesis - replaces the earlier rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant.

C.1.3 Fractal Hierarchy Of Magnetic Flux Sheets And The Hierarchy Of Genomes

The notion of magnetic body is central in the TGD inspired theory of living matter. Every system possesses magnetic body and there are strong reasons to believe that the magnetic body associated with human body is of order Earth size and that there could be an entire hierarchy of these bodies with even much larger sizes. Therefore the question arises what one can assume about these magnetic bodies. The quantization of magnetic flux suggests an answer to this question.

1. The quantization condition for magnetic flux reads in the most general form as $\oint (p - eA) \cdot dl = n\hbar$. If supra currents flowing at the boundaries of the flux tube are absent one obtains $e \int B \cdot dS = n\hbar$, which requires that the scaling of the Planck constant scales up the flux tube thickness by r^2 and scaling of B by $1/r$. If one assumes that the radii of flux tubes do not depend on the value of r , magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint (p - eA) \cdot dl = 0$. 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.
2. From the point of view of EEG especially interesting are the flux sheets which have thickness $L = 10$ nm (the thickness of cell membrane) carrying magnetic field having strength of endogenous magnetic field. $L = 10$ nm corresponds to p-adically scaled electron Compton length $L_e(151)$. In absence of supra currents these flux sheets have very large total transversal length proportional to r^2 . The condition that the values of cyclootron energies are above thermal energy implies that the value of r is of order 2^{k_d} , $k_d = 44$. Strongly folded flux sheets of this thickness might be associated with living matter and connect their DNAs to single coherent structure. One can of course assume the presence of supra currents but outside the organism the flux sheet should fuse to form very long flux sheets.

3. Suppose that the magnetic flux flows in head to tail direction so that the magnetic flux arrives to the human body through a layer of cortical neurons. Assume that the flux sheets traverse through the uppermost layer of neurons and also lower layers and that DNA of each neuronal nuclei define a transversal sections organized along flux sheet like text lines of a book page. The total length of DNA in single human cell is about one meter. It seems that single organism cannot provide the needed total length of DNA if DNA dominates the contribution. This is of course not at all necessarily since supra currents are possible and outside the organism the flux sheets can fuse together. This implies however correlations between genomes of different cells and even different organisms.

These observations inspire the notion of super- and hyper genes. As a matter fact, entire hierarchy of genomes is predicted. Super genes consist of genes in different cell nuclei arranged to threads along magnetic flux sheets like text lines on the page of book whereas hyper genes traverse through genomes of different organisms. Super and hyper genes provide an enormous representative capacity and together with the dark matter hierarchy allows to resolve the paradox created by the observation that human genome does not differ appreciably in size from that of wheat.

C.1.4 Bose-Einstein Condensates At Magnetic Flux Quanta In Astrophysical Length Scales

The model for the topological condensation at magnetic flux quanta of endogenous magnetic field $B_{end} = .2$ Gauss is based on the dark matter hierarchy with levels characterized by the values of Planck constant. The hypothesis for the preferred values of Planck constants allows to build quantitative model for the Bose-Einstein condensation at magnetic flux quanta assuming that the value of B_{end} scales like $1/\hbar$. A justification for this hypothesis comes from flux quantization conditions and from the similar scaling of Josephson frequencies [K13].

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and $\hbar$ has the ordinary value. For instance, the formation of Cooper pairs involves dynamics at $k_d = 24 = 151 - 127$ level of dark matter hierarchy if one assumes that electrons and Cooper pairs have size given by the cell membrane thickness equal to $L_e(151)$. Also the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta obeying $k_d > 24$ dynamics.
2. Cyclotron energies scale as $\hbar$ so that for a sufficiently high value of k_d thermal stability of cyclotron states at room temperature is achieved for a fixed value of B . Same applies to spin flip transitions in the recent scenario. The model for EEG based on dark matter hierarchy [K13] involves the hypothesis that EEG quanta correspond to Josephson radiation with energies in the visible and UV range and that they produce in the decay to ordinary photons either bunches of EEG photons or visible/UV photons. This identification allows to deduce the value of k_d when the frequency of the dark photon is fixed. The Mersenne hypothesis for the preferred p-adic length scales and values of Planck constants leads to very precise predictions.
3. Cyclotron energies $E = (\hbar/2\pi) \times ZeB/Am_p$ are scaled up by a factor $r = 2^{k_d}$ from their ordinary values and for 10 Hz cyclotron frequency are in the range of energies of visible light for $k_d = 46$.

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> [L11].

C.2 General TGD Based View About Super-Conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [D75]. 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 superfluidity and super-conductivity which helps non-specialist to get a rough quantitative overall view about super-conductivity [D75].

C.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 [D55, D23] 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 [D23]. The article [D55] 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 [D75] 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 [D75] 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 [D75] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

$$\lambda \geq 2d = 2\left(\frac{n_c}{g}\right)^{-1/D} \quad (\text{C.2.1})$$

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

$$T_c \leq \frac{\hbar^2}{4Dm} \left(\frac{n_c}{g}\right)^{2/D} . \quad (\text{C.2.2})$$

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

$$\begin{aligned} n_c &= \frac{1}{2} \frac{4\pi k_F^2 \Delta k}{\frac{4}{3}\pi k_F^3} n , \\ kT_c &= E_F - E(k_F - \Delta k) \simeq \frac{\hbar^2 k_F \Delta k}{m} . \end{aligned} \quad (\text{C.2.3})$$

Analogous expressions can be deduced in $D = 2$ - and $D = 1$ -dimensional cases and one has

$$n_c(D) = \frac{D}{2} \frac{T_c}{E_F} n(D) . \quad (\text{C.2.4})$$

The dimensionless coefficient is expressible solely in terms of n and effective mass m . In [D75] it is demonstrated that the inequality C.2.2 replaced with equality when combined with C.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. C.2.4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations C.2.2 and C.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. C.2.4 to Eq. C.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

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} . \quad (\text{C.2.5})$$

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

$$\xi = \frac{4\hbar v_F}{E_g} . \quad (\text{C.2.6})$$

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 [D75]. For cuprates one obtains $\xi = 2n^{-1/3}$ [D75]. 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 calculational 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.

C.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. C.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 high 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.

$$\begin{aligned} E_g &= \hbar\omega_c \exp(-1/X) , \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} . \\ \omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} . \end{aligned} \tag{C.2.7}$$

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 electrons of Cooper pair and should not depend on $\hbar$. For a structure of size $L \sim 1 \mu\text{m}$ 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 $T_c > .15 \text{ K}$. 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

$$H_c(T) = \frac{\Phi_0}{\sqrt{8\pi}\xi(T)\lambda(T)} , \quad (\text{C.2.8})$$

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

$$\int 2eBdS = n\hbar 2\pi . \quad (\text{C.2.9})$$

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.

C.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 [D55, D39] is made possible by quantum criticality [D92]. 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 superconductivity 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 superconductors (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 [D19] 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 [D55, D23]. 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 [D39]. 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 [K90] and condensed matter [K76] 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. [K76, K75]. 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 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 [K75] 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 [K76] 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 $L(171) = 10 \mu\text{m}$, 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.

C.2.4 Space-Time Description Of The Mechanisms Of Super-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 [D75] suggests 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 [D55] 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 [K24, K29]. 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 [K78]. 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 $u\bar{u}$ and $\bar{d}d$ 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 [K76].
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 [K24]. Finally I understood that this applies also to their super-symmetric partners, which can be also fermion [K78]. 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 [K67] 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 [D6] [D6] 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 .

C.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 [D42]. 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 carriers 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 [J12] 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 $L(167) = 2.5 \mu\text{m}$ 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 $E_0(k_2) = 3\hbar^2/4m_e L^2(k_2)$. Translational energy gap $E_g = 3E_0(k_2) = 3\hbar^2/4m_e L^2(k_2)$ is smaller than the effective energy gap $E_0(k_1) - E_0(k_2) = \hbar^2/4m_e L^2(k_1) - \hbar^2/4m_e L^2(k_2)$ 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.

C.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.

C.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 [D62, D65].

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 [D53] and the references mentioned in [D62]). 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 [D59]. 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 [D65], 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 $1/L$ [D65].

From free fermion gas to Fermi liquids to quantum critical systems

The article of Jan Zaanen [D63] 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. ^3He 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 super-conductivity 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 [D21].

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 [D72] at $T_{c1} > T_c$ conforms with this interpretation. In particular, the pseudo-gap is non-vanishing already at T_{c1} 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 [D45]. 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 [D45]. 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 [D48, D43, D34] 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 [D48, D43, D34]. The transferred energy is concentrated in a remarkably narrow range around E_w rather than forming a continuum.

In [D15] it 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.

C.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 $T_{c1} > T_c$ 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_{c1} [D9], 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_{c1} 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 manners. 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 [D6] 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 [D66] 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 [D4]. 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 superconductivity 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 superconductivity in question. Proper sizes of Cooper pairs (coherence lengths) are $\xi = 1-3$ 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 momentum 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 appearance 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 superconductivity 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 superconductivity. 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/jfz3145>) popularizing the work of David Hawthorn, Canada Research Chair Michel Gingras, doctoral student Andrew Achkar and post-doctoral student Zhihao Hao published in Science [D35] (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 at 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 [D47] (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 $\hbar_{eff} = n \times \hbar$: 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 that there is a competition. 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 competition between the phases between these two temperatures corresponds to quantum criticality in which phase transitions $\hbar_{eff}/\hbar = n_1 \leftrightarrow n_2$ 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 [L28] [K70]. 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 [D48, D43, D34] 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 of 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 [K95]. 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 octet 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 $\bar{d}$ 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

$$\begin{aligned}
 E_g &= \hbar \omega_D \exp(-1/X) , \\
 \omega_D &= (6\pi^2)^{1/3} c_s n^{1/3} \\
 X &= n(E_F) U_0 = \frac{3}{2} N(E_F) \frac{U_0}{E_F} , \\
 n(E_F) &= \frac{3}{2} \frac{N(E_F)}{E_F} .
 \end{aligned}
 \tag{C.3.1}$$

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

$$\begin{aligned}
 E_g &= \hbar \omega \exp(-1/X) , \\
 \omega &= k c_s n .
 \end{aligned}
 \tag{C.3.2}$$

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

$$\exp(-1/X) = \frac{E_g}{E_w} \quad (C.3.3)$$

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 to 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

$$T_{c1} \leq \frac{\hbar^2}{8m_e} \left(\frac{n_c}{g}\right)^2 . \quad (C.3.4)$$

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

$$T_{c1} \simeq \frac{r^2(1 - p_h)^2}{9x^2} \times 6.3 \text{ meV} . \quad (C.3.5)$$

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

$$p_h = \frac{p_d}{p_s} . \quad (C.3.6)$$

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

$$\frac{T_c}{T_{c1}} = 32\pi^2 \frac{m_e a}{\hbar_0} x^2 g^2 \frac{p_s}{(1 - (p_d/p_s)^2)^2} \frac{x_c}{r} . \quad (\text{C.3.7})$$

This prediction allows to test the proposed admittedly somewhat ad hoc formula. For $p_d \ll p_s$ 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 $k = 151, 152, \dots, 155$ 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 ^5Li , ^{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 [D36].

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/oymvosv>) [D6]. 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.

C.3.3 Speculations

21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade [D10]. Emission forms a wide band (with width about 4 micrometers) in the infrared spectrum, which suggests that it comes from a large complex molecule or a solid or simple molecules found around stars. 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 kinetic energy 61.5 meV of proton Cooper pair at $k = 139$ space-time sheet estimated from the formula

$$\Delta E(2m_p, 139) = \frac{1}{2} \frac{\pi^2}{(2m_p)L_e(139)^2} = \frac{1}{8} \Delta E(m_p, 137) \simeq 61.5 \text{ meV} .$$

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 $\bar{d}$ 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 $r = .5 \mu\text{m}$. $r = 151 - 127 = 24$ favored by Mersenne hypothesis would predict $r = .4 \mu\text{m}$. 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 $.4 \mu\text{m}$ 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.

C.4 Models For Ionic Superconductivity

In this section the model for ionic superconductivity is constructed as a straightforward generalization of the model of high T_c electronic superconductivity. There is however a loophole involved. TGD based model of atomic nucleus predicts that fermionic ions can have bosonic chemical equivalents for which one of the color bonds connecting nucleons to nuclear string is charged. Dark fermionic ions like Na^+ , K^+ , and Cl^- could be actually exotic ions of this kind having different mass number and be able to form Bose-Einstein condensates. This is required by the recent model for nerve pulse [K36]. The prediction can be tested.

The new model for the topological condensation at magnetic flux quanta of endogenous magnetic field differs radically from the earlier model and allows to understand that effects of ELF em fields on brain. Bose-Einstein condensates of bosonic ions are predicted to be of special importance for the functioning of living systems. Also a quantitative understanding of the effects of Schumann resonances and EEG emerges.

C.4.1 Model For Ionic Superconductivity

Exactly the same mechanisms are expected to work also in the case of ions and the only differences come from the different mass and charge of ion.

1. Magnetic flux tubes are carriers of supra currents and magnetic fields favor the formation of spin 1 Cooper pairs which are parallel and have also spins parallel to the flux tubes. In living matter the flux tubes could be dark magnetic flux tubes connecting different biomolecules. For instance, DNA as topological quantum computer model [K58] assumes that flux tubes connect nucleotides of DNA with the lipid layers of nuclear or cell membrane.
2. Mersenne hypothesis discussed in the introduction is assumed and makes possible precise quantitative predictions using scaling arguments. With the motivation coming from the model of cell membrane as Josephson junction it is also assumed that magnetic field scales as $1/\hbar$ and that the supra currents at the boundaries of flux tubes guarantee that the quantization condition $\oint (p - eA) \cdot dl = 0$ is satisfied. This allows the flux tubes to have a fixed transversal size (cell membrane thickness) irrespective of the value of Planck constant. An attractive hypothesis is that the $B_{end} = 0.2$ Gauss and its $1/\hbar$ scaled variants define preferred values of magnetic field.
3. In the case of ionic super-conductivity there is no antiferromagnetic lattice present. Therefore there is no obvious reason for having higher critical temperature $T_{c,1}$. Percolation type mechanism is possible if a recombination of shorter magnetic flux tubes to form longer ones takes place at critical temperature. According to the model of DNA as topological quantum computer recombination of the flux tubes is a basic mechanism of information processing mechanism in living matter so that percolation type criticality might be present.
4. For large values of $\hbar$ the gap for magnetic cyclotron energies implies that proton Cooper pairs condense to the ground state in the degrees of freedom transversal to the flux tube in which harmonic oscillator states provide a good approximate model. In the longitudinal degrees of freedom one has effectively particle in box. The corresponding energy gap $E = \pi^2 \hbar^2 / 2m_p L^2$ is below thermal energy at room temperature for flux tube lengths L of order $L(139)$ for ordinary value of $\hbar$. For electron this length scale is by a factor $m_p/m_e \simeq 2^{11}$ longer and corresponds to about 100 nm. The value of flux tube length however scales as $\hbar$ if one assumes that energy does not change in the scaling of $\hbar$. Hence arbitrarily long flux tube lengths are possible. For ion with mass number A the minimum value of $\hbar$ allowing given flux tube length L scales as $\hbar \propto AL$.
5. In the case of bosonic ions there is no need for Cooper pairs and super-conductivity would be due to the Bose-Einstein condensation of ions. TGD based nuclear physics also predicts exotic ions, which are chemically like their fermionic counterparts but are actually bosons. This is made possible by the possibility of the color flux tubes connecting nucleons to nuclear string to carry charges 1, 0, -1.

<i>Ion</i>	f_c/Hz	<i>Pseudo-ion</i>	f_c/Hz
$^{23}Na^+$	13.1	$^{19}Ne_+$	15.7
$^{23}Na^+$	13.1	$^{24}Mg^{++}$	12.5
$^{39}K^+$	7.7	$^{40}A_+$	7.5
$^{39}K^+$	7.7	$^{40}Ca^{++}$	7.5
$^{35}Cl^-$	8.6	$^{40}A_-$	7.5

(C.4.1)

Table C.1: The modification of cyclotron frequencies of most important ions are modified by simplest replacements with exotic ions

6. Whether the Cooper pairs of fermionic ions can be thermally stable is far from obvious. The model for electronic super-conductivity would suggest transversal fluctuations of the flux tube as the mediator of the attractive interaction winning Coulomb repulsion and making possible the formation of the Cooper pairs.

One might hope that the ions are trapped to the neighboring nodes of the transversal standing wave type oscillations and in this manner form correlated pairs. The size of the Cooper pairs would correspond to a multiple of wavelength for the transversal oscillations in this case. The approximation of the magnetic flux tube as string would suggest that waves are of form $\sin(\omega t)\sin(kz)$, $k = \omega$. The frequencies $\omega = n\pi/L$ would be allowed for a flux tube of length L .

Perhaps it would be more appropriate to say that one has Bose-Einstein condensate of transverse phonons making possible the Bose-Einstein condensate of Cooper pairs. It is quite possible that metabolic energy must be pumped to the Bose-Einstein condensate of transverse oscillations in order to not lose the ionic super-conductivity.

C.4.2 Super Conductors Of Exotic Bosonic Counterparts Of Fermionic Ions

If ion is boson, no Cooper pairs is needed in order to have a super conductor, and Ca^{++} and Mg^{++} ions at dark magnetic flux tubes with large value of Planck constant could give rise to high T_c super-conductors in this manner. Fermionic ions (Na^+ , K^+ , Cl^- , ..) would not define supra currents. The explanation of the effects of ELF em fields on vertebrate brain however suggests cyclotron Bose-Einstein condensates of also ions behaving chemically like fermionic ions. Also the model of nerve pulse requires Josephson currents of ions which are chemical equivalents of fermionic ions.

TGD based nuclear physics [L4] allows this kind of ions. The model indeed predicts the possibility of exotic nuclei for which one or more color bonds connecting nucleons to the nuclear string are charged. These exotic nuclei with electronic states identical to those of genuine ions could save the situation. The **Table C.1** describes how cyclotron frequencies for $B = .2$ Gauss of the most important ions are modified in the simplest replacements with exotic ions. For instance, the notation Mg^{++} tells that there is double electronic ionization and electron shell of Argon as usual but that one color bond is negatively charged.

$f_c(K^+)$ and $f_c(Cl^-)$ are replaced with the frequency 7.5 Hz and one can do only using the cyclotron frequencies $f(Ca^{++})/2 = 7.5$ Hz, $f_c(Mg^{++}) = 12.5$ Hz, and $f(Ca^{++}) = 15$ Hz. The nominal values of the lowest Schumann frequencies are 7.8 Hz and 14.3 Hz. All ions with relevance for nerve pulse and EEG could be bosonic ions or bosonic pseudo-ions. I do not know how well the needed ionization mechanisms are understood in the standard framework.

C.4.3 More Quantitative Picture About Bose-Einstein Condensates

Cyclotron frequencies of biologically important ions in the endogenous magnetic field $B_{end} = 0.2$ Gauss are involved with the effects of ELF em fields on vertebrate brain and are also central in the model of EEG [K13]. This motivates a more detailed study of these frequencies. Also the cyclotron frequencies of biologically important molecules are interesting.

Ion	f_1/Hz	E_1/eV
${}^6\text{Li}^+$	50.1	3.3
${}^{24}\text{Mg}^{2+}$	25.0	1.65
${}^{16}\text{O}^{2-}$	37.6	2.48
${}^{32}\text{S}^{2-}$	18.8	1.24
${}^{40}\text{Ca}^{2+}$	15.0	.99
${}^{55}\text{Mn}^{2+}$	11.4	.75
${}^{56}\text{Fe}^{2+}$	10.8	.71
${}^{59}\text{Co}^{2+}$	10.0	.66
${}^{64}\text{Zn}^{2+}$	9.4	.62
${}^{80}\text{Se}^{2-}$	7.6	.5

Table C.2: The first columns give the cyclotron frequencies and cyclotron energies for biologically relevant bosonic ions in $B_{\text{end}} = .2 \times 10^{-4}$ Tesla. The third column gives cyclotron energy.

Bose-Einstein condensates of bosonic ionized atoms

The number of elements for which ions are bosons is not very large. **Table C.2** lists the cyclotron frequencies of bosonic ions which are biologically important for $B_{\text{end}} = .2 \times 10^{-4}$ Tesla.

Table C.2 inspires some comments.

1. For Li^+ the dominating isotope ${}^7\text{Li}^+$ is fermion. ${}^6\text{Li}^+$ is boson and its abundance is 5 per cent. Li^+ ions are used as medications in mania and represents mood stabilizer [J2]. A possible explanation is that the cyclotron oscillations of Bose-Einstein condensate of ${}^6\text{Li}^+$ ions serve as a biological clock helping to stabilize the mood. The cyclotron frequency is however 50 Hz and higher than thalamocortical resonance frequency having nominal value 40 Hz.

An alternative explanation for the effect of Li^+ is based on the observation that ${}^7\text{Li}^+$ has cyclotron frequency equal to 42.9 Hz for $B_{\text{end}} = .2 \times 10^{-4}$ Tesla, which is at the upper limit of the 40 Hz resonance band. The presence of lithium ions or their Cooper pairs could enhance thalamocortical resonance.

These hypothesis could be tested by looking whether the use of pure $A = 6$ ($A = 7$) isotope of Li^+ amplifies the beneficial effect and the use of $A = 7$ ($A = 6$) isotope nullifies it.

2. For Mg^{2+} cyclotron energy corresponds to the energy of photon of green light. Chlorophyll is not able to convert nutrients to sugar without magnesium, which suggests that cyclotron transitions of Mg BE condensate are at least partially responsible for the green color of plants. Mg BE condensate could control the coherent occurrence of photosynthesis in the size scale of plant.
3. For oxygen ion the cyclotron frequency is 37.6 Hz and rather near to ~ 40 Hz thalamocortical resonance frequency, which suggests that the cyclotron transitions of oxygen ions might play key role in inducing coherent firing of neurons at this frequency. This would mean that oxygen would be much more than a mere provider of metabolic energy. Note also that $\Delta n = 3$ cyclotron transition of Na^+ ion corresponds to frequency 39 Hz and might be involved with the synchronous firing.
4. Ca^{2+} ions play a unique role in the functioning of living matter. In particular, calcium waves appearing in a wide range of time scales are known to serve a crucial role in nervous system [J22]. Ca^{2+} corresponds to .99 eV cyclotron energy scale, which is twice the energy of metabolic energy quantum. Hence one can ask whether the cyclotron transitions of Ca^{2+} BE condensate could induce a collective emission of metabolic energy quanta and in this manner induce coherent metabolic activity in the scale of entire body.
5. The cyclotron frequencies Mn, Fe, Co, Cu, and Zn are in alpha band and corresponding cyclotron energies are somewhat above metabolic energy quantum. These energy quanta

Ion	f/Hz	E_c/eV
${}^7\text{Li}_+$	42.9	
F^-	15.8	1.04
Na^+	13	.86
Al^+	11.1	.73
Cl^-	8.5	.56
K^+	7.5	.50
Cu^+	4.8	333.9
Ag^+	2.8	.18
I^+	2.4	.16
Au^+	1.5	.10

Table C.3: The first columns give cyclotron frequencies and corresponding cyclotron energies for some ions in $B_{\text{end}} = .2 \times 10^{-4}$ Tesla for some fermionic ions.

could drive protons from larger space-time sheet to $k = 137$ atomic space-time sheet. 10 Hz frequency is known to define an important biological clock and Co ions could be essential for the functioning of this clock. $n = 3$ multiple of Co^{2+} cyclotron frequency corresponds to the 30 Hz threshold of gamma band known to be important for cognition. Also $3f_c(\text{Fe}^{2+}) = 32.2$ Hz and $3f_c(\text{Mn}^{2+}) = 34.2$ belong to gamma band. The presence of Bose-Einstein condensates of these ions in length scale of $5L(212) = 141$ km could mean that these bio-rhythms are shared by different organisms inside regions of this size.

6. The fact that the cyclotron frequency of Se^{2-} ion, which is known to be a biologically important trace element, corresponds to the nominal value of the metabolic energy quantum, raises the question whether Selenium BE condensate might act as a metabolic synchronizer.

Cyclotron frequencies and Schumann frequencies

Even in the case that Cooper pairs of fermionic ions are not thermally stable, the cyclotron transitions of fermionic ions like K^+ , Cl^- , and Na^+ are expected to be important. In **Table C.3** cyclotron frequencies and energies of some fermionic ions are given. Notice that the cyclotron energy of K^+ ion corresponds to metabolic energy quantum. Quite generally fermionic ions cannot be involved with the generation of Josephson part of EEG.

The first thing to notice is the close relationship of cyclotron frequencies with the lowest resonance frequencies in the spectrum of geo-electromagnetic field starting from 5 Hz, so called Schumann frequencies [?], are 7.8, 14, 20, 26, 33, 39 and 45 Hz. 5 Hz corresponds roughly to the threshold 4 Hz of theta frequency range below which EEG spectrum lies during sleep which suggests that wake-up state involves the coupling of brain with geo-electro-magnetic activity. 7.8 Hz corresponds to the threshold for alpha waves associated with wake-up state without cognition; 14 Hz corresponds to threshold of 13 Hz for beta waves accompanying cognitive activities, and 33 Hz is quite near to the threshold 30 Hz for gamma waves known to be important in the temporal coding of sensory data.

Consider now examples of cyclotron frequencies keeping in mind that Schumann frequencies vary typically within 1 Hz interval around their mean values [?].

1. As already noticed, the frequencies, which are multiples of 15 Hz can be assigned to Ca^{2+} ion. The excitations $n = 3, 5, 7, \dots$ correspond to the frequencies 45, 75, 105, ... Hz. All these frequencies have been observed. The two lowest frequencies correspond to Schumann frequencies 14 and 45 Hz with accuracy of 1 Hz.
2. Na_+ has $A = 23$ and gives $f = 13$ Hz. This is the lower bound for the frequency of beta EEG waves which are associated with conscious cognition. This would suggest that the presence of em field of 13 Hz frequency correlates with large fluxes of Na_+ ions through the axonal cell membrane during nerve pulse generation. This could result from increased amplitude of Na_+ Josephson current facilitating the emission of nerve pulses at the second half of the

EEG cycle. Silencing of mind by meditation or closing eyes reduces amplitudes associated with EEG frequencies below 13 Hz and conscious cognition disappears.

$n = 3$ excitation of Na_+ corresponds to 39 Hz, which is one of the Schumann frequencies and quite near to the 40 Hz resonant frequency associated with the thalamocortical circuit. This could correspond to jumping of Na_+ ions from ground state to $n = 3$ state or vice versa. $n = 5$ quantum jumps correspond to 65 Hz which is average EEG frequency during REM sleep! Thus 13, 39 and 65 Hz frequencies correspond to the basic signatures of conscious cognition. The two lowest transition frequencies correspond to Schumann frequencies 14 and 45 Hz within accuracy of 1 Hz.

3. K_+ has $A = 39$ and gives $f = 7.5$ Hz, which is theta frequency rather near to the lowest Schumann resonance frequency 7.8 Hz. K_+ ion flux could correlate with em fields in the range of the alpha frequencies creating cyclotron resonance. Theta activity dominates during sleep and Adey's observations [J12] demonstrate that 7 Hz ELF field increases reaction times. Second and third transition frequencies are within 1.5 Hz Schumann frequencies 20 and 37.5 Hz.
4. Cl_- ion has $A = 35$ and gives $f = 8.5$ Hz. Chloride ion has inhibitory effect. $n = 3, 7, \dots$ excitations correspond to 25.5, 42.5 Hz, ... Rather interestingly, frequencies rather near to 40 Hz associated with thalamo-cortical loops appear as excitations for all ions relevant to nerve pulse activity. Note that 39 Hz is also Schumann frequency. Two lowest transition frequencies of Cl_- are quite near to Schumann frequencies 7.8 and 25 Hz.
5. Fe^{2+} has $A = 56$ and corresponds to 10.7 Hz. $3f_c(Fe^{2+}) = 32.2$ Hz is rather near to Schumann frequency 33 Hz whereas Co^{2+} corresponds to 10 Hz in excellent accuracy. Co has especially large nuclear magnetic moment and serves as a natural magnet. Fe^{2+} and/or Co^{2+} could be present in magnetic sensory organ possessed also by humans making it possible to navigate using magnetic fields. Yarrow suggests that Co makes B_{12} magnetic vitamin [J12] so that it can serve as fundamental biological clock at frequency very precisely equal to 10 Hz. Co is carried by B_{12} vitamin and is known to be important for normal consciousness: among other things the lack of B_{12} causes fatigue, blurred vision and cognitive problems.
6. Mg^{2+} has $A=24$ and $f = 25$ Hz which is near to Schumann frequency: $n = 3$ corresponds 75 Hz. Charged polypeptides could also form BE condensates and be involved with cyclotron mechanism: they are rather heavy and their cyclotron frequencies are in Hz range. Negatively charged organic molecules are indeed known to be present in neurons.

To sum up, surprisingly many magnetic transition frequencies are near to Schumann frequencies which suggests strong resonant interaction between brain and geo-electromagnetic fields.

What about proton's cyclotron frequency?

There are good reasons to expect that the cyclotron frequency of proton and its odd harmonics play an important role in brain functioning. The cyclotron frequency of proton in $B_{end} = .2$ Gauss is $f(p) = 300$ Hz. The frequency associated with $n = 3$ transition would be $3f(p) = 900$ Hz. Third harmonics of cyclotron frequencies of many ions with f_c in alpha band belong to gamma band known to relate to cognition. Perhaps this is true also in the case of proton.

The duration of single bit of the memetic codeword consisting of 127 bits and having total duration defined by the p-adic timescale $T_{M_{127}}^{(2)} = .1$ seconds corresponds to the frequency $f_m = 1027$ Hz. This frequency is by 10 per cent higher than the cyclotron frequency of proton for $B_{end} = .2$ Gauss. If magnetic homeostasis is realized, as will be discussed later, and if it allows 10 per cent variation of the strength of magnetic field as the width 1 Hz of alpha band suggests, it is possible to realize this frequency as proton's cyclotron transition frequency.

The frequency of neuronal synchronization, which is obviously associated with cognitive processing, is $\simeq 1$ kHz and might well be identifiable with f_m . The maximum rate of neuronal firing is slightly below kHz: this rate however corresponds to the rate of quantum jumps rather than oscillation frequency at space-time level.

Bose-Einstein condensates of bosonic molecular ions

Also biologically relevant bosonic molecular ions such SO_4^{2-} , CO_3^{2-} , NO_3^- , NO_2^- could form Bose-Einstein condensates. The cyclotron frequencies for bosonic molecular ions satisfying the thermal stability condition $A \leq 233 \times Z$ at room temperature are typically in theta and delta band and above $f_{\min} = 1.29$ Hz.

DNA is negatively charged and an interesting question is whether DNA satisfies the stability condition. The molecular weights of DNA nucleotides A, T, C, G are 132, 126, 96, 149. The molecular weight of deoxyribose sugar attached to the nucleotide is 100 and that of phosphate group PO_4^{2-} is 95. Altogether this makes molecular weights 327, 321, 291, 344. Since phosphate group is doubly charged this structure has cyclotron energy which is higher than thermal energy. Also DNA sequences satisfy the thermal stability condition. The presence of DNA Bose-Einstein condensates at magnetic flux quanta could mean that DNA can be transferred between different organisms along these space-time sheets and that DNAs of different organisms of same species could form quantum coherent systems inside regions where magnetic field can be regarded as a constant.

C.5 About high T_c superconductivity and other exotic conductivities

During years I have been developing a model for high T_c superconductivity (see <http://tinyurl.com/b25sucr>). The recent view is already rather detailed but the fact that I am not a condensed matter physicist implies that professional might regard the model as rather lopsided. Quite recently I read several popular articles related to superconductivity and various types of other exotic conductivities: one can say that condensed matter physics has experienced an inflation of poorly understood conductivities. This of course is an fascinating challenge for TGD. In fact, super string theorist Subir Sachdev has taken the same challenge (see <http://tinyurl.com/hu4a27f>).

In particular, the article about superconductivity (see <http://tinyurl.com/h59yqn4>) provides a rather general sketch about the phase diagram for a typical high T_c super conductor and discusses experimental support for the idea quantum criticality in standard sense and thus defined only at zero temperature could be crucial for the understanding of high T_c super conductivity.

The cuprates doped with holes by adding atoms binding some fraction of conduction electrons are very rich structured. The transition from antiferromagnetic insulator to ordinary metal involves several steps described by a 2-D phase diagram in the plane defined by temperature and doping fraction. Besides high T_c super conducting region the phases include pseudogap region, a region allowing charge oscillations, strange metal region, and metal region.

In the following I consider the general vision based on magnetic flux tubes carrying the dark $h_{\text{eff}}/n = n$ variants of electrons as Cooper pairs or as free electrons allowing to understand not only high T_c super-conductivity and various accompanying phases but also exotic variants of conductivity associated with strange and bad metals, charge density waves and spin density waves. One could also understand the anomalous conductivity of SmB_6 [L17], and the fact that electron currents in graphene behave more like viscous liquid current than ohmic current (see <http://tinyurl.com/jlgd2we>).

The TGD inspired model for the anomalous conductivity of SmB_6 as flux tube conductivity developed during last year [L17] forms an essential element of the mode. This model implies that Fermi energy controlled by the doping fraction would serve as a control variable whose value determines whether electrons can be transferred to magnetic flux tubes to form cyclotron orbits at the surface of the tube. Also the metals (such as graphene) for which current behaves more like a viscous flow rather than Ohmic current can be understood in this framework: the liquid flow character comes from magnetic field which is mathematically like incompressible liquid flow.

C.5.1 The phase diagram and observation

The popular article “The Quantum Secret to Superconductivity” (see <http://tinyurl.com/h59yqn4>) tells about an article published in Nature [D24] (see <http://tinyurl.com/go9k8cs>)

about the work of a group of researchers at the National Laboratory for Intense Magnetic Fields (LNCMI) in Toulouse, France led by Cyril Proust and Louis Taillefer.

The popular article contains a phase diagram, which gives a bird's eye of view about high T_c superconductors and provided the stimulus for this article. The diagram describes the phases of a doped cuprate (now yttrium barium copper oxide superconductor $\text{YBa}_2\text{Cu}_3\text{O}_7$, see <http://tinyurl.com/ycpscdfc>). Doping means an addition of impurities, which bind electrons and lead to the formation of holes. Also electron doping is possible. The diagram contains several regions representing phases of the system.

The diagram (see **Fig. C.1**), which probably should not be taken too literally, can be seen as a qualitative representation of the phase transition sequence leading from an antiferromagnetic insulator to a conducting metal. It is considerably more complex than the corresponding diagram for the ordinary insulator metal transition. One starts from un-doped antiferromagnetic insulator and increases the doping fraction and ends up with metal. The holistic strategy is to try to understand all transitions and phases appearing in the entire diagram using same basic model rather than the mere transition to superconductivity.

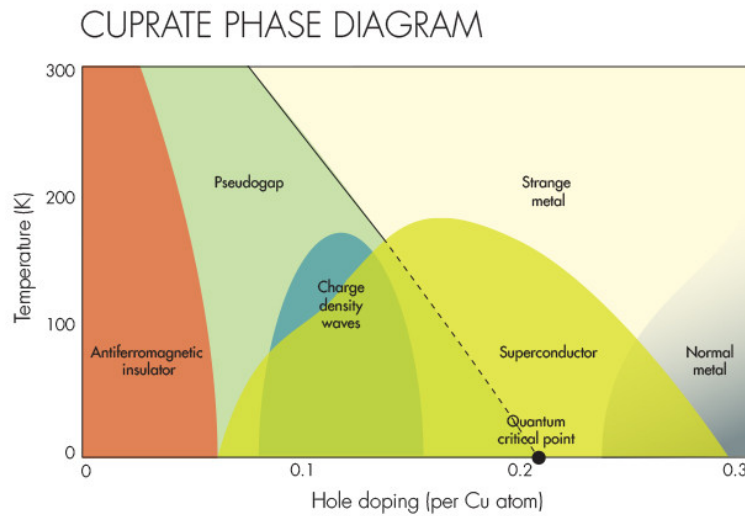


Figure C.1: The phase diagram of typical high T_c superconductor

1. Above temperature dependent critical doping around $d = .05$ (meaning addition of impurities) a transition to so called pseudogap phase occurs. At a higher temperature dependent critical doping ratio varying in the range $(.05, .14)$ emerges a hill representing high T_c superconductivity.
2. There is also a parabola shaped region bounded at the top of superconducting hill in which charge density wave define the ground state. In this phase kind of jerky conductivity but not yet superconductivity occurs. The piece of parabola is contained in doping fraction interval between $(.08, .13)$ (reader might disagree, I apologize for my bad eye sight).
3. At temperature above 170 K and for temperature depending doping ratio decreasing with temperature linearly pseudogap is transformed to a strange metal bounded by superconductor hill below. Farthest to the right is the ordinary metal phase bounded by superconducting hill and strange metal region. Critical doping fraction for the transition from superconductivity to ordinary conductivity decreases with temperature and is in the range $(.26, .29)$.

The challenge is to understand what these regions correspond physically and what happens in the transitions between them. The crucial observation is following. The researchers realized that the line representing the boundary between pseudogap and strange metal seems to continue

below the super-conducting regions. Could one destroy the superconducting region to see whether it meets the $T = 0$ axis at the bottom and could at this point quantum phase transition occur at critical value of doping?

This was done by putting the system to a strong magnetic field of 90 Tesla destroying the superconducting phase by making Cooper pair unstable. It was indeed observed that the number of holes per Cu atom - called charge carrier density (perhaps misleadingly) - increased by a factor 6 at this critical point - actually in its vicinity since $T = 0$ is not reachable exactly. The researchers think that this might be crucial guideline in attempts to understand high T_c superconductivity and I share their belief. The understanding of what really happens in the transition to superconductivity or rather in the transition from the pseudogap state to superconductivity is the problem.

C.5.2 Alternative proposals for the mechanism of superconductivity

What has been observed is quantum critical point at $T = 0$ at which the density of holes per atom increases by a factor of 6. This does not mean that the superconducting charge carriers are Cooper pairs of holes. The phenomenon might have nothing to do with superconductivity in superconducting phase. The phenomenon is observed by using strong magnetic fields preventing superconductivity so that one in principles does not study the same system anymore.

Several hypothesis for the mechanism of super conductivity have been proposed and some of them are mentioned in the popular article (see <http://tinyurl.com/h59yqn4>) .

1. Spin density waves (mentioned in Wikipedia article but not discussed in the popular article) would take the role of phonons and induce the formation of Cooper pairs by a kind of water bed effect. These waves do not appear in the phase diagram. Now the Coulomb repulsion forces the members of Cooper pair to reside at different lattice sites and the outcome would be d-wave Cooper pair having a node at origin. In TGD the members of Cooper pair at parallel flux tubes so that also now d-wave is obtained for spin singlet state and p-wave for spin triplet.
2. Charge density wave fluctuations would somehow be involved with the formation of Cooper pairs. Phase diagram for charge density fluctuations does not support this picture since the superconducting regions is much larger. Transitions to superconductivity can happen from 4 regions: pseudo gap region, the regions with fluctuating charge density, strange conductor, and ordinary conductor. Also spin density wave fluctuations could have similar role.
3. A phase transition occurring to the anti-ferromagnetic phase is suggested to somehow induce the formation of Cooper pairs. The called Mermin-Wagner theorem stating the absence of breakdown of continuous symmetry in two-dimensional models of statistical physics at non-zero temperatures does not support this hypothesis. One could circumvent this problem by assuming that only patches forming kind of checkerboard consisting of super-conducting and non-superconducting regions can develop in 2-D. No checkerboards have been observed. Note that there is however an objection against Mermin-Wagner theorem. Antiferromagnetic order has been detected in undoped cuprates with the same 2-D structure.

Subir Sachdev is a super string theoretician, who has been developing superstring inspired methods - in particular AdS/CFT correspondence - to study quantum critical phenomena. Sachdev and collaborators have developed methods for studying "strange metals". These systems are exceptional in that they do not have any quasiparticle excitations. Sachdev has correctly predicted charge density fluctuations in high T_c superconductors and also proposed that the precursor for high T_c superconductivity would be what he calls fractionized Fermi liquid meaning fractional spin and charge. One would have something like ordinary conductivity but with fractional charges. This phase could correspond to strange metal.

C.5.3 TGD proposal for the mechanism of high T_c superconductivity

The challenge for TGD inspired qualitative model is to understand these phases in terms of magnetic flux tubes and dark electrons possibly forming Cooper pairs at them.

Formulation of the model

The starting point is the model developed hitherto.

1. Consider first Merlin-Wagner theorem as an objection against breaking of 2-D continuous symmetries. TGD suggests however a mechanism allowing a breakdown of 2-D continuous symmetries (by strong form of holography TGD space-time is almost 2-D as far as scattering amplitudes are considered: string world sheets and partonic 2-surfaces). The continuous symmetries in question include supersymplectic transformations having conformal structure meaning that the generators are labelled by conformal weights which come as integer multiples of generating weights. This symmetry breaking would lead from the original symmetry algebra to its sub-algebra isomorphic with the original. Just a zoom up of the original symmetry would be the outcome! Maybe Merlin and Wagner could tolerate this!

Now one would have something different from a checkerboard of patches. There would be quantum critical phase in which a phase containing Cooper pairs at short flux tubes with Planck constant $\hbar_{eff}/\hbar = n_1$ and phase containing long flux tubes with $n_2 > n_1$ but no Cooper pairs at them. There would be fluctuations between these phases. Fluctuation would have in ZEO as correlate space-time surface connecting three surfaces at opposite boundaries of CD such that the values of n would be different at them [L28] (see <http://tinyurl.com/y7znls3j>).

2. The earlier model [L19] (see <http://tinyurl.com/yaoghft8>) identifies the pseudogap as quantum fluctuating phase in which there is a competition between short and long flux tubes pairs related by re-connections for short flux tubes containing Cooper pairs such that their members are at parallel flux tubes of pair carrying magnetic fields in opposite direction. Long flux tubes cannot carry Cooper pairs and this together with fluctuations spoils macroscopic superconductivity in pseudogap phase and makes it a poor conductor.

Pseudogap is present in the density of states since part of electrons goes to the short flux tubes. The transition to superconducting phase identified in terms long flux tubes carrying Cooper pairs would occur when Cooper pairs go also to the long flux tubes and would be analogous to the percolation phase transition in which water begins to dribble through a sand layer. Pseudogap phase is quantum critical: zero energy ontology (ZEO), which allows to see quantum theory as a square root of thermodynamics at single particle level indeed allows quantum criticality also at non-vanishing temperatures.

3. Strange metal phase can be identified as a phase in which only short superconducting flux tubes are present and carry supra currents but in short scales only. Since Cooper pairs have spin zero, the charged currents do not carry spin: this conforms with the observation that the resistance for spin currents has different temperature dependence than for charged currents. Therefore the generalization to 2-D case of the charge-spin separation possible in 1-D case (but also in this case non gauge-invariant notion, (see <http://tinyurl.com/znsver8>) is not needed. Quite generally, the possibility of short scale $S = 0$ super conductivity could explain the charge-spin separation.

The fact that scattering leads from dark phase at flux tubes to ordinary phase could explain the linear temperature dependence of the resistance of strange metals. In ordinary metals the dependence is quadratic: the reason is that the number of initial and final state electrons is proportional to T . If the number of dark Cooper pair at flux tubes does not depend on temperature one obtains linear dependence.

The absence of quasiparticle excitations in strange metal would be due to the fact that Cooper pairs are dark and at magnetic flux tubes. Both n_1 and $n_2 > n_1$ phase would be present below critical doping fraction in the experiment discussed and would correspond to a situation in which there is fluctuation between the short length scale superconductivity and long length scale flux tubes not containing Cooper pairs. The strong magnetic field used in the experiment would not destroy the long flux tubes and the quantum critical phase would survive.

4. The quantum critical phase transition discussed in the article at zero temperature and critical doping fraction increases the number of holes per copper atom by a factor 6. Also this can

be understood qualitatively. The transfer of electrons to dark Cooper pairs generates holes. In pseudogap region the long flux tubes do not carry Cooper pairs. As the phase transition occurs, only short flux tubes remain and accept pairs maximal number so that the number of holes per copper atom increases. Also the properties of pseudogap can be understood. Pseudo gap means a low density of states at certain points of Fermi surface (the point defines a preferred direction of current) and is known to be only in direction parallel to CuO bonds: this can be understood if flux tubes are parallel to them.

Charge density waves and spin density waves and their fluctuations

Can TGD say something interesting about charge density waves (see <http://tinyurl.com/y9g7t34j>) and spin density waves (see <http://tinyurl.com/y97vmya7>)?

1. Charge density wave defines a ground state of the system having lower energy than the state with constant density of electrons. These waves are periodic standing waves with wavelength $\lambda = \hbar/k_F$. Wavelength does not in general correspond to a multiple of lattice constant. In presence of these waves conduction occurs in random jerkwise fashion like the water dribbling from faucet. The standard explanation for the jerkwise current is that the charge density wave is in a potential well caused by defect and when the electric field exceeds the critical value it is released and slides generating an ohmic current. Below the threshold the system would behave as an insulator.
2. Spin density waves are very similar to charge density waves: instead of charge, the direction of spin varies in oscillatory manner with wavelength defined by Fermi wave vector in ground state. Also now a current is formed in direction of the magnetic field above critical value of magnetic field. Sliding mechanism is proposed also now as the underlying mechanism of conductivity.
3. The key question is where a spatially varying fraction of charge/spin goes as charge/spin density wave is formed. In TGD Universe the answer would be rather obvious: "To flux tubes!". Both charge density wave and spin density could involve a sequence of magnetic flux loops with a period defined by k_F so that supra currents could flow below this length scale. Charge density wave could result from a transfer of electrons to flux tubes producing oscillator charge density at the flux tube inducing corresponding charge density oscillation in lattice. In the case of spin density wave the spin directions would be correlated at flux tubes and induce corresponding correlation in the lattice.
4. The conductivity associated with charge density wave above critical electric field could correspond to a kind of premature and temporary phase transition to super-conducting phase in which long flux tubes contain Cooper pairs but are still unstable. In the transition to super-conductivity a reconnecting to long flux loop looking like long and thin rectangle would be formed by reconnections. One would have a system fluctuating between short and long scale superconductivities. One could of course consider also sliding of the flux tubes but this does not seem so plausible option in TGD framework.

The conductivity induced by critical magnetic field could be understood if the magnetic field induced a phase transition reconnections transforming the periodic short flux tube structure to a pair of long flux tubes. Why the magnetic field would induce this, is not clear. Same question of course applies in the case of the critical electric field inducing the generation of current in charge density wave.

The role of doping fraction

Can one understand the role of doping fraction?

1. The number of holes per copper atom depends on the doping fraction. The holes would be created when dark Cooper pairs are generated. If the density of dark Cooper pairs increases dramatically at critical doping fraction, the density of holes must increase. Somehow the over-critical doping fraction would favor the formation and stability of short dark flux tubes. Maybe it becomes energetically more favorable for electrons to go to flux tubes. This might

relate to cyclotron energy proportional to $\hbar_{eff}$ at flux tubes and Fermi energy E_F : a kind of resonant transfer suggests itself.

For some time ago I constructed a model for the anomalous conductivity of SmB_6 in external field in terms of Haas-van-Alphen effect for non-standard value of $\hbar_{eff}$ [L17] (see <http://tinyurl.com/y8oblpl9>). A resonant transfer of electrons to flux tubes occurs if the energy at the surface of the Fermi sphere corresponds to energy for a cyclotron orbit at the surface of the flux tube. The largest orbit at Fermi sphere would be at the surface of the flux tube. This implies the occurrence of Haas van Alphen as a periodic dependence of magnetization on the value of external magnetic field $1/B$ and also explains also the anomalous conductivity of SmB_6 as flux tube conductivity occurring when the resonance condition is satisfied.

A rather natural expectation is that same happens now. The doping fraction would control the value of Fermi energy, and this in turn would control the rate for the leakage of electrons to Cooper pairs at flux tubes by resonance condition. If the dependence of the Fermi energy on doping fraction is slow this could allow to understand why an entire range of doping fractions is possible. That the electrons must have Fermi energy must correlate with the wave length of charge and spin density waves. The length of the short flux tube loop corresponds to Fermi wave vector.

There is also a feedback effect involved. When electrons become Cooper pairs at short flux tubes, their density in lattice is reduced and this reduces Fermi energy so that resonance condition might fail to be satisfied. If flux tubes carry monopole flux, flux is quantized and the value of the magnetic field depends on the thickness of the flux tube, which could also be dynamical.

2. Below critical doping fraction long flux tubes would be possible but would be unstable and unable to carry stable Cooper pairs. The reason could be that the resonance condition for the transfer fails to be satisfied (the thickness of long flux tubes would not satisfy the resonance condition). Superconductivity and strange metal property would disappear above certain temperature dependent value of the doping fraction. Also this could be understood in terms the failure of the resonance condition for both short and long flux tubes. In the charge density wave region the resonance condition would be satisfied for the long flux tubes.

Connection with Sachdev's ideas

Sachdev's ideas mentioned above have correspondences in TGD. AdS/CFT is central in Sachdev's approach and it has been also proposed as a solution of so called sign problem (see <http://tinyurl.com/h9ogjjd>) plaguing QFT models and statistical physics models in dimension $D \geq 3$. Sign problem gives one additional good reason for the localization of the induced spinor fields at 2-D string world sheets in TGD framework [K56].

1. AdS/CFT relies on conformal symmetry: in TGD framework the conformal symmetry is generalized to super-symplectic symmetry and other symmetries having conformal structure and assignable to the boundary of light-cone and to the light-like orbits of partonic 2-surfaces at which the induced metric changes its signature from Minkowskian to Euclidian.
2. TGD Universe is quantum critical so that also this aspect is shared. AdS/CFT correspondence relies on holography: in TGD framework one has strong form of holography and one can say that the 10-D bulk is replaced with 4-D space-time surface in $M^4 \times CP_2$.
3. Charge and spin fractionization are plausible also in TGD: the unit would be scaled down by $1/n$ ($\hbar_{eff}/\hbar = n$) and in twistorial approach [K80] this is understood quite satisfactorily.
4. Also in TGD the precursor would be strange metal. I have already explained how charge spin separation reflecting itself as different temperature dependences of resistances for charged and spin currents and the linear dependence of resistivity on temperature can be understood.

There are also differences. In TGD framework strange conductor would be flux tube super-conductor in short length scales with $\hbar_{eff}/\hbar = n_1 < n_2$ rather than fractional ordinary conductor.

Bad and strange metals and metals behaving like water

Besides high T_c superconductors there are also other exotic conductors such as strange and so called bad metals <http://tinyurl.com/zzyyep>) difficult to understand using the ideas of existing condensed matter physics.

In the case of bad metals (see <http://tinyurl.com/k54k9oa>) the conductivity is low but is preserved to too high temperatures. The problem is that if the electrons scatter as usual the time τ between collisions becomes too small and at higher temperatures Uncertainty Principle requiring $T \times \tau \geq h$ fails to be satisfied. Quite recent proposal [D37] is that current carrying electrons somehow disappear and this fluctuation is not only responsible for low but on-vanishing conductivity. These fluctuations could be due to the quantum critical fluctuations transforming electrons to Cooper pairs at short flux tubes. Bad metal would be unable to decide whether to be an insulator or strange metal.

Also graphene behaves in a strange manner (see <http://tinyurl.com/hffdl8s>) in the sense that currents behave more like viscous liquid flow rather than ohmic currents. The presence of vortices is a basic signal about this. A model assuming a negative resistance allowing electrons to move in “wrong direction” in electric field is considered as an explanation. To me this option looks tricky.

Liquid like behavior might be understood if the currents flow at magnetic flux tubes. Magnetic field is mathematically analogous to an incompressible liquid flow. Flux tubes would be like water pipes forming a network and the topology of the ohmic currents would reflect the topology of this loopy magnetic network. The direction of the electric field inside flux tube space-time sheet would be parallel to the flux tube so that negative resistance would not be required: electric field would change direction locally rather than resistance its sign. In long scales at the space-time sheets assignable to the ordinary matter the direction of electric field would be constant. The phenomenon would reflect many-sheetedness of space-time lost in the gauge theory limit of TGD. Note that if currents are supra currents along flux tube pairs in short scales, there would be no resistivity in these scales.

To sum up, the notions of magnetic flux tube and dark matter hierarchy suggest common mechanisms for all the exotic conductivities. From this it is of course a long way to quantitative models.

C.5.4 New findings about high-temperature super-conductors

Bozovic et al have reported rather interesting new findings about high T_c super-conductivity: for over-critical doping the critical temperature is proportional to the density of what is identified as Cooper pairs of electronic super-fluid. Combined with the earlier findings that super-conductivity is lost - not by splitting of Cooper pairs - but by reduction of the scale of quantum coherence, and that below minimal doping fraction critical temperature goes abruptly to zero, allows to add details to the earlier TGD inspired model of high T_c super-conductivity. The super-conductivity would be indeed lost by the reconnection of flattened square shaped long flux loops to shorter loops of pseudogap phase. Quantum coherence would be reduced to smaller scale as h_{eff} is reduced. Transversal flux tube “sound waves” would induce the reconnections. Electrons at flux loops would stabilize them by contributing to the energy density and thus to the inertia increasing the string tension so that the average amplitude squared of oscillations is reduced and critical temperature increases with electron density.

Results

A popular article in Phys.org (see <http://tinyurl.com/htr2qjj>) tells about new interesting results about high T_c superconductivity. Bozovic et al have published in Nature an article titled “Dependence of the critical temperature in overdoped copper oxides on superfluid density” (see <http://tinyurl.com/gqo9j67>) [D26]. The abstract of the article gives first glimpse about the work.

The physics of underdoped copper oxide superconductors, including the pseudogap, spin and charge ordering and their relation to superconductivity is intensely debated. The overdoped copper oxides are perceived as simpler, with strongly correlated fermion physics

evolving smoothly into the conventional Bardeen–Cooper–Schrieffer behaviour. Pioneering studies on a few overdoped samples indicated that the superfluid density was much lower than expected, but this was attributed to pair-breaking, disorder and phase separation. Here we report the way in which the magnetic penetration depth and the phase stiffness depend on temperature and doping by investigating the entire overdoped side of the $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ phase diagram. We measured the absolute values of the magnetic penetration depth and the phase stiffness to an accuracy of one per cent in thousands of samples; the large statistics reveal clear trends and intrinsic properties. The films are homogeneous; variations in the critical superconducting temperature within a film are very small (less than one kelvin). At every level of doping the phase stiffness decreases linearly with temperature. The dependence of the zero-temperature phase stiffness on the critical superconducting temperature is generally linear, but with an offset; however, close to the origin this dependence becomes parabolic. This scaling law is incompatible with the standard Bardeen–Cooper–Schrieffer description.

I do my best in order to understand what this says. The Wikipedia article (see <http://tinyurl.com/b25sucr>) helps to get overall view about high T_c superconductivity. The Phys.org article (see <http://tinyurl.com/htr2qjj>) gives first clues in attempts to understand what the abstract says. The earlier article of Bozovic et al (see <http://tinyurl.com/hk88h5w>) [D25] stating that the loss of super-conductivity does not mean splitting of Cooper pairs but loss of quantum coherence or rather its reduction to shorter length scale gives additional insights.

In the following I proceed by self-Socratean method by making questions and bringing in the TGD view based on quantum criticality and magnetic flux tube pairs as carriers of members of Cooper pairs responsible for the supra current.

Basic notions

I try first to understand the notions of doping and phase stiffness.

1. In the work under discussion [D26] overdoped cuprate superconductors were studied. Doping by holes and electrons is possible. Underdoped superconductors are studied and are not well-understood. Superconductivity appears in some range for the values of the doping fraction: the minimal doping is typically something like .05 for holes and .2 for electrons from the diagram of Wikipedia article.

“Overdoping” is achieved by the addition of strontium atoms as impurities. It had been already known that overdoping induces a reduction of the density of electron pairs and that critical temperature is reduced as a consequence. In the experiments discussed the critical temperature was found to depend linearly on the density of what was identified as super-fluid electron pairs linearly and going to zero as the doping fraction increases. In TGD pairs would correspond to small scale super-conductivity.

There is also the notion of self-doping, see the popular article titled “*Self-doping may be the key to superconductivity in room temperature*” at <http://tinyurl.com/jxrdagm> telling about the article of Magnuson et al [D41] (see <http://tinyurl.com/zvfhqu2>). There are mysterious chains between the lattice planes of cuprate carrying negative charge. Self doping means that the system itself generates them and controls the charge density at them. Could these chains be associated with the flux tube pairs carrying the Cooper pairs in TGD framework?

2. Phase stiffness refers to the phase of a complex order parameter (see the article “*Weak phase stiffness and nature of the quantum critical point in underdoped cuprates*” of Yildirim and Ku at <http://tinyurl.com/yauzaz6r>), which might correspond to that assignable to the short range super-conductivity (or superfluidity as authors identify it). One poses twisted boundary conditions forcing the phase to vary spatially. How this is done, I do not understand.

The phase stiffness corresponds to energy density forced by these boundary conditions. In lowest order approximation energy density is proportional to the square of the gradient of the phase and coefficient is analogous to string tension. This parameter is proportional the density of Cooper pairs theoretically. The strange thing is that phase stiffness goes to zero

below the minimal doping rather than going to zero smoothly. In overdoped region the phase stiffness at zero temperature limit was found to depend linearly on the critical temperature.

TGD based model for the findings

TGD inspired model for high T_c superconductivity and bio-superconductivity have been developed gradually during two decades [K8, K9, K33, K34] [L19, L21]. The new results allow to add new details to this model, in particular to the understanding of what happens when the superconductivity is lost.

1. The popular article says that the critical temperature is controlled by the 2-dimensional density of electron pairs identified as super-fluid Cooper pairs. They would correspond to the so called pseudogap phase. An important point is that super conductivity is not lost due to the breaking of Cooper pairs as in the ordinary super-conductivity but due to too small value of the density of electron pairs: this is also the TGD view. In an earlier work to which Bojovic also contributed it is claimed that super-conductivity is lost due to the loss of quantum coherence rather than splitting of Cooper pairs [D25] (see <http://tinyurl.com/zmbeynz>).

Both these findings conform with the TGD view that transition to super-conductivity means a phase transition increasing the value of h_{eff} increasing the range of quantum coherence scaling like h_{eff} . Cooper pairs exist also in pseudogap phase and can have non-standard value of h_{eff} but the closed flattened square shaped flux loops along which the members of pairs flow are too short to give rise to super-conductivity in macroscopic scales. In TGD framework the electron super-fluid about which the article talks would correspond to short scale superconductivity.

The density of Cooper pairs for small value of h_{eff} identified by authors as super-fluid carriers would be the critical quantity: for some range of this parameter the h_{eff} increasing phase transition would take place. This range would in turn correspond to a range for the energy assignable to the pair if the energy is proportional to 2-D Fermi energy.

2. This allows to consider TGD based model of high T_c super-conductivity in which Cooper pairs have their members at parallel magnetic flux tubes closing to a loop and carrying magnetic fluxes in opposite direction in the case of antiferromagnet. In pseudogap phase the pairs would have their members at the flux tubes with opposite spin directions. In the phase transition to superconductivity the value of h_{eff} would increase and the flux tubes would reconnect to much longer flux tubes and macroscopic super current would flow.
3. What happens in the phase transition increasing h_{eff} giving rise to superconductivity in macroscale? The lengths of closed flux loops are scaled up in reconnection. Longitudinal energy is not affected. It seems that the transversal distances between flux tubes cannot change.

What happens to the strength of magnetic field? It should be reduced to keep cyclotron energy proportional to $h_{eff}B$ constant? For monopole flux, flux conservation requires that magnetic flux BS does not change so that the area S of the flux tube would scale like h_{eff} . That cyclotron energy is not changed at all would conform with the intuition about quantum criticality.

4. Why the phase transition to larger h_{eff} phase occurs only above the critical temperature? Why these flux loops are unstable against reconnection above critical temperature? Cooper pairs do not split but reconnection splitting long closed flux loop to a sequence of shorter ones takes place.

Some energy assignable to large h_{eff} flux tubes is reduced below the thermal energy above critical temperature and a transition to small h_{eff} phase. In reconnection process the parallel flux tubes with opposite fluxes touch each other. This touching occurs if there are oscillations of flux tubes in transversal direction analogous to transversal sound waves.

Does the average amplitude of transversal “sound waves” become so large above critical temperature that reconnections occur? This brings in mind ordinary BSC superconductivity in which phonon-electron interaction makes possible formation of Cooper pairs as bound

states. Phonons for the ordinary super-conductivity however corresponds to lattice oscillations and make superconductivity possible. Now just the opposite happens.

5. What the proportionality of T_c to the density of small Cooper pairs could mean? The energy of transversal phonon is proportional to its amplitude squared. If the amplitude and thus energy is above critical value the reconnection occurs.

Why the critical thermal energy increases with the density of small Cooper pairs? Does the presence of Cooper pairs stabilize the flux tubes: for too small density flux tubes are not stable since their string tension is too low and they are too soft and have large amplitude of thermal fluctuations.

Does the presence of Cooper pairs increase the inertia of flux tubes and therefore their string tension? The thermal energy of stringy sound waves proportional to critical temperature becomes proportional to electron density if the electron density dominates in string tension. This would explain also the lower critical value for the doping fraction. Below it flux tubes become so soft that reconnection occurs too fast to allow super-conductivity at all. Above pseudogap temperature even the short loops would become unstable.

What we have obtained? In TGD framework the super-conductivity is not spoiled by the splitting of Cooper pairs but by the reconnection of flattened square shaped long flux loops. Super-conductivity is lost by the reconnection of flattened square shaped long flux loops to shorter loops of pseudogap phase, which is super-conducting but in smaller scale. Transversal flux tube “sound waves” induce the reconnections. Electrons at flux tubes stabilize them by contributing to the energy density and thus to the inertia increasing the string tension so that the average amplitude squared of oscillations is reduced and critical temperature increases with electron density.

C.6 Self Hierarchy And Hierarchy Of Weakly Coupled Super Conductors

The realization that bio-systems are full of macroscopic quantum phases led to the general idea about the dynamical realization of the self-hierarchy as a master-slave hierarchy formed by weakly coupled super conductors. It is now clear that mere Josephson currents are not enough: the breaking of super-conductivity due to leakage of supra currents from the super-conducting space-time sheets might also be an essential part of bio-control. A possible general conclusion is that Josephson currents are responsible for coordination whereas dissipative currents are related with the control aspect. The idea about charge entanglement made possible by W MEs and generating the dissipative currents makes this vision more precise.

One of the great ideas was that soliton sequences associated with the Josephson currents underly nerve pulse sequences. This idea turned out to be wrong as such: as a matter, soliton sequences correspond to various bio-rhythms such as kHz resonance frequency and various EEG rhythms in the recent model and nerve pulses could be understood as a perturbation of this sequence when rotational motion of some pendulum in the sequence of penduli becomes oscillatory. Since homeostasis as a many-sheeted ionic flow equilibrium involves also Josephson currents in an essential manner, it would be however light hearted to assume that Josephson currents and the dynamics at the level of cell membrane were totally uncorrelated. The model for sol-gel phase transition indeed demonstrates that Josephson currents generate Josephson photons crucial for stabilizing gel phase.

The hierarchy of favored Planck constants predicted by the Mersenne hierarchy implies a hierarchy of Josephson junctions defined by cell membranes and the value of Planck constants defines the evolutionary level of cell. As already noticed, EEG radiation and its fractal generalization and bio-photons can be identified as decay products of dark Josephson radiation in the case that the cell membrane space-time sheet is almost vacuum extremal. The frequency of the possible Josephson currents associated with the atomic space-time sheets of the cell membrane (or some larger space-time sheets with the same potential difference by the average many-sheeted ir-rotationality of the cell membrane electric field) corresponds in the resting potential of about -70 mV. For almost vacuum extremal option the Josephson currents could define bio-rhythms in

extremely wide range from 10^{-15} s time scale to time scales comparable to the duration of life cycle.

Also hierarchies with levels characterized by the size scale of the membrane like structure involved can be considered but experimentally the situation remains open. Potential differences are in any case limited by the condition that Josephson energies are above thermal threshold. One possibility is that pairs or parallel super-conducting magnetic flux tubes form Josephson junctions. Indeed, at the higher levels of dark matter hierarchy one obtains both time-like and space-like soliton sequences and their Lorentz boosts.

What remained open in the earlier picture was the relationship between Josephson current circuitry and EEG, and nerve pulse generation and the possible analogs of EEG, ZEG (and WEG) and nerve pulse generation in various other frequency scales. The possibility of generalized EEG hierarchy associated with dark matter hierarchy lead to a general quantitative picture in this respect and allows to interpret the components of generalized EEG in terms of cyclotron radiation and Josephson radiation as a response to cyclotron radiation. The general manner to code information about sensory input and motor actions is in terms of frequency modulation of the EEG frequencies defining EEG rhythms. A fascinating possibility is that scaled up variants of nerve pulses with typical time scale of about 2 seconds instead of millisecond associated with say neuronal bi-layers are realized in higher vertebrates. At the next level the “nerve pulses” would have duration of order 1.1 hours.

Supra currents running parallel to the axon suggest an important additional piece to the picture about of quantum control. Constructive interference of supra currents leads to a large net Josephson current and various biological clocks could rely on this mechanism. When reference supra current representing the expected sensory input and a current representing real sensory input and flowing in parallel manner in weakly coupled super conductors, are sufficiently near to each other, constructive interference of the Josephson currents occurs and can give rise to a synchronous firing. This makes possible conscious comparison circuits. Conscious novelty detectors can be build easily from comparison circuits using inhibitory and excitatory synaptic connections.

It must be emphasized that detailed models cannot be taken too seriously. There are simply quite too many new physic mechanisms to be considered. The following considerations actually represent the first general vision about the role of super conductivity in living matter, and also this is a good reason for not taking them too literally. As in the case of other similar sections, I have made the decision to keep it as such since the general vision might apply also in the recent framework although it failed in the original model of nerve pulse and EEG. The replacement of the representation of Josephson junction by magnetic flux tubes carrying dark variants of electrons and ions might provide a general realization of the vision. For instance, standing wave solitons associated with the Josephson currents between cytoskeletal microtubules and regions of the cell membrane could be involved with DNA - cell membrane TQC. These currents - at least in the case of axons- might be also responsible for ordinary EEG (note that a hierarchy of fractal variants of EEG are predicted [K13]).

C.6.1 Simple Model For Weakly Coupled Super Conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Solitons represent quantized Josephson currents which are large and able to facilitate the generation of nerve pulse in the case of Na_+ and Ca_{++} . Soliton sequences are the simplest solutions of Sine-Gordon equation for the Josephson junctions associated with a linear structure such as axon idealized as an infinitely long and thin cylindrical surface and are mathematically equivalent with a rotating gravitational pendulum.

The most general formulation starts from the Klein-Gordon equation for the order parameters Ψ_i , $i = 1, 2$ for the super-conductors coupled linearly to each other in the junction

$$\begin{aligned} D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\ D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\ D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu) \end{aligned} \tag{C.6.1}$$

Here m denotes the charge of the super-conducting particle (say Cooper pair) and m_{12}^2 is real

parameter characterizing the coupling between the super conductors. A_μ denotes electromagnetic vector potential associated with the super conductors. D denotes d'Alembert operator $\partial_t^2 - \nabla^2$.

Weakly coupled super conductors are assumed to possess cylindrical symmetry and can be regarded as inner and out cylinder with Josephson junctions idealized with smooth distribution of them. If ME acts as Josephson junctions this assumption is exact. Weak coupling means that the densities of charge carriers are same at the two sides of the junction in a good approximation:

$$\Psi_i = \sqrt{n} \exp(i\Phi_i) , \quad i = 1, 2 . \quad (\text{C.6.2})$$

Under these assumptions one obtains for the phase difference $\Phi \equiv \Phi_1 - \Phi_2$ the Sine-Gordon equation with a coupling to the vector potential

$$\partial^\mu [\partial_\mu \Phi - q \Delta A_\mu] = m_{12}^2 \sin(\Phi) \quad (\text{C.6.3})$$

ΔA_μ denotes the difference of the vector potential over the junction. q denotes the charge of the super-conducting charge carrier.

Note that Lorentz gauge condition

$$\partial_\mu A^\mu = 0 \quad (\text{C.6.4})$$

does not trivialize the coupling to the vector potential since the equation holds true only in 3-dimensional surface defining the junction and the contribution from the direction of the normal is not present.

Josephson current J_J can be identified as the divergence of the 4-current $j_\mu = Ze\rho = Ze\Psi^*(\partial_\mu^\rightarrow - \partial_\mu^\leftarrow)\Psi$ at the either side of the junction.

$$J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 \sin(\Phi) . \quad (\text{C.6.5})$$

The Josephson current per unit length of axonal membrane of radius R and thickness d is given by

$$J = Ze \times \frac{n2\pi R d}{m} \times m_{12}^2 \sin(\Phi) . \quad (\text{C.6.6})$$

The parameter m_{12}^2 is analogous to the inverse of the magnetic penetration length squared ($\hbar = c = 1$) for the super-conductors involved.

$$m_{12}^2 = \frac{1}{\Lambda^2} . \quad (\text{C.6.7})$$

If one can regard the Josephson junction region as a defect in a super-conductor, Λ is apart from a numerical constant of order unity equal to the thickness of the Josephson junction. In the case of the cell membrane this would mean that the small oscillations associated with the Josephson junction have frequencies of order 10^{16} Hz and correspond to quanta with energies of order 100 eV.

The covariant constancy conditions

$$\begin{aligned} \partial_t \Phi &= ZeV(t, z) , \\ \partial_z \Phi &= ZeA_z(t, z) . \end{aligned} \quad (\text{C.6.8})$$

are mutually consistent only if the electric field in the axial direction vanishes. They are not however consistent with the right hand side of the equation and only one of the conditions can be

satisfied. The condition effectively reduces the equation to an ordinary differential equation. Of course, one cannot assume the condition for general solutions.

For a constant potential difference V_0 the Josephson current is sinusoidal for $\partial_t \Phi = ZeV_0$ ansatz with the basic frequency given by $\omega = eV_0$. An exact treatment replaces the sinusoidal time dependence of Φ with the time dependence of the angle coordinate of gravitational pendulum so that higher harmonics are involved. In the case of cell membrane $V(t)$ is typically a sum of constant part and time dependent part giving rise to frequency modulation of the basic Josephson current:

$$\omega(t) = eV = eV_0 + eV_1(t) .$$

Entire hierarchy of frequency modulations is possible since also eV_1 can be frequency modulated by Josephson currents.

C.6.2 Simplest Solutions Of Sine-Gordon Equation

Free Sine-Gordon equation resulting, when the coupling to the em field can be neglected, gives a good view about the solutions of full equation. In cylindrical geometry Sine-Gordon equation becomes effectively 2-dimensional under rather natural conditions. This is rather nice since two-dimensional Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges [B2].

Sine-Gordon equation allows two kinds of vacua. The vacua of first type correspond to $\Phi = 2n\pi$ ground state configuration and vacua second type to $\Phi = (2n+1)\pi$. The small perturbations around these vacua correspond to massive 1+2 dimensional free field theory with field equations

$$\begin{aligned} D\Phi &= \epsilon \frac{1}{\Lambda^2} \Phi ; \\ D &= \partial_t^2 - \nabla^2 , \\ \epsilon &= -1 \text{ for } \Phi = 2n\pi , \\ \epsilon &= 1 \text{ for } \Phi = (2n+1)\pi . \end{aligned} \tag{C.6.9}$$

In the language of quantum field theory, the small perturbations around $\Phi = 2n\pi$ describe particle with mass squared $m^2 = \frac{1}{\Lambda^2}$ whereas the small perturbations of the $\Phi = (2n+1)\pi$ vacuum describe tachyons with negative mass squared $m^2 = -\frac{1}{\Lambda^2}$. Therefore these vacua will be referred to as time like and space-like respectively.

One might argue that the space-like vacua are un-stable in the case that the continuous sheet of the Josephson junctions consists actually of discrete Josephson junctions, whose dynamics is given by the differential equation

$$\frac{d^2 \Phi}{dt^2} = -\frac{\sin(\Phi)}{\Lambda^2}$$

allowing only $\Phi = 2n\pi$ as stable ground state. For MEs acting as Josephson junction the situation is different. On the other hand, the ground state at which soliton generation is possible should be quantum critical and hence very sensitive to external perturbations. Note that time like and space-like sectors in axonal portion of neuron are permuted by a duality transformation $z \leftrightarrow vt$ ($v=c=1$), $\Phi \rightarrow \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

The propagating waves are of form $\sin(u)$, where one has

$$\begin{aligned} u &= \gamma_P \left(t - \frac{v_P z}{v^2} \right) , \text{ time like case} \\ u &= \gamma_P (z - v_P t) , \text{ space-like case} \\ \gamma_P &= \sqrt{\frac{1}{1 - \left(\frac{v_P}{v} \right)^2}} . \end{aligned} \tag{C.6.10}$$

Here v_P is the velocity parameter characterizing the boost. The frequency of these small propagating oscillations (plane waves) is in two cases given by

$$\begin{aligned}\Omega &= \frac{\gamma_P v}{\Lambda} , \quad \text{time like case} , \\ \Omega &= \frac{\gamma_P v_P}{\Lambda} , \quad \text{space-like case} .\end{aligned}\tag{C.6.11}$$

The frequency is very high for time like waves, of order 10^{10} Hz and therefore a typical time scale for the conformational dynamics of proteins. In space-like case the phase velocity of the propagating waves is $v_P < v$ and frequencies are small and one could consider the possibility of identifying these oscillations as propagating EEG waves. For the time like excitations phase velocity is $v_p = v^2/v_P > v$ and larger than light velocity. For ordinary elementary particles the situation is same but since phase velocity is in question, there are no interpretational problems.

One-dimensional solutions of the Sine-Gordon equation give quite satisfactory picture about the situation as far as the physical interpretation is considered. The simplest solutions of this type correspond to solutions depending on time or spatial coordinates only. For time like vacua one-dimensional solutions depend on time only: note that these solutions are possible for arbitrary geometry of the Josephson junction. For space-like like vacua one-dimensional solutions are possible in the axonal portions of the neuron: the simplest one-dimensional solutions depend on the axonal coordinate z only.

Field equations reduce to the equations of motion for gravitational pendulum:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2} \sin(\Phi) .\tag{C.6.12}$$

$u = vt$ holds true in time like case ($v = c \equiv 1$ is good approximation). $u = z$ holds true in space-like case (in this case equation makes sense for axonal portions only). Energy conservation for the gravitational pendulum gives

$$\frac{1}{2}v^2\left(\frac{d\Phi}{du}\right)^2 + \frac{v^2}{\Lambda^2} [1 - \cos(\Phi)] = K \frac{2v^2}{\Lambda^2} ,\tag{C.6.13}$$

where K is dimensionless constant analogous to energy. There are two kinds of solutions: oscillating solutions ($K < 1$) and rotating solutions ($K > 1$): single soliton solution corresponds to $K = 1$.

One can integrate the conservation law for energy to give the time/spatial period of oscillation or rotation (T/λ). For oscillating solutions one has

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v} \int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2[-\cos(\Phi_0) + \cos(\Phi)]}} .\tag{C.6.14}$$

Here Φ_0 is maximum value of the phase angle for oscillating solution. For the rotation period one obtains

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v} \int_0^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2[1 - \cos(\Phi)]}} .\tag{C.6.15}$$

By Lorentz-boosting space-like axonal solutions to move with velocity v_p one obtains propagating soliton sequences.

Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges. In quantum theory the eigenvalues of mutually commuting charges characterize the quantum state and these charges are basic quantum observables. Does it make sense to quantize Sine-Gordon and could one characterize the state of the axonal membrane in terms of these charges? Here one must point out the similarity to the ideas of Nanopoulos [J13], who speculates with the possibility that certain 2-dimensional conformal field theory characterizes the state of micro-tubule and the infinite number of conserve charges characterize the information content of the micro-tubule. It is perhaps also worth of mentioning that the quantum group $SU(2)$ appears in the quantization of the Sine-Gordon equation [B22]: could quantum groups have important applications in biology?

C.6.3 Are Both Time Like And Space-Like Soliton Sequences Possible Ground States?

The model for the Josephson junction predicts the existence of both time like and space-like soliton sequences. Mathematician would expect that both ground states of coupled super conductors are realized in brain. The presence of space-like and time like modes could provide general insights to brain functioning and could relate to the fundamental dichotomies of brain consciousness.

Time like soliton sequences do not in general propagate and if they propagate, the phase velocity exceeds light velocity (due to $t - vx/c^2$ dependence). The size of coherence region in the case of gap junction connected neurons can be rather large. Also micro-tubuli could form large coherent regions.

The time scales involved with the time like soliton sequence are however very fast, much faster than the time scales of EEG. This suggests that soliton sequences and oscillations are responsible for a synchronization in various scales defined by p-adic and dark matter hierarchies. One cannot exclude the possibility that the appearance of time like soliton sequences correlates with the emergence of standing EEG waves and synchronous firing whereas propagating space-like soliton sequences could accompany nerve pulse conduction. Since non-propagating collective firing does not occur, standing soliton sequences could be associated with glial cells and propagating soliton sequences with neuronal axons.

Soliton sequences could provide a general realization of biological clocks and facilitate the generation of macroscopic quantum systems. Also the gap junction connected neuron groups associated with primary sensory organs, various organs and brain could correspond to time like solitons.

For ordinary value of $\hbar$ the small oscillations for time like ground state have period of order 10^{-10} seconds: this follows solely from the spatial extension of nerve pulse of order $\Lambda \sim 10^{-2}$ meters and involves no assumptions about the detailed properties of the super conductor. These oscillations could coordinate protein dynamics. I do not know whether endoplasmic membranes inside cells have resting potential: if not, they are good candidates for the carriers of time like ground states with oscillating voltage.

For cell membrane situation is different and the only possible interpretation is that the resting potential for ordinary value of Planck constant and for far-from-vacuum ground state corresponds to the 10^{-13} second time scale determined by the membrane voltage and the mechanical analog is very rapidly rotating gravitational pendulum. Almost vacuum extremal property and large values of Planck constant change the situation and $k_d = 47$ level would correspond to 5 Hz oscillation frequency. Note that the hypothesis is $\hbar_{eff} = n\hbar$, where n is product of distinct Fermat primes and power 2^{k_d} . These time-like soliton sequences could indeed be interpreted as standing EEG waves whereas space-like soliton sequences would correspond to propagating EEG waves. The presence of perturbations appearing at multiples of cyclotron frequencies of biologically important ions means that standing and moving waves at other frequencies are possible. Nerve pulse patterns induces frequency modulations of the corresponding Josephson currents and Josephson radiation.

Glial cells [I9] form a considerable fraction of cell population of brain are glial cells and are connected to each other by gap junctions, which can serve as Josephson junctions. In glial cells large amplitude oscillations with longer oscillation period could be present. The ciliar beating of monocellular animals [I9] could be coordinated to coherent motion (making possible swimming of the monocellular organism) by the “EEG” waves.

Gap junctions between the nerve cells are not common but are encountered in the large coherently firing groups of nerve cells in the brain, in the sensory organs and other organs such as heart. The value of the parameter K is only slightly larger than the critical value $K = 1$ for EEG since the period of EEG oscillations is typically by a factor of order 10^8 longer than the period of small oscillations. The problem disappears when higher levels of dark matter hierarchy are allowed. Of course, if the potential difference in question corresponds to the membrane potential, one must have $K \gg 1$. One can wonder whether the criticality might have some deeper significance: perhaps phase transitions between EEG: s corresponding to rotating and oscillating gravitational penduli are possible.

C.6.4 Quantum Tools For Bio-Control And -Coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled superconductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled superconductors would make possible quantum control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [I23]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in the case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

Homeostasis as many-sheeted ionic flow equilibrium

The experimental work of Ling, Sachs and Qin [I19, I26] and other pioneers [I13, I8] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from super-conducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along super-conducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Super-conducting space-time sheets contain a plan of the bio-system coded to ion densities and magnetic quantum numbers characterizing the super currents. Bio-control by em fields affects these super currents and one can understand the effects of ELF em fields on bio-system in this framework. The model relies crucially on the liquid crystal property of bio-matter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [J10]: among other things the circuitry could explain how acupuncture works.

Quantum model for pattern recognition

Time translation invariant pattern recognition circuit can be realized by using two coupled superconductors. The first super-conductor contains the reference supra current and second super-conductor contains the supra current determined by the sensory input. Supra currents are assumed to have same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current

facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favors the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If interference is destructive, synchronous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supra-currents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and quantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a manner to realize a biological clock. Josephson current can be written in the form [D98]

$$\begin{aligned} J &= J_0 \sin(\Delta\Phi) = J_0 \sin(\Omega t) , \\ \Omega &= ZeV , \end{aligned} \tag{C.6.16}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [D98]

$$J_0 = \frac{\pi \sigma_s \Delta}{2e d} . \tag{C.6.17}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) \sin(\Omega t + \Delta\Phi(n)) . \tag{C.6.18}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector “wakes-up” into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.
2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the un-stability of the structure. When the supra current in the circuit dissipates below a critical value, un-stability emerges. This provides a general mechanism of biological alarm clock.

Assume that the second super conductor carries a supra current. As the time passes the reference current dissipates by phase slippages [D85, D98]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a un-stability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The un-stability itself can regenerate the reference current to the clock. If the alarm clock actually “wakes-up” the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

How MEs could generate soliton sequences?

MEs could as bio-controllers using the same general mechanism which underlies remote mental interactions and this aspect of bio-control could be seen as endogenous remote mental interactions between cells and other parts of organism. Pairs of low and high frequency MEs are involved. Low frequency MEs, say EEG MEs, serve as correlates for quantum entanglement between body parts: already this is enough for remote viewing regarded as sharing of mental images by fusion of mental images. The psychokinesis aspect is possible by high frequency MEs propagating like massless particles inside low frequency MEs. These MEs induce bridges and thus leakage of ions between various space-time sheets at the receiving end. This means self-organization by dissipation.

MEs can also act as Josephson junctions connecting super-conducting space-time sheet characterized by p-adic primes which can be different. This kind of Josephson junction contains the em field associated with ME as an external field and the mathematical description of this coupling follows from the model for the coupling of electromagnetic field to super conducting order parameters. In Minkowski coordinates the modification of the Sine-Gordon equation is simple:

$$\partial^\mu [\partial_\mu \Phi - Ze\Delta A_\mu] = m_{12}^2 \sin(\Phi) . \quad (C.6.19)$$

Here Φ denotes the phase difference over the Josephson junction, which is idealized with a continuous Josephson junction, and actually is a continuous Josephson junction in the case of ME. ΔA_μ denotes the difference of the vector potential over the junction.

The coupling to the vector potential can in the lowest order described by the condition

$$\partial_\mu \Phi_0 = Ze \Delta A_\mu$$

assumed to hold for a maximal number of components of vector potential. Here of course integrability conditions pose restrictions. One can develop perturbation series for Φ by substituting Φ_0 to the right hand side and calculating Φ_1 using the right hand side as a source term, and so on.

If the transversal em field associated with ME contains time independent radial electric field this gives rise to a constant potential term giving rise to a generation of soliton sequences. The period Ω of rotation for the soliton satisfies $\Omega = eV$, where eV corresponds to the potential difference defined by the constant part of the electric field of ME. It can also happen that ME contains only the oscillatory electromagnetic field: if the frequency is same as the frequency associated with small oscillations of the Sine-Gordon pendulum a resonant coupling is expected to result. In this case the frequency is in radio frequency range.

Also noise is present and it is quite possible that the noise provides the energy needed to amplify the weak periodic signal provided by ME to a soliton sequence by stochastic resonance. The mechanism is discussed in detail in the chapter “Quantum model for EEG and nerve pulse”. This suggests that MEs could basically control small very fast oscillations of the membrane potential.

C.7 Model For The Hierarchy Of Josephson Junctions

As far as hierarchy of EEGs and its generalizations is considered the hierarchy of Josephson junctions assignable to cell membrane itself is relevant. Dark matter hierarchy and p-adic fractality allow to imagine a fractal hierarchy of structures analogous to cell membrane with arbitrarily large thickness. One can even imagine scaled up variants of cell membrane with different p-adic length scale and value of Planck constant but possessing same membrane potential as ordinary cell membrane. The generalization of the imbedding space helps to understand what is involved and is discussed in Appendix.

C.7.1 The Most Recent Model For The Generation Of Nerve Pulse

For some time ago I learned [J6, J8, J18, J19, J21] (thanks to Ulla Mattfolk) that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large $\hbar$ and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping is needed. Combining this input with the model of DNA as topological quantum computer (TQC) [K58] leads to a rather precise model for the generation of nerve pulse.

1. The system would consist of two superconductors- microtubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of TQC. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating soliton solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between them would generate moving kHz synchronous oscillation. Periodic boundary conditions at the ends of the axon rather than chemistry determine the propagation velocities of kHz waves and kHz synchrony is an automatic consequence since the times taken by the pulses to travel along the axon are multiples of same time unit. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.
2. During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence.

The velocity of kHz wave and nerve pulse is fixed by periodic boundary conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which $\hbar$ should be correspondingly larger): synchrony is predicted also now.

3. The previous view about microtubules in nerve pulse conduction can be sharpened. Microtubular electric field (always in the same direction) could explain why kHz and EEG waves and nerve pulse propagate always in same direction and might also feed energy to system so that soliton velocity could be interpreted as drift velocity. This also inspires a generalization of the model of DNA as TQC since also microtubule-cell membrane systems are good candidates for performers of TQC. Cell replication during which DNA is out of game seems to require this and microtubule-cell membrane TQC would represent higher level TQC distinguishing between multi-cellulars and mono-cellulars.
4. New physics would enter in several manners. Ions should form Bose-Einstein cyclotron condensates. The new nuclear physics predicted by TGD [L4], [L4] predicts that ordinary fermionic ions (such as K^+ , Na^+ , Cl^-) have bosonic chemical equivalents with slightly differing mass number obtained by replacing one or more neutral color flux tubes connecting nucleons of neutral atom with a charged one. Anomalies of nuclear physics and cold fusion provide experimental support for the predicted new nuclear physics. Electronic supra current pulse from microtubules could induce the kick of pendulum inducing nerve pulse and induce a small heating and expansion of the axon. The return flux of ionic Josephson currents would induce convective cooling of the axonal membrane. A small transfer of small positive charge into the inner lipid layer could induce electronic supra current by attractive Coulomb interaction. The exchange of exotic W bosons which are scaled up variants of ordinary $W^\pm$ bosons is a natural manner to achieve this if new nuclear physics is indeed present.

C.7.2 Quantum Model For Sensory Receptor

This original model of nerve pulse and EEG was still based on the implicit assumption that the space-time sheet carrying the Josephson currents is far from vacuum. The model for sensory receptor and sensory qualia however led to a the proposal that the space-time sheet in question is near vacuum extremal [K15, K35]. Near vacuum extremal property does not affect the general structure of the model in an essential manner.

1. The only change [K35, K36] is the replacement of charges ± 1 of ions with effective charges given as

$$Q_{eff} = -\frac{Z - N}{2p} + 2Z + q_{em} . \quad (C.7.1)$$

Z and N denote nuclear charge and neutron number. $p = \sin(\theta_W)$ corresponds to Weinberg angle. 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 C.4** gives the values of Josephson energies for some values of resting potential for $p = \sin(\theta_W) = .0295$ reproducing the frequencies of peak sensitivity for photoreceptors. Rather remarkably, they are in IR or visible range.

2. The energies are in UV and visible range. Hence one can consider also Josephson junctions with considerably lower membrane potentials of order mV are possibly without losing the thermal stability. For instance, one could consider $k = 151, 157, 163, 167$ Josephson junctions with a membrane potential scaling as $1/L(k)$. For $k = 167$ the energies would be scaled down

Ion	Na^+	Cl^-	K^+	Ca^{++}
$E_J(.04 \text{ mV}, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065 \text{ V}, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40 \text{ mV}, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50 \text{ mV}, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55 \text{ mV}, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65 \text{ mV}, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70 \text{ mV}, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75 \text{ mV}, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80 \text{ mV}, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90 \text{ mV}, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95 \text{ mV}, p = .0295)/eV$	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 C.4: 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.

by a factor $2^{-(167-151)/2} = 2^{-8}$ giving for $V_{eff} = .09 \text{ V}$ a photon energy somewhat below the thermal energy at room temperature. On the other hand, the fact that Josephson junctions with a vanishing Z^0 field are at the verge of thermal instability suggests that also they might be present in living matter.

3. From **Table C.4** one can evaluate the value of Planck constant for a given Josephson frequency for various ions. For $f_J = 5 \text{ Hz}$ giving a first estimate for neuronal Josephson frequency and $V = -55 \text{ mV}$ corresponding to the critical voltage for the generation of action potential one obtains the values $r = \hbar/\hbar_0 = (1.51, 1.89, 2.11, 1.59) \times 2^{46}$ for $(Na^+, Cl^-, K^+, Ca^{++})$. For $V = -70 \text{ mV}$ corresponding to the resting potential of neuron and same Josephson frequency one obtains $r = (0.961, 2.01, 3.41, 0.1) \times 2^{47}$. For Ca^{++} ion r is very near to a power of 2. A good mnemonic is that the Josephson energies of biologically important ions vary in an interval, which is in a reasonable approximation half octave ($E_J(K^+)/E_J(Na^+) = 1.3958 \simeq \sqrt{2} \simeq 1.4142$).

It is interesting to try to interpret the resting potentials of various cells in this framework in terms of the Josephson frequencies of various ions. **Table C.4** gives the values of Josephson frequencies of basic biological ions for typical values of the membrane potential.

1. The maximum value of the action potential during nerve pulse 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.

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.

C.7.3 The Role Of Josephson Currents

The general vision is that Josephson currents of various ions generate Josephson photons having dual interpretations as bio-photons and EEG photons. Josephson photons can in principle regenerate the quale in the neurons of the sensory pathway. In the case of motor pathways the function would be different and the transfer of metabolic energy by quantum credit card mechanism using phase conjugate photons is suggested by the observation that basic metabolic quanta 2 eV *resp.* 4 eV are associated with smooth muscle cells *resp.* skeletal muscle cells.

As already found in the previous section, the energies of Josephson photons associated with the biologically important ions are in general in visible or UV range except when resting potential has the value of -40 mV which it has for photoreceptors. In this case also IR photons are present. Also the turning point value of membrane potential is +40 mV so that one expects the emission of IR photons.

Josephson photons could be used to communicate the qualia to the magnetic body.

1. If Josephson currents are present during the entire action potential, the entire range of Josephson photons down to frequencies of order 2 kHz range is emitted for the standard value of $\hbar$. The reason is that lower frequencies corresponds to cycles longer than the duration of the action potential. The continuum of Josephson frequencies during nerve pulse makes it possible to induce cyclotron transitions at the magnetic body of neuron or large structure. This would make possible to communicate information about spatial and temporal behavior of the nerve pulse pattern to the magnetic body and build by quantum entanglement a sensory map.
2. The frequencies below 2 kHz could be communicated as nerve pulse patterns. When the pulse rate is above $f = 28.57$ Hz the sequence of pulses is experienced as a continuous sound with pitch f . f defines the minimum frequency for which nerve pulses could represent the pitch and there remains a 9 Hz long range to be covered by some other communication method.
3. The cyclotron frequencies of quarks and possibly also of electron would make possible a selective reception of the frequencies emitted during nerve pulse. Same applies also to the Josephson frequencies of hair cell (, which does not fire). If the value of Planck constant is large this makes possible to communicate the entire range of audible frequencies to the magnetic body. Frequency would be coded by the magnetic field strength of the flux tube. Two options are available corresponding to the standard ground state for which Z^0 field is very weak and to almost vacuum extremals. For the first option one as ordinary cyclotron frequencies. The cyclotron frequency scales for them differ by a factor

$$r(q) = \frac{Q_{eff}(q)}{Q_{em}(q)} = \frac{\epsilon(q)}{2pQ_{em}(q)} + 1, \quad \epsilon(u) = -1, \quad \epsilon(d) = 1 \quad (C.7.2)$$

from the standard one. For $p = .0295$ one obtains $(r(u), r(d), r(e)) = (24.42, 49.85, 15.95)$. The cyclotron frequencies for quarks and electron with masses $m(u)=2$ MeV, $m(d)=5$ MeV, and $m(e)=.5$ MeV are given by **Table C.5** for the two options. If one assumes that B_{end} defines the upper bound for field strength then the standard option would require both d

fermion	$f_c(e)/MHz$	$f_c(u)/MHz$	$f_c(d)/MHz$
standard	.564	.094	.019
nearly vacuum extremal	8.996	2.275	.947

Table C.5: Cyclotron frequencies of quarks and electron in magnetic field $B_{end} = .2$ Gauss for standard vacuum with very small Z^0 field and nearly vacuum extremal.

quark and electron. For d quark with kHz CD the upper bound for cyclotron frequencies would be 20 kHz which corresponds to the upper limit of audible frequencies.

- Besides cyclotron frequencies also the harmonics of the fundamental frequencies assignable to quark and electron CDs could be used and in case of musical sounds this looks a highly attractive option. In this case it is now however possible to select single harmonics as in the case of cyclotron transitions so that only the rate of nerve pulses can communicate single frequency. Lorentz transform sub-CD scales up the frequency scale from the secondary p-adic time scale coming as octave of 10 Hz frequency. Also the scaling of $\hbar$ scales this frequency scale.

C.7.4 What Is The Role Of The Magnetic Body?

The basic vision is that magnetic body receives sensory data from the biological body- basically from cell membranes and possibly via genome - and controls biological body via genome. This leaves a huge amount of details open and the almost impossible challenge of theoretician is to guess the correct realization practically without any experimental input. The following considerations try to clarify what is involved.

Is magnetic body really needed?

Libet's findings and the model of memory based on time mirror (see **Fig.** <http://tgdtheory.fi/appfigures/timemirror.jpg> or **Fig. ??** in the appendix of this book) hypothesis suggests that magnetic body is indeed needed. What is the real function of magnetic body? Is it just a sensory canvas? The previous considerations suggest that it is also the seat of geometric qualia, in particular the pitch of sound should be coded by it. It would be relatively easy to understand magnetic body as a relatively passive sensory perceiver defining sensory map. If one assumes that motor action is like time reversed sensory perception then sensory and motor pathways would be just sensory pathways proceeding in opposite time directions from receptors to the various layers of the magnetic body. Brain would perform the information processing.

Certainly there must exist a region in which the motor and sensory parts of the magnetic body interact. What comes in mind is that these space-time sheets (or actually pairs of space-time sheets) are parallel and generate wormhole contacts between them. This interaction would be assignable to the region of the magnetic body could receive positive energy signals from associative sensory areas and send negative energy signals to motor neurons at the ends of motor pathways wherefrom they would propagate to premotor cortex, supplementary motor cortex and to frontal lobes where the abstract plans about motor actions are generated.

Is motor action time reversal of sensory perception in zero energy ontology?

One could argue that the free will aspect of motor actions does not conform with the interpretation as sensory perception in reversed direction of time. On the other hand, also percepts are selected -say in binocular rivalry [J16]. Only single alternative percept need to be realized in a given branch of the multiverse. This makes possible metabolic economy: for instance, the synchronous firing at kHz frequency serving as a correlate for the conscious percept requires a lot of energy since dark photons at kHz frequency have energies above thermal threshold. Similar selection of percepts could occur also at the level of sensory receptors but quantum statistical determinism would guarantee reliable perception. The passivity of sensory perception and activity of motor activity would reflect the breaking of the arrow of time if this interpretation is correct.

What magnetic body looks like?

What magnetic body looks like has been a question that I have intentionally avoided as a question making sense only when more general questions have been answered. This question seems however unavoidable now. Some of the related questions are following. The magnetic flux lines along various parts of magnetic body must close: how does this happen? Magnetic body must have parts of size at least that defined by EEG wavelengths: how do these parts form closed structures? How the magnetic bodies assignable to biomolecules relate to the Earth sized parts of the magnetic body? How the personal magnetic body relates to the magnetic body of Earth?

1. The vision about genome as the brain of cell would suggest that active and passive DNA strands are analogous to motor and sensor areas of brain. This would suggest that sensory data should be communicated from the cell membrane along the passive DNA strand. The simplest hypothesis is that there is a pair of flux sheet going through the DNA strands. The flux sheet through the passive strand would be specialized to communicate sensory information to the magnetic body and the flux sheet through the active strand would generate motor action as DNA expression with transcription of RNA defining only one particular aspect of gene expression. Topological quantum computation assignable to introns and also electromagnetic gene expression would be possible.
2. The model for sensory receptor in terms of Josephson radiation suggests however that flux tubes assignable to axonal membranes carry Josephson radiation. Maybe the flux tube structures assigned to DNA define the magnetic analog of motor areas and flux tubes assigned with the axons that of sensory areas.
3. A complex structure of flux tubes and sheets is suggestive at the cellular level. The flux tubes assignable to the axons would be parallel to the sensory and motor pathways. Also microtubules would be accompanied by magnetic flux tubes. DNA as topological quantum computer model assumes and the proposed model of sensory perception and cell membrane level suggests transversal flux tubes between lipids and nucleotides. The general vision about DNA as brain of cell suggest flux sheets through DNA strands.

During sensory perception of cell and nerve pulse the wormhole flux tube connecting the passive DNA strand of the first cell to the inner lipid layer would recombine with the flux tube connecting outer lipid layer to some other cell to form single flux tube connecting two cells. In the case of sensory organs these other cells would be naturally other sensory receptors. This would give rise to a dynamical network of flux tubes and sheets and axonal sequences of genomes would be like lines of text at the page of book. This structure could have a fractal generalization and would give rise to an integration of genome to super-genome at the level of organelles, organs and organism and even hypergenome at the level of population. This would make possible a coherent gene expression.

4. This vision gives some idea about magnetic body in the scale of cell but does not say much about it in longer scales. The CDs of electrons and quarks could provide insights about the size scale for the most relevant parts of the magnetic body. Certainly the flux tubes should close even when they have the length scale defined by the size of Earth.

Additional ideas about the structure follow if one assumes that magnetic body acts a sensory canvas and that motor action can be regarded as time reversed sensory perception.

1. If the external world is represented at part of the magnetic body which is stationary, the rotation of head or body would not affect the sensory representation. This part of the magnetic body would be obviously analogous to the outer magnetosphere, which does not rotate with Earth.
2. The part of the magnetic body at which the sensory data about body (posture, head orientations and position, positions of body parts) is represented, should be fixed to body and change its orientation with it so that bodily motions would be represented as motions of the magnetic , which would be therefore analogous to the inner magnetosphere of rotating Earth.

3. The outer part of the personal magnetic body is fixed to the inner magnetosphere, which defines the reference frame. The outer part might be even identifiable as the inner magnetosphere receiving sensory input from the biosphere. This magnetic super-organism would have various life forms as its sensory receptors and muscle neurons. This would give quantitative ideas about cyclotron frequencies involved. The wavelengths assignable to the frequencies above 10 Hz would correspond to the size scale of the inner magnetosphere and those below to the outer magnetosphere. During sleep only the EEG communications with outer magnetic body would remain intact.
4. Flux quantization for large value of $\hbar$ poses an additional constraint on the model.
 - (a) If Josephson photons are transformed to a bunch of ordinary small $\hbar$ photons magnetic flux tubes can correspond to the ordinary value of Planck constant. If one assumes the quantization of the magnetic flux in the form

$$\int B dA = n\hbar$$

used in super-conductivity, the radius of the flux tube must increase as $\sqrt{\hbar}$ and if the Josephson frequency is reduced to the sound frequency, the value of $\hbar$ codes for the sound frequency. This leads to problems since the transversal thickness of flux tubes becomes too large. This does not however mean that the condition might not make sense: for instance, in the case of flux sheets going through DNA strands the condition might apply.

- (b) The quantization of magnetic flux could be replaced by a more general condition

$$\oint (p - ZeA) dl = n\hbar \quad , \quad (C.7.3)$$

where p represents momentum of particle of super-conducting phase at the boundary of flux tube. In this case also $n = 0$ is possible and poses no conditions on the thickness of the flux tube as a function of $\hbar$. This option looks reasonable since the charged particles at the boundary of flux tube would act as sources of the magnetic field.

- (c) Together with the Maxwell's equation giving $B = ZeNv$ in the case that there is only one kind of charge carrier this gives the expression

$$N = \frac{2m}{RZ^2e^2} \quad (C.7.4)$$

for the surface density N of charge carrier with charge Z . R denotes the radius of the flux tube. If several charge carriers are present one has $B = \sum_k N_k Z_k e v_k$, and the condition generalizes to

$$N_i = \frac{2m_i v_i}{RZ_i \sum_k Z_k v_k e^2} \quad . \quad (C.7.5)$$

It seems that this condition is the most realistic one for the large $\hbar$ flux sheets at which Josephson radiation induces cyclotron transitions.

What are the roles of Josephson and cyclotron photons?

The dual interpretation of Josephson radiation in terms of bio-photons and EEG photons seems to be very natural and also the role of Josephson radiation seems now relatively clear. The role of cyclotron radiation and its interaction with Josephson radiation are not so well understood.

1. At least cell membrane defines a Josephson junction (actually a collection of them idealizable as single junctions). DNA double strand could define a series of Josephson junctions possibly assignable with hydrogen bonds. This however requires that the strands carry some non-standard charge densities and currents- I do not know whether this possibility is excluded

experimentally. Quarks and antiquarks assignable to the nucleotide and its conjugate have opposite charges at the two sheets of the wormhole flux tube connective nucleotide to a lipid. Hence one could consider the possibility that a connection generated between them by reconnection mechanism could create Josephson junction.

2. The model for the photoreceptors leads to the identification of bio-photons as Josephson radiation and suggests that Josephson radiation propagates along flux tubes assignable to the cell membranes along sensory pathways up to sensory cortex and from there to motor cortex and back to the muscles and regenerates induced neuronal sensory experiences.
3. Josephson radiation could be used quite generally to communicate sensory data to/along the magnetic body: this would occur in the case of cell membrane magnetic body at least. The different resting voltages for various kinds of cells would select specific Josephson frequencies as communication channels.
4. If motor action indeed involves negative energy signals backwards in geometric time as Libet's findings suggest, then motor action would be very much like sensory perception in time reversed direction. The membrane resting potentials are different for various types of neurons and cells so that one could speak about pathways characterized by Josephson frequencies determined by the membrane potential. Each ion would have its own Josephson frequency characterizing the sensory or motor pathway.

The basic questions concern the function of cyclotron radiation and whether Josephson radiation induces resonantly cyclotron radiation or vice versa.

1. Cyclotron radiation would be naturally associated with the flux sheets and flux tubes. The simplest hypothesis is that at least the magnetic field $B_{end} = .2$ Gauss can be assigned with the some magnetic flux quanta at least. The model for hearing suggests that B_{end} is in this case quantized so that cyclotron frequencies provide a magnetic representation for audible frequencies. Flux quantization does not pose any conditions on the magnetic field strength if the above discussed general flux quantization condition involving charged currents at the boundary of the flux quantum are assumed. If these currents are not present, $1/\hbar$ scaling of B_{end} for flux tubes follows.
2. The assumption that cyclotron radiation is associated with the motor control via genome is not consistent with the vision that motor action is time reversed sensory perception. It would also create the unpleasant question about information processing of the magnetic body performed between the receipt of sensory data and motor action.
3. The notion of magnetic sensory canvas suggests a different picture. Josephson radiation induces resonant cyclotron transitions at the magnetic body and induces entanglement of the mental images in brain with the points of the magnetic body and in this manner creates sensory maps giving a third person perspective about the biological body. There would be two kind of sensory maps. Those assignable to the external world and those assignable to the body itself. The Josephson radiation would propagate along the flux tubes to the magnetic body.
4. There could be also flux tube connections to the outer magnetosphere of Earth. It would seem that the reconnections could be flux tubes traversing through inner magnetosphere to poles and from there to the outer magnetosphere. These could correspond to rather low cyclotron frequencies. Especially interesting structure in this respect is the magnetic flux sheet at the Equator.

C.7.5 Dark Matter Hierarchies Of Josephson Junctions

The hierarchy of Josephson junctions assignable to cell membrane and characterized by values of Planck constant provides a rather nice model for cell membrane but one can consider also more general dark hierarchies of Josephson junctions. This model conforms with the general vision that living matter processes information by locating it to various pages of the "Big Book".

Maximization of Planck constant in quantum control and communication in living matter

The sectors of the imbedding space for which CD and CP_2 are replaced with their n_a - resp. n_b -fold coverings define the most promising candidates concerning the understanding of living matter, at least the quantum control of living matter. The reason is that the value of the Planck constant is maximized and given by $r = \hbar/\hbar_0 = n_a n_b$. Also the number of pages with same Planck constant would be finite unlike for the more general option allowing rational values of Planck constant. In particular, infinite number of pages with the standard value of Planck constant would be possible and this might lead to mathematical difficulties.

Experimental constraints allow to consider also the possibility that only covering spaces are possible. One must be however very cautious in making hasty conclusions. If also factor spaces are allowed one can have G_a or G_b as discrete and exact symmetry groups at the level of dark matter and these symmetries would be manifested as approximate symmetries of the visible matter topologically condensed around the dark matter.

1. In M^4 degrees of freedom since the restriction to the orbifold $\hat{M}^4/G_a$ is equivalent to the exact G_a -invariance of dark matter quantum states. Molecular rotational symmetries correspond typically to small groups G_a and might relate to this symmetry. Small values of n_a would not affect dramatically the value of Planck constant if n_b is large.
2. $G_a = Z_n$, $n = 5, 6$ are favored for molecules containing aromatic cycles. Also genuinely 3-dimensional tetrahedral, octahedral, and icosahedral symmetries appear in living matter.

In the sequel only integer values of Planck constant will be considered. An especially interesting hierarchy corresponds to ruler and compass integers expressible as a product of power of two and distinct Fermat primes (see Appendix). The reason is that these integers correspond to number theoretically very simple quantum phases. This hierarchy includes as a special case powers of two and one can imagine a resonant interaction between p-adic length scale hierarchy and hierarchy of Planck constants.

Dark hierarchy of Josephson junctions with a constant thickness

The model for EEG relies on fractal hierarchy of cell membrane like structures with a fixed thickness and membrane potential. Therefore cell membrane thickness is not scaled by $\hbar$ as one might naïvely expect. Same applies to magnetic flux tubes: this is possible since the condition for the quantization of magnetic flux can be replaced with a more general one if one allows charged currents at the boundaries of flux quanta [K35]. In this model the value of $\hbar$ becomes a measure for the evolutionary level of cell and neurons in hippocampus, associative regions of cortex and their motor counterparts, and frontal lobes are expected to correspond to the largest values of $\hbar$ measuring also the time scale of long term memory and planned action. Note that cell membrane corresponds to twin primes $k = 149$ and $k = 151$ with $k = 151$ defining a Gaussian Mersenne so that it is indeed very special.

Page of a book is rather precise metaphor for the magnetic flux sheet going through a linear array of strings of nuclei and also for a collection flux tubes parallel to axons. This raises several questions. Do the lines of the text of this book correspond to axons in neural circuits? Do the pages correspond to larger structures formed by the axons?

The quantum model for qualia [K35] implies that Josephson radiation travels through flux tubes parallel to sensory pathways and there could be also a horizontal organization of the neurons—at least at the level of sensory receptors in the sense that magnetic flux tubes connecting DNA nucleotides to lipids of cell membrane fuse to form longer flux tubes between DNA nucleotides of different cells when sensory receptor is active. Axons could thus be seen as the analogs of text lines which however can interact with each other. Similar organization would appear at the level of flux sheets traversing through DNA strands.

Books are made for reading and one can thus ask whether the book metaphor extends. Could the observed moving brain waves scanning cortex relate to the “reading” of the information associated with these sheets of book by the magnetic body and does our internal speech correspond to this “reading”? One is also forced to ask whether these brain waves are induced by waves

$(k, k + 2)$	(137, 139)	(149, 151)	(167, 169 = 13^2)	(179, 181)
$L_e(k)$	.78 <i>A</i>	5 <i>nm</i>	2.5 μm	.32 <i>mm</i>
$(k, k + 2)$	(191, 193),	(197, 199)		
$L_e(k)$	1 <i>cm</i>	8 <i>cm</i>		

Table C.6: Twin primes define especially interesting candidates for double membrane like structures defining Josephson junctions. Also included the pair (137, $13^2 = 169$) although $k = 169$ is not prime. The two largest scales could relate to structures appearing in brain.

propagating along magnetic flux quanta of the magnetic body of Earth or personal magnetic body in the case that it has components other than magnetic flux sheets serving as Josephson junctions.

An objection against a fractal hierarchy of Josephson junctions with thickness scaling as $\hbar$

One can consider also a hierarchy of Josephson junctions with a scaled up thickness proportional to $\hbar$ instead of constant thickness. If these junctions have same voltage at all levels of the hierarchy a resonant interaction between various levels of the hierarchy would become possible.

One can represent common sense objections against this idea. The electric field involved with the higher levels of Josephson junction hierarchy is very weak: something like 10^{-7} V/m for lito-ionospheric Josephson junctions (of thickness about 176 km from the scaling of the cell membrane thickness by $\lambda^4 = 2^{44}$) which might be responsible for EEG. The electric field of the Earth at space-time sheets corresponding to ordinary matter is much stronger: about $10^2 - 10^4$ V/m at the surface of Earth but decreasing rapidly as ionosphere is approached being about .3 V/m at 30 km height. The estimate for the voltage between ionosphere and Earth surface is about 200 kV [?].

The many-sheeted variant of Faraday law implies that on order to have a voltage of order .08 V over lito-ionospheric Josephson junction at dark matter space-time sheet, the voltage over ionospheric cavity must be almost completely compensated by an opposite voltage over litosphere so that lito-ionospheric double layer could be seen as a pair of capacitor plates in a radial electric field of order 10^{-7} V/m generated by the charge density in sub-litospheric part of Earth. This condition requires fine-tuning and therefore looks unrealistic.

A natural distance scale in which the electric field is reduced would correspond to 10-20 km thick layer in which whether phenomena are present. The mirror image of this layer would be Earth's crust. The cell membrane counterpart would be a dipole layer like charge density between the lipid layers of the cell membrane. Note that the electric field at dark matter space-time can be constant. However, as far as Josephson junction is considered, it is only the net voltage what matters.

C.7.6 P-Adic Fractal Hierarchy Of Josephson Junctions

p-Adic length scale hypothesis allows to imagine a hierarchy of Josephson junctions at least in length scales regarded usually as biologically relevant. The voltage through the junction need not however be same as for the ordinary cell membrane anymore. Twin primes are especially interesting since they would naturally correspond to pairs of structures analogous to a pair of lipid layers defining cell membrane.

In particular, twin primes abundant in the p-adic length scale range assignable to living matter could define double layered structures acting as Josephson junctions.

Also Gaussian Mersennes define highly interesting p-adic length scales and the length scale range between cell membrane thickness and the size of cell contains as many as four Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$. Only the smallest one is associated with a twin prime but p-adic length scale hypothesis allows also non-prime values of k .

The possibility of a p-adic hierarchy of membrane like structures accompanied by Josephson junctions

One can imagine the existence of fractally scaled up variants of cell membrane defining hierarchy of Josephson junctions possibly realized as magnetic flux tubes. The possible existence of this hierarchy is however not relevant for the model of EEG in its recent form.

The first hierarchy correspond to the p-adic length scales varying in the range of biologically relevant p-adic length scales $L(k)$ involving membrane like structures. Twin primes $(k, k+2)$ are good candidates here (Table 3). Second hierarchy corresponds to dark matter hierarchy for which length scales come as $\sqrt{r}L(k)$, $r = \hbar/\hbar_0$. Later the question which values of r are favored will be discussed.

The size of cell nucleus varies in the range ($L(169) = 5 \mu m, 2L(169) = 10 \mu m$). This is consistent with the assumption that cell nucleus provides the fundamental representation for this block. This would mean that at least the multiply coiled magnetic flux quantum structures associated with DNA appear as fractally scaled up copies.

Each dark matter level corresponds to a block of p-adic length scales $L(k)$, $k = 151, \dots, 169$. Also new length scales emerge at given level and correspond to $L(k)$, $k > 169$. The dark copies of all these length scales are also present. Hence something genuinely new would emerge at each level.

Fractal hierarchy of magnetic bodies assignable to cell

Second hierarchy corresponds to a dark matter hierarchy involving values of Planck constant. The original hypothesis was that the values of Planck constant comes as $r \equiv \hbar/\hbar_0 = 2^{11k}$ of given p-adic length scale assignable to biological membrane like structure. A possible justification for the hypothesis is that the ratio of electron and proton masses is rather near to 2^{11} and that this number appears in quantum TGD in the role of fundamental constant. This hypothesis is however un-necessarily restrictive and it is better to consider at least the values of r given as products of two ruler and compass integers n_F expressible as a product of distinct Fermat primes and some power of two. The justification comes from the number theoretic vision about evolution and number theoretical simplicity of the phases $q = \exp(i2\pi/n_F)$ (Appendix).

The emergence of a genuinely new structure or function in evolution would correspond to the emergence of new level in this fractal hierarchy. Quantum criticality would be essential: phases corresponding different values of Planck constant would compete at quantum criticality.

The flux sheet or tubes through cell membranes should integrate to larger structures at the higher levels of dark matter hierarchy implying the integration of sensory inputs from a large number of cells to single coherent input at higher levels of dark matter hierarchy. One can think two options: the sensory inputs from cell membranes are communicated directly to the magnetic body or via the DNA. The second option would require that the flux sheets or tubes starting from cell membrane traverse also the DNA.

Appendix D

Quantum Model for Bio-Superconductivity: II

D.1 Introduction

The models for EEG and its variants and for nerve pulse rely on a general model of high T_c superconductivity [K8, K9]. In this chapter the general vision behind model of cell membrane as super-conductor inspired by the identification of dark matter in terms of hierarchy of Planck constants and the notion of magnetic body considered in the previous chapter is tested by applying it to various anomalous findings about the behavior of the cell membrane.

D.1.1 Exotic Charge Transfer Between Cell Interior And Exterior As Fundamental Control Mechanism

The notions of ionic channels and pumps associated with the cell membrane are central for the standard cell biology [I25]. There are however puzzling observations challenging this dogma and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they not depend on the cell membrane at all [I19, I14, I8, I26, I13]. One of the pioneers in the field has been Gilbert Ling [I19]. who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [I18]) gives an excellent layman summary about the paradoxical experimental results.

One can imagine several charge transfer mechanisms.

1. Ionic supra currents and Josephson currents define the first candidate for exotic charge transfer. The experimental data led to a model for cell homeostasis as a flow equilibrium in which very small densities of super-conducting ions (also molecular ions) and ionic supracurrents at cellular and other super-conducting space-time sheets dictate the corresponding densities at the atomic space-time sheets.
2. The most feasible model for cell membrane and charge transfer found hitherto relies on Pollack's observations about fourth gel like phase of water. The model for the findings leads to a generalization of the cell membrane as Josephson junction obtained by adding to Josephson energy the difference of the cyclotron energies of dark ion at two sides of the cell membrane. Cyclotron energy difference replaces chemical potential difference in the generalization of the thermodynamical model inspired by Zero Energy Ontology, and replacing thermodynamical distributions with their quantal "square roots". Charge transfer would be induced by a phase transition changing the value of Planck constant at either or both sides of the membrane. This would induce the change of the equilibrium concentrations of ions and also charge transfer.
3. I have also considered the exchange of exotic W bosons as a non-local charge transfer mechanism involving quantum entanglement in an essential manner. Z^0 super-conductivity possible

for almost vacuum extremals in principle allows to generalize the model also to the control of the densities of neural atoms and molecules at atomic space-time sheets.

This control mechanism need not be the only one. Magnetic flux tubes serving as colored braid strands connecting different bio-molecules in highly selective manner and phase transitions reducing or increasing $\hbar$ could explain the mysterious precision of bio-catalysis as how the prebiotic evolution has led to the known biology [K58]. Magnetic flux tubes could also act as Josephson junctions between widely separated structures.

D.1.2 Further Experimental Findings

There are further experimental findings giving support for the TGD based vision about living cell. The following findings are discussed.

1. Mainstream scientists refuse often to take seriously water memory and homeopathy using arguments which do not tolerate daylight. There is rich amount of evidence that water is able to store information about diluted molecules even at the limit of vanishing dilution [K18]. The explanation is of course that water somehow stores the information about molecules instead of molecules (this kind of explanation should be easy to discover at the computer era but the simplistic argument of skeptics is that those taking seriously water memory are crackpots not able to realize that the density of molecules after the preparation of homeopathic remedy is vanishingly small!). The notion of magnetic body and Pollack's findings about fourth phase of water inspired TGD based model of water memory. The emergence of vertebrate genetic code in the model of dark proton and nuclei allows even the possibility that exclusion domains of Pollack define primitive life forms.
2. Chiral selection of bio-molecules is one of the basic mysteries of biology. Dark matter realized in terms of a hierarchy of Planck constants suggests that electroweak physics could appear as scaled up dark and also ordinary copies in various preferred p-adic length scales. Below the Compton lengths dark and p-adically scaled-up weak bosons would behave like massless particles implying that weak interactions have same strength as electromagnetic interactions so that parity breaking effects caused by the axial couplings of weak bosons would be large and could explain chiral selection.
3. The observation that the irradiation of water by radiowaves "burns" water by inducing a visible flame is not easy to understand in standard physics framework. If the radio waves involves dark photons with large enough Planck constant, the high energy of radiowave photons induce large energy transfer to the water and can induce the effect.

D.1.3 Evidence For Axonal Supra Currents

Hafedh Abdelmelek and collaborators [J15] have found evidence for effective super-conductivity in the sciatic nerves of both endotherms (rabbit) and poikilotherms (frog). The basic finding is that the resistance of the sciatic nerve is reduced by a factor of about ten below a critical temperature at the lower edge of the range of the physiological temperatures. The reduction of the temperature occurs inside a narrow temperature range ΔT , $\Delta T/T_c \sim .04$. This suggests effective super-conductivity. Furthermore, the critical temperature T_c for the breaking of the effective super-conductivity raises from 240 K to 300 K in the transition from poikilotherms (say frog) to endotherms (say rabbit). A TGD inspired model for these currents is discussed.

D.1.4 DC Currents Of Becker

Robert Becker [J10] proposed on basis of his experimental work that living matter behaves as a semiconductor in a wide range of length scales ranging from brain scale to the scale of entire body. Direct currents flowing only in preferred direction would be essential for the functioning of living manner in this framework.

One of the basic ideas of TGD inspired theory of living matter is that various currents, even ionic currents, are quantal currents. The first possibility is that they are Josephson currents

associated with Josephson junctions but already this assumption more or less implies also quantal versions of direct currents.

A TGD inspired model for quantal direct currents is proposed and its possible implications for the model of nerve pulse are discussed.

D.1.5 Two Views About Cell Membrane

I have considered two possible views about cell membrane. First view might apply to sensory receptors and involves in an essential manner the classical Z^0 fields which could be present even in cellular length scales if the hierarchy of Planck constants is realized. Second view is inspired by Pollack's findings.

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. It has however become clear that the argument fixing the value of Weinberg angle is however rather weak. The assumption that the membrane potentials through receptors are different for biologically important ions and their Cooper pairs allows to reproduce the photon energies which are absorbed maximally by photoreceptors.

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.

Pollack's findings about fourth phase of water

Pollack and Zheng discovered what they call exclusions zone in water. Exclusion zone is negatively charged and has rather intriguing properties suggesting its biological relevance. I have considered this finding in TGD context for few years ago and decided to keep the proposed model as an example about how ideas develop. I also discuss the recent model inspired by the lecture of Pollack [L14] about the fourth phase of water.

The discovery of negatively charged exclusion zone formed in water bounded by gel phase was the motivation for Pollack to propose the notion of gel like fourth phase of water.

The TGD inspired 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 [K18, L4]. 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.

This leads to a model of cell membrane as a generalized Josephson junction. Generalized Josephson energy is identified as the sum of the Coulombic part and difference of cyclotron energies at the two sides of the cell membrane. Zero energy ontology inspires a model of cell membrane defined as "square root" of the thermodynamical model of cell membrane. This leads to the identification of EEG and its variants in terms of dark photons with generalized Josephson energies. Biophotons would result as decay products of these dark photons. This model allows generalization to the case of almost vacuum extremal.

D.1.6 Implications Of Strong Gravimagnetism For TGD Inspired Quantum Biology

Physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity.

Tajmar et al have proposed the gravimagnetic effect as an explanation of an anomaly related to the superconductors. The measured value of the mass of the Cooper pair is slightly larger than the sum of masses whereas theory predicts that it should be smaller. The explanation would be that actual Thomson field is larger than it should be because of gravimagnetic contribution to quantization rule used to deduce the value of Thomson field. The required value of gravimagnetic Thomson field is however 28 orders of magnitude larger than General Relativity suggests. TGD inspired proposal is based on the notion of gravitational Planck constant assignable to the flux tubes connecting to massive objects. It turns out that the TGD estimate for the Thomson field has correct order of magnitude. The identification $h_{eff} = h_{gr}$ at particle physics and atomic length scales emerges naturally.

A vision about the fundamental role of quantum gravitation in living matter emerges. The earlier hypothesis that dark EEG photons decay to biophotons with energies in visible and ultraviolet range receives strong quantitative support. Also a mechanism for how magnetic bodies couple bio-chemistry emerges. The vision conforms with Penrose's intuitions about the role of quantum gravity in biology.

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> [L11].

D.2 Exotic Charge Transfer Between Cell Interior And Exterior As Fundamental Control Mechanism

The notions of ionic channels and pumps associated with the cell membrane are central for the standard cell biology [I25]. There are however puzzling observations challenging this dogma and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they not depend on the cell membrane at all [I19, I14, I8, I26, I13]. One of the pioneers in the field has been Gilbert Ling [I19], who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [I18]) gives an excellent layman summary about the paradoxical experimental results.

It was a pleasant surprise to find that these experimental findings give direct support for the existence of an exotic charge transfer between cell interior and exterior.

Ionic supra currents and Josephson currents or the exchange of exotic W bosons could be in question. For the first option, the experimental data led to a model for cell homeostasis as a flow equilibrium in which very small densities of super-conducting ions (also molecular ions) and ionic supercurrents at cellular and other super-conducting space-time sheets dictate the corresponding densities at the atomic space-time sheets. Z^0 super-conductivity possible for almost vacuum extremals in principle allows to generalize the model also to the control of the densities of neural atoms and molecules at atomic space-time sheets.

This control mechanism need not be the only one. Magnetic flux tubes serving as colored braid strands connecting different bio-molecules in highly selective manner and phase transitions reducing or increasing $\hbar$ could explain the mysterious precision of bio-catalysis as how the prebiotic evolution has led to the known biology [K58]. Magnetic flux tubes could also act as Josephson junctions between widely separated structures.

D.2.1 Strange Behavior Of The Intracellular Water

The basic strange feature of cellular interior is related to its gelatinous nature and is in fact familiar for everyone. Although 80 percent of hamburger is water, it is extremely difficult to extract this

water out. Ling [I14] has demonstrated this at cellular level by using a centrifuge and cells for which cell membrane is cut open: centrifugal accelerations as high as 1000 g fail to induce the separation of the intracellular water.

The assumption that cytoplasm behaves like gel explains these findings. Egg is very familiar example of gel phase so that this proposal could have been made already by the pioneers. The dipolar nature of bio-molecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [I19]. This cohesion gives rise to liquid [?] [D5] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [I22, I21, I19]. For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [K10]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [I20] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

D.2.2 Are Channels And Pumps Really There?

Standard neurophysiology relies strongly on the concepts of what might be called hydro-electro-chemistry. The development of the theory has occurred through gradual improvements saving the existing theory.

The development began from the basic observation that cells are stable gelatinous entities not mixing with the surrounding water. This led to the hypothesis that cell membrane takes care that the contents of the cell do not mix with the cell exterior. It was however soon found that cell membrane allows some ions to flow through. The interaction between theory and experiment led gradually to the notions of ion channel and ion pump, which are still central for the standard paradigm of the cell [I25]. Note that also “electric pump” taking care that membrane potential is preserved, is needed.

These notions developed gradually during the period when cell was seen as a bag containing water and a mixture of various biochemicals. If cell biology would have started to develop during the latter half of this century and after the discovery of DNA, cell as a computer metaphor might have led to a quite different conceptualization for what happens in the vicinity of the cell membrane. Also the notion of liquid crystals [D5] would have probably led to different ideas about how homeostasis between cell interior and exterior is realized [I22, I21, I19].

For me it was quite a surprise to find that pump-channel paradigm is not at all so well-established as I had believed as an innocent and ignorant outsider. The first chapter of the book “Cells, Gels and the Engines of Life” of Gerald Pollack [I18] provides a summary about the experimental paradoxes (the interested reader can find the first chapter of this book from web).

The standard theoretical picture about cell is based on the observation that cell exterior and interior are in a relative non-equilibrium. The measured concentrations of various atomic ions and organic molecules are in general different in the interior and exterior and cell membrane seems to behave like a semi-permeable membrane. There is also a very strong electric field over the cell membrane. In standard approach, which emerged around 1940, one can understand the situation by assuming that there are cell membrane pumps pumping ions from cell interior to exterior or vice versa and channels through which the ions can leak back. Quite a many candidates for proteins which seem to function like pump and channel proteins have been identified: even a pump protein for water [I18] ! This does not however prove that pumping and channelling is the main function of these proteins on the case of basic biological ions or that they have anything to do with how ionic and molecular concentrations in the interior and exterior of the cell are determined. It could quite well be that in the case of basic ions pump and channel proteins are receptors involved with the transfer of information rather than charges and only effectively act as pumps and channels.

There are several serious objections of principle against the vision of cell as a bag of water containing a mixture of chemicals. Even worse, the hypothesis seems to be in conflict with experimental data.

Selectivity problem

Cell membrane is extremely selective and this leads to an inflation in the complexity of channels and pumps. The problem might be christened as a dog-door problem: the door for dog allows also cat go through it. Channels cannot be simple sieves: it is known that channels which let some ions through do not let much smaller ions through. There must be more complicated criteria than geometric size for whether the channel lets the ion go through. Quite generally, channels must be highly selective and this seems to require complicated information processing to decide which ion goes through and which not. As a consequence, the models for channels inflate in their complexity.

The only reasonable way to circumvent the problem is to assume that there is kind of binary coding of various chemical compounds but it is difficult to see how this could be achieved in the framework of the standard chemistry. The notion of fractional atom proposed in [K76] to give rise to the emergence of symbols at the level of biochemistry could however allow this kind of coding. Channels and pumps (or whatever these structures actually are) could be also generated by self-organization process when needed.

Inflation in the number of pumps and channels

Channels and pumps for atomic ions and channels and pumps for an astronomical number of organic molecules are needed. The first question is where to put all those channels and pumps? Of course, one could think that pumps and channels are constructed by the cell only when they are needed. But how does the cell know when a new pump is needed if the cell as never met the molecule in question: for instance, antibiotic or curare molecule?

To realize how weird the picture based on channels and pumps is, it is useful to imagine a hotel in which there is a door for every possible client letting only that client through but no one else. This strange hotel would have separate door for every five point five milliard humans. Alternatively, the building would be in a continual state of renovation, new doors being built and old being blocked.

There is however an TGD based objection against this slightly arrogant argument. In TGD framework cell is a self-organizing structure and it might be that there is some mechanism which forces the cell to produce these pumps and channels by self-organization. Perhaps the basic characteristic of quantum control in many-sheeted space-time is that it somehow forces this kind of miracles to occur.

Why pumping does not stop when metabolism stops?

One can also wonder how metabolism is able to provide the needed energy to this continual construction of pumps and channels and also do the pumping. For instance, sodium pump alone is estimated to take 45-50 per cent of the cell's metabolic energy supply. Ling has studied the viability of the notion of the ionic pump experimentally [I19] by exposing cell to a cocktail of metabolic poisons and depriving it from oxygen: this should stop the metabolic activities of the cell and stop also the pumping. Rather remarkably, nothing happened to the concentration gradients! Presumably this is the case also for the membrane potential so that also the notion of metabolically driven electrostatic pumps seems to fail. Of course, some metabolism is needed to keep the equilibrium but the mechanism does not seem to be a molecular mechanism and somehow manages to use extremely small amount of metabolic energy.

How it is possible that ionic currents through silicon rubber membrane are similar to those through cell membrane?

A crucial verification of the channel concept was thought to come in the experiment of Neher and Sakmann [I27] (which led to a Nobel prize). The ingenious experimental arrangement was following. A patch of membrane is sucked from the cell and remains stuck on the micropipet orifice. A steady voltage is applied over the patch of the membrane and the resulting current is measured. It was found that the current consists of discrete pulses in consistency with the assumption that a genuine quantum level current is in question. The observation was taken as a direct evidence for the postulate that the ionic currents through the cell membrane flow through ionic channels.

The later experiments of Fred Sachs [I26] however yielded a complete surprise. Sachs found that when the patch of the cell membrane was replaced by a patch of silicon rubber, the discrete currents did not disappear: they remained essentially indistinguishable from cell membrane currents! Even more surprisingly, the silicon rubber membrane showed ion-selectivity features, which were essentially same as those of the cell membrane! Also the currents through synthetic polymer filters [I13] were found to have essentially similar properties: as if ion selectivity, reversal potential, and ionic gating would not depend at all on the structure of the membrane and were more or less universal properties. Also experiments with pure lipid-layer membranes [I8] containing no channel proteins demonstrated that the basic features – including step conductance changes, flickering, ion selectivity, and in-activation– characterized also cell membranes containing no ionic channels.

The in-escapable conclusion forced by these results seems to be that the existing 60-year old paradigm is somehow wrong. Ionic currents and their properties seem to be universal and depend only very weakly on the properties of the membrane. This conclusion need not apply to the currents of polar molecules for which genetically coded pump and channel proteins certainly exist. Neither does it imply that pumps and channels could not be used to achieve a more efficient transfer of ions. Pump - and channel proteins seem to be a well-established notion and TGD approach suggests that they serve as Josephson junctions.

This however requires a generalization of the ordinary thermodynamical approach to cell membrane by starting from zero energy ontology and replacing Boltzmann weight with the complex square roots. Chemical potentials giving dominant part to the change of energy as it goes through cell membrane is replaced with the difference of cyclotron energy which is in visible and UV range from the condition that dark EEG photons have energies of bio-photons [K13]. One ends up with a generalization of Josephson junction: the generalized Josephson energy includes besides Coulombic energy difference also the cyclotron energy difference. Dark cyclotron contribution raises the energy scale of 0.05-0.1 eV associated with cell membrane to 5-10 eVs and one can understand the nominal value 5 eV of metabolic energy currency.

D.2.3 Cytoplasm As Gel

The solution to the above described anomalies proposed by Pollack is that cytoplasm is gel phase [I18]. Pollack describes in detail various aspects of cytoplasm as a gel phase and here only short summary can be given.

1. Cytoplasm can be regarded as a network consisting of cross-linked negatively charged proteins. Water is condensed around the proteins to form structured water. If protein is hydrophilic, water self-organizes around it as a multilayered structure: the number of molecular layers can be as high as 600 and the thickness of the layered structure is a considerable fraction of micrometer. If the protein is hydrophobic, water forms another structured phase known as clathrate water: in this case the number of hydrogen bonds between water atoms is large. These phases can be regarded as intermediate between ice and water. Also ordinary ions have this kind of layered structure around them. Chemical cross-links tend to be stable with heat, pH, and solvent composition whereas physical cross-links formed by intermolecular interactions are sensitive to environmental interactions and are of special interest from the point of view of phase transitions.
2. Pollack proposes that the formation of polymers takes place in an environment containing layered water for the simple reason that monomers cannot diffuse to the layered water so that the probability of association with the end of the growing polymer increases.
3. Cell interior is populated by micro-tubules, various filamentary structures, and the so called micro-trabecular matrix. Micro-trabecular network divides cell into compartments in such a manner that the typical distance between two proteins in water is about 5 nm: this corresponds to the p-adic length scale $L(149)$, the thickness of the lipid layer of cell membrane. This is probably not an accident and the micro-trabecular network might be closely involved with the highly folded network of intracellular membranes. There would be a layer of thickness of about 6 water molecules per given protein surface so that a dominating portion of intracellular water could be structured.

4. The layered water has several tell-tale signatures that have been observed in gels. It freezes at much lower temperature than ordinary water; various relaxation times are shorter since the energy transfer to the water lattice occurs faster than to non-structure water; the diffusion rates of particles into the structured water are much slower than to ordinary water by entropy argument; a simple geometric argument tells that the larger the size of the hydrated ion the lower the diffusion rate; strong gradients of ionic concentrations can form in gel phase as has been observed.

The identification of the cytoplasm as a gel has profound implications for the standard views about cell.

1. The original motivation for postulating semipermeable cell membrane, channels, and pumps was the need to hinder the diffusion of various ions between cell interior and exterior taking place if cytoplasm is ordinary water into which molecules are dissolved. If cytoplasm is in gel phase, cell membrane need not perform pumping and channeling anymore except perhaps in situations involving the formation of a local sol phase. This raises the question about the proper functions of the cell membrane.
2. It is possible to drill to cell membrane holes with size of order $1\ \mu\text{m}$ without an appreciable effect on the functioning of the cell and also show that these holes remain as such for long periods of time [I18]. It is also possible to splice cells into pieces continuing to function for days. That K^+ flux through cell membrane does not change when lipids are partially removed. These findings force to ask whether the assumption about the continuity of the cell membrane might be too strong [I18]. Electron micrographs however demonstrate the presence of the bi-layered structure. What is intriguing that this structure is seen even in the absence of lipid layers. In TGD framework this paradoxical finding might be understood in terms of a presence of space-time sheets corresponding to p-adic length scales $L(k)$, $k = 149, 151$ as vacuum structures predicted also by TGD inspired model of high T_c super-conductivity [K8].
3. There is also the strange finding that water flux through cell membrane is much higher than the flux through isolate lipid bi-layer as if some unidentified channels were present. In TGD framework this might be seen as an evidence for the presence of (wormhole) magnetic flux tubes as carriers of water molecules.
4. The fundamental assumptions about ionic equilibrium must be reconsidered, and the Hodgkin-Huxley model for the generation of nerve pulse becomes more or less obsolete. Indeed, it has been found that action potentials can be generated even in absence of Na^+ and K^+ ions playing a key role in Hodgkin-Huxley model. Rather remarkably, the high concentration of K^+ ions and low concentration of Na^+ ions in cytoplasm could be understood on basis of gel property only. Also new view about cell (note membrane-!) potential emerges. The standard paradigm states that the resting potential is over the cell membrane. Potentials of same order of magnitude have been however seen in de-membraned cells (50 mV in slight excess of action potential and critical potential), colloidal suspensions, and gels which suggest that larger part of cell than mere cell membrane is involved with the generation of the action potential and one should thus speak of cell potential instead of membrane potential.
5. Pollack suggests that the phase transitions of the gel phase make possible to realize various functions at molecular and cellular level and represents empirical evidence for the phase transition like aspects assigned to these functions including sensitivity to various factors such as pH, temperature, chemical environment, electromagnetic fields, mechanical forces, etc... and the threshold behavior [I18]. Also the responses are typical for phase transitions in that they involve dramatic changes in volume, shape, di-electric constant, etc.. With these motivations Pollack discusses phase transition based models for contraction, motility, secretion, transport of molecules, organized flow of particles during cell division, cell locomotion, contraction of muscle, generation of action potentials, etc.. For instance, the transport of bio-molecules along micro-tubule could involve propagating gel-sol-gel phase transition meaning also propagating melting of the layered water around micro-tubule.

6. Divalent ions, such as Mg^{+2} and Ca^{+2} can act as cross links between negatively charged proteins binding them to form networks. Monovalent ions cannot do this. Peripheral cytoskeleton is this kind of network consisting of micro-tubules and actin molecules cross-linked - according to Pollack- by Ca^{+2} ions. On the other hand, it is known that Mg^{+2} (Ca^{+2}) ions dominate in the cell interior (exterior) and that the presence of Ca^{+2} ions in the cell exterior is crucial for the generation of nerve pulse. The influx of Na^+ ions having higher affinity to proteins can induce a phase transition to sol-like phase. Pollack suggests a model of nerve pulse based on this mechanism of gel-sol phase transition for peripheral cytoskeleton: this model does not actually explain why Ca^{+2} ions in the exterior of axon are necessary.

D.2.4 TGD Based Vision Inspired By The Findings

The vision about dark matter and the model of nerve pulse formulated in terms of Josephson currents brings an additional perspective to the role of pumps and channels and allows to achieve harmony with the standard views about their role.

1. In long length scales visible matter forms roughly 5 per cent of the total amount of matter. In TGD Universe the dark matter would correspond to matter with large Planck constant including dark variants of ordinary elementary particles. In living matter situation could be the same and visible matter could form only a small part of the living matter. Dark matter would be however visible in the sense that it would interact with visible matter via classical electromagnetic fields and photon exchanges with photons suffering Planck constant changing phase transition. Hence one can consider the possibility that most of the biologically important ions and perhaps even molecules reside at the magnetic flux quanta in large $\hbar$ phase.
2. Bosonic ions could form Bose-Einstein condensates at the flux tubes in which case supra currents flowing without any dissipation would be possible. The model for high T_c superconductivity suggests that only electronic and protonic superconductivity are possible at room temperature. If so, Cooper pairs of fermionic ions are excluded. New nuclear physics predicted by TGD could however come in rescue here. The TGD based model for atomic nucleus assumes that nuclei are strings of nucleons connected by color bonds having quark and antiquark at their ends. Also charged color bonds are possible and this means the existence of nuclei with anomalous charge. This makes possible bosonic variants of fermionic ions with different mass number and it would be interesting to check whether biological important ions like Na^+ , Cl^- , and K^+ might actually correspond to this kind of exotic ions.

This leads to the following TGD inspired vision about cell as a gel.

1. DNA as TQC hypothesis and cell membrane as sensory receptor provide possible candidates for the actual functions of the cell membrane and ionic channels and pumps could act as kind of receptors. That standard physics is able to describe gel phase is of course a mere belief and (wormhole) magnetic flux tubes connecting various molecules (DNA, RNA, amino-acids, biologically important ions) would be “new physics” cross-links could explain the strong correlations between distant molecules of the gel phase.
2. Dark ionic currents are quantal currents. If the dark ions flow along magnetic or wormhole magnetic flux tubes connecting cell interior and exterior, their currents through cell membrane would be same as through an artificial membrane.
3. Pumps and channels could serve the role of sensory receptors by allowing to take samples about chemical environment. One cannot exclude the possibility that proteins act as pumps and channels in sol phase if magnetic flux tubes are absent in this phase since also in TGD Universe homeostasis and its control at the level of visible matter in sol phase might require them. The metabolic energy needed for this purpose would be however dramatically smaller and a reliable estimate for this would allow an estimate of the portion of dark matter in living systems.

4. Quantum criticality suggests that the phase transitions for the gel phase are induced by quantum phase transitions changing the value of Planck constant for magnetic flux tubes and inducing the change of the length of the flux tube. Macroscopic quantum coherence would explain the observed co-operativity aspect of the phase transitions. Concerning locomotion and transport mountain climbing using pickaxe and rope inspires a guess for a general mechanism. For instance, a packet of molecules moving along actin molecule or a molecule carrying a cargo along micro-tubule could repeat a simple basic step in which a magnetic flux tube with large $\hbar$ is shot along the direction of the electric field along micro-tubule and stuck to a ratchet followed by a phase transition reducing the value of $\hbar$ and shortening the flux tube and forcing the cargo to move forward. The metabolic energy might be provided by the micro-tubule rather than molecular motor.
5. The reconnection of flux tubes would be a second phase transition of this kind. This phase transition could lead from a phase in phase proteins are unfolded with flux tubes connecting amino-acids to water molecules and thus possessing a large volume of layered water around them to a phase in which they become folded and flux tubes connect amino-acids to each other in the interior of protein. The phase transition could be associated with the contraction of connecting filaments of muscle cell. The phase transitions are also seen in “artificial protein” gels used for drug delivery applications, and are built from polymers arranged in alpha helices, beta sheets and common protein motifs [I18]. If wormhole magnetic flux are taken as a basic prerequisite of life, one must ask whether these “artificial proteins” represent artificial life.
6. The fact that cytoskeleton rather than only cell membrane is involved with the generation of action potential conforms with the idea that nerve pulse propagating along axon involves also axonal micro-tubules and that Josephson currents between axon and micro-tubules are involved in the process.
7. Di-valent ions (Ca^{+2} ions according to Pollack) serve as cross links in the peripheral cytoskeleton. The influx of monovalent ions from the exterior of axon induces gel-sol phase transition replacing di-valent ions with monovalent ions. One can consider two models.
 - (a) The minimal assumption is that this phase transition is induced $\hbar$ increasing phase transition the flow of the monovalent ions like Na^+ from the cell exterior along the magnetic flux tubes connecting axonal interior and interior. Suppose that in the original situation the flux tubes end to axonal membrane (this is not the only possibility, they could also end to Ca^{+2} ions). The flux tubes extending to the axonal exterior could result by $\hbar$ increasing phase transition increasing the length of the flux tubes connecting peripheral cytoskeleton to the axonal membrane so that they extend to the exterior of axon. This option is rather elegant since gel-sol phase transition itself can be understood in terms of “standard chemistry”. In this model the very slow diffusion rate of the ions to gel phase would have explanation in terms of new physics involving dark matter and (wormhole) magnetic flux tubes.
 - (b) One can consider also an option in which divalent ions such as Ca^{+2} or Mg^{+2} are connected by two flux tubes to amino-acids of two negatively charged proteins whereas monovalent biological ions like Na^+ would have single flux tube of this kind and could not act as cross links. In the phase transitions removing the cross links the replacement of divalent ion with two monovalent positively charged ions would take place. If one believes in standard chemistry, Na^+ ions would flow in automatically. First the increase of Planck constant would induce the lengthening of the magnetic flux tubes and thus the expansion of the gel phase making possible the influx of monovalent ions. If Na^+ ions are dark, flux tubes connecting peripheral cytoskeleton to the axonal exterior are required and the mechanism of option i) is also needed.
8. The mechanisms i) and ii) could be fused to a single one. The hint comes from the presence of Ca^{+2} ions in the exterior of axon is necessary for the generation of action potential. The simplest possibility is that the flux tubes connecting proteins to intracellular Ca^{+2} cross links in gel phase connects them after the length increasing phase transition to extracellular Ca^{+2} ions and Na^+ ions flow along these flux tubes.

9. The increase of the Planck constant would induce the expansion of the peripheral cytoskeleton making possible the inflow of Na^+ ions, and divalent ions binding negatively charged actin molecules to a network would be replaced with inflowing Na^+ ions. After this a reverse phase transition would occur. Both phase transitions could be induced by a quantal control signal (Josephson current) inducing quantum criticality and a change of Planck constant.
10. A propagating Ca^{+2} wave inducing the gel-sol-gel phase transition of peripheral cytoskeleton would accompany nerve pulse. Quite generally, Ca^{+2} waves are known to play a fundamental role in living matter as kind of biological rhythms. Irrespective of whether one believes option a) or b), this might relate to the cross-linking by flux tubes and gel-sol-gel phase transitions induce by phase transitions increasing Planck constant temporarily. The velocities and oscillation periods of Ca^{+2} waves vary in an extremely wide range: this can be understood if the flux tubes involved correspond to a very wide spectrum of Planck constant.

Besides basic ions cell membrane is non-permeable to various polar molecules such as the basic building bricks of DNA and amino-acids. The safest assumption is that genetically coded pump and channel proteins make possible the transfer. One must of course consider the possibility that channels and pumps are used to make the transfer of basic ions more effective. Taking this into account, the proposed vision does not differ so radically from the standard one as one might think first and only the model for nerve pulse generation must be modified radically.

To sum up, the strange discoveries about the behavior of cell membrane provide direct experimental evidence for the presence of dark matter in living systems, for the prediction that it interacts with ordinary matter via classical electromagnetic fields, and for the assumption that it does not dissipate appreciably and could therefore have large value of $\hbar$ and form macroscopic quantum phases.

D.3 Further Experimental Findings

In this section I discuss further experimental findings giving support for the TGD based vision about living cell.

D.3.1 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 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 [K37]. 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 this. 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 species, 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 $300\ \mu$ [I6] 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 [K58]. 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 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 ~ 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 [L12] [K35] (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.

D.3.2 A Model For Chiral Selection

Chiral selection of bio-molecules is one of the basic mysteries of biology and it is interesting to see whether the existing bits of data combined with vision about quantum TGD could help to build a coherent picture about the situation. Let us first try to identify the most important pieces of the puzzle.

1. Chiral selection requires parity breaking in the scale of biomolecules. Standard model predicts parity breaking interactions but the effects are extremely small above intermediate boson length scale which is by a factor 10^{-7} shorter than atomic length scale. The proposed solution of the problem is that dark variants of intermediate gauge bosons are in question so that the Compton lengths of intermediate gauge bosons are scaled up by a factor $r = \hbar/\hbar_0$. Below the dark Compton length weak gauge bosons would be effectively massless and above it possess ordinary masses. Large parity breaking effects induced by dark intermediate gauge bosons would be possible.
2. For instance, for $r = 2^{44}$ for which EEG photons have energies just above thermal threshold at room temperature, the effective p-adic length scale would correspond to $L(k)$, $k = 89 + 44 = 133$ of about .2 Angstrom. This scale in turn would scale up to $L(133 + 44 = 177)$. Secondary p-adic length scale assignable to $k = 89$ which is important in zero energy ontology would correspond to $k = 2 \times 89 = 178$ which corresponds to about $L(178) \simeq 100 \mu\text{m}$, the length scale assignable to large cells and the thickness of water layers in the experiment of Pollack.
3. Parity breaking interaction is associated with spin and the interaction energy of form $ks \cdot E_Z$, where s is the spin of particle and E_Z is Z^0 electric field. Classical induced gauge fields are very strongly correlated in TGD since they are expressible in terms of four CP_2 coordinates and their gradients. Hence classical electromagnetic field E is in the generic case accompanied by classical Z^0 field $E_Z = aE$. This means that if there is classical electromagnetic field and charge density at the dark space-time sheet, large parity breaking effect is possible at the level of spin. The induced Z^0 electric field could force the spins to become parallel and in this manner induce also magnetization.

The crucial finding about which I learned three years ago is that L glutamate is more stable than R glutamate in water and that heavy water does not induce this effect [I29]. This suggests a connection with Pollack-Zheng effect [D101]. Heavy water nuclei have vanishing spin whereas hydrogen nuclei have spin 1/2 so that H_2 in water molecules can be in spin singlet or triplet states (para and orto configurations). Could the nuclear spin of water molecules somehow induce parity breaking and the magnetic interaction distinguishing between these molecules?

1. Suppose that bio-molecules in question have magnetic moment and water carries magnetic field, most naturally at dark magnetic flux tubes. The parity breaking interaction energy $-p \cdot E$ with dark electric field remains invariant under reflection and rotation of π changing the orientation of the mirror image of the molecule with respect to electric field. The interaction energy with magnetic field however changes its sign since magnetic moment is not affected by the reflection but changes direction under rotation. The angular momentum of the molecule responsible for the magnetic moment can of course change sign but since the transformation involves acts on angular momenta only, it is not a symmetry of entire system. Indeed, if there is interaction between angular momentum degrees of freedom and geometric degrees of freedom the magnetic interaction energy for the mirror image is different. Suppose that the breaking of reflection symmetry induced by the chirality of the molecule induces internal electric field E_{int} . The parity breaking interaction energy $ks \cdot E_{int}$ would indeed break the symmetry in the transformation changing the directions of angular momenta and spins.
2. It deserves to be emphasize that the parity breaking of the molecule itself would induce the symmetry breaking if molecule possesses dark magnetic body. One can actually imagine a cascade of parity breakings proceeding from shorter to longer length scales in this manner.
3. The mechanism creating electric field could be the charging of water, perhaps by the Pollack-Zheng mechanism and having in TGD framework an interpretation as a basic mechanism

storing the energy of sunlight to metabolic energy (kicking of electrons and/or protons to a smaller space-time sheet so that oppositely charge space-time sheets emerge as a consequence). A direct connection with metabolism would be admittedly a highly satisfactory feature of the mechanism.

4. Parity breaking energy $ks \cdot E$ for say dark protons assignable to hydrogen nuclei of bio-molecules in the internal electric field of the molecule or dark protons of water molecules in the electric field induced by Pollack-Zheng effect [D101] does not change sign under the reflection of the molecule so that spin polarization independent of chirality could result from both water molecules in crystal like phase and for bio-molecules possessing dark protons (and dark hydrogen atoms). This could in turn serve as a seed for magnetization essential for the existence of dark magnetic flux tubes.

If water is replaced with heavy water there is no difference between L and R. What distinction H and D could explain this difference?

1. The basic difference between water and heavy water nuclei is that for water nucleus is just proton having spin $1/2$ so that H_2 in water molecule can be in spin triplet and singlet states. Fractions of the two states are $3/4$ and $1/4$ in the absence of external magnetic field.
2. On the other hand, in atto-second time scale (corresponding length scale is 3 Angstroms) water is known to behave effectively as $H_{1.5}O$. A possible explanation is that $1/4$ of H nuclei/atoms are effectively dark having large Planck constant. The dark protons cannot correspond to H_2 in spin singlet state since the interaction energy $ks \cdot E$ would be small in this case. Dark spin triplet states of H_2 could however induce parity breaking in water and make crystal like water phase both electret and magnet. If the spin $s_z = 1$ with negative interaction energy with E becomes dark then $1/4$ of hydrogen atoms would be dark and $H_{1.5}O$ formula would hold true. For D_2O this mechanism would not work.
3. The model for homeopathy led to the idea that dark nuclei consisting of scale up variants of nucleons possibly having size of order atomic length scale could be crucial for understanding living matter. The states of nucleons correspond naturally to those DNA, RNA, and amino acids and vertebrate genetic code emerges naturally with DNA code word replaced with 3 quark state with entanglement between the quarks representing the information. Could it be that dark protons of water combine to form dark nuclei providing a fundamental representation of the genetic code and could the spin of protons induce electro-weak chiral symmetry breaking. Also now this mechanism fails for D_2O .

D.3.3 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 [D80, D78, D76, D79] 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" [D80] told about the formation of exclusion zones around hydrophilic surfaces, typically gels in the experiments considered [D101]. 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 suggest 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?" [D76] 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” [D79] 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 [D77]. 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 [D78]. 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 [K20].

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 [D73, D67, D86, D44]. 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 1.5 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?" [D76] 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 $E_{rf} = .561 \times 10^{-7}$ eV and provides only a minor fraction $E_{rf}/E = .436 \times 10^{-7}$ 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 $[\cdot35, \cdot46]$ 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 photons 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) [I10], and that even a realization of genetic code in terms of the time variation of polarization direction could be involved. TGD based model [K6, K43] 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 of fact, there are reports about [D8]. 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 [D7] - 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 earlier of remote metabolism and provides universal metabolic energy quanta. It is also involved with TGD based models of “free energy” phenomena. No perpetual 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 $\hbar_{eff}$ 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 [H4] 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 [K21] 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 or cyclotron energy. Quantum numbers would not change: rather, 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.

Free radicals, expanding Earth, water memory, and Cambrian revolution

The title is intentionally chosen to involve notions which one would expect to have absolutely nothing in common. The purpose is to show that this expectation might be wrong. Consider first the free radical theory [I1]. The theory states that free radical produced in mitochondria are responsible for the ageing since they are highly reactive and cause damage for the DNA. One can however wonder what is the mechanism causing the generation of the free radicals.

A TGD based justification for the free radical theory came as unexpected application of the quantum model for how metabolic batteries are loaded in many-sheeted space-time. The kicking of electrons, protons, or ions to smaller space-time sheet loads metabolic batteries in TGD Universe. A more refined model is based on a phase transition which increases p-adic prime and decreases the value of h_{eff} so that the two length scale changes compensate each other. The zero point kinetic energy or cyclotron energy associated with the magnetic flux tube is reduced in the process and liberate. Therefore this kind of process could liberate metabolic energy.

These processes could occur all the time in $ADP \leftrightarrow ATP$ "Karma's" cycle. In this case the transfer of protons through the cell membrane would induce the change of Planck constant and therefore a liberation of metabolic energy stored in roughly the same manner as it is stored in battery. Now however the liberated energy is sum of electrostatic energy and difference of cyclotron energies replacing the difference of chemical potentials in the case of ordinary battery. The quantitative model for the burning of water producing hydrogen peroxide and hydrogen (this process could provide a mechanism of storing solar energy by a mechanism analogous to photosynthesis) would also rely on this mechanism.

Burning water, photo synthesis, and water memory

The burning of water, photons synthesis and water memory are closely interrelated phenomena in TGD Universe. Recall first what was observed in the experiments carried out by the group led by Luc Montagnie.

1. What was done was filtration of human cells infected by bacteria in sterilization purpose to eliminate the infected cells. Human cells were added to the filtrate. Rather magically, the infection returned to the filtrate within few weeks. Something having size of order of

nanoscale leaked through. It was also found that when the filtrate was diluted by water to produce an analog of homeopathic remedy, it produced at multiples of kHz if the dilution factor was in the range $10^{-7} - 10^{-12}$.

2. The second discovery was that if you have two bottles containing a solute of nanostructures such that for the first one dilution factor is small and for the second in the critical range so that it radiates at kHz frequencies. What was found that in the final situation neither radiates but only if the dilutions correspond to the same bacterial species! I proposed two interpretations. The first one was that the nanoscale systems in the highly diluted system are starving and gain metabolic energy by sending negative energy photons to the low dilution system and this makes them possible to replicate and achieve higher dilution after which the process stops.
3. One of the most fascinating possibilities suggested by the discovery is that the nanoscale structures identified as certain gene of the bacteria plus possibly something else (the magnetic body of gene in TGD context) might have been able to regenerate the bacteria themselves! This would require a non-chemical representation of genetic code and its translation to DNA or RNA. For about year ago I indeed discovered a realization of genetic code in terms of dark nuclei with states of nucleons representing the code words [L4], [L4].

These findings allow a more detailed interpretation of the findings of the experiments of the group of Luc Montagnie.

1. The mysterious burning of water induced by radio waves in GHz range and interpreted in terms of a decomposition of water molecules to hydrogen peroxide and hydrogen: $2H_2 \rightarrow H_2O_2 + H_2$ is closely related to the splitting of water to hydrogen and oxygen occurs also in photosynthesis. The interpretation was that radio waves are resonantly transformed to dark photons with same frequency but with very large value of Planck constant and hence of energy followed by a transformation to ordinary IR photons with much higher frequency but same energy around 4 eV [K18, K37]. The finding that Raman scattering (non-elastic scattering of photons on molecules) around this energy occurs in the burning water supports this view. The natural guess is that also in the recent case something similar occurs.
2. This kind of frequency scaling is one of the basic mechanisms of water memory as I learned for the first time from the lecture of Cyril Smith in CASYS conference many years ago. One of the basic findings was that there is an unknown mechanism transforming low frequencies to high ones and vice versa. The low frequencies are scaled up by a factor which has a preferred value $r \simeq 2 \times 10^{11}$ interpreted in TGD framework as the ratio of the dark matter Planck constant to the ordinary one. I christened this correlation as a scaling law of homeopathy.
3. It is interesting to apply the law to kHz frequency. In this case the law would give frequency $f = 2 \times 10^{14} > \text{Hz}$. The corresponding energy is 826 eV, which is essentially twice the energy quantum associated with burning water and thus has interpretation as a p-adically scaled up frequency (by one octave). Interestingly, Mae-Wan Ho states in [D77] that *“to use water as electron-donor, and hence to produce oxygen, requires the creation of the chlorophyll-a in cyanobacteria and green plants that can be boosted to a higher electrochemical potential of 0.82 V”*. Hence 83 eV is very near to a metabolically interesting energy.
4. This finding supports the view that kHz radiation produced by nano-structures corresponds to dark phase conjugate photons with energy equal to a metabolic energy quantum. The interpretation would be that the unidentified nanoscale systems in the highly diluted system are starving and get metabolic energy by sending negative energy quanta in the hope that there are metabolic energy reservoirs around able to absorb them. If bio-photons are Bose Einstein condensates of dark cyclotron photons at the flux tubes of magnetic body acting like population reversed lasers, they could serve as metabolic energy reservoir as suggested in on basis of the discovery described by Mae-Wan Ho in [D80].
5. A continual fight for metabolic resources is raging everywhere in Nature, presumably also at the monocellular level. It would not be surprising if harmful bacteria would try to steal the

metabolic energy of other organisms stored (say) as bio-photons by sending phase conjugate light to the bio-photon resources of multicellular organisms. Nor it would be surprising if living organisms would have developed manners to prevent this. The fine tuning of the metabolic frequencies so that only the members of the same species can share the energy could guarantee this. Also password like protocols might have developed and either or both of them might be involved.

In the two-bottle experiments the nanoscale systems in the highly diluted system would gain metabolic energy by sending negative energy photons received by the low dilution system. The gain of metabolic energy would make possible for the nanosystems to replicate and achieve higher dilution after which the process would stop as was indeed observed. That this took place only for the bacteria of same species supports the interpretation that frequency tuning or password mechanism was involved. This metabolic mechanism (quantum credit card as I have called it) could be a completely general mechanism energy sharing mechanism for cells of the same multicellular organism and perhaps even same species in TGD Universe.

D.4 A Model For The Effective Electronic Super-Conductivity In Axons

Also the following model for axonal electronic super-conductivity was constructed before the progress induced by the model of DNA as TQC and the inspiration coming from the model of nerve pulse by Danish researches [J19] and is not completely consistent with the new model. I however decided to keep the text because it reflects the development of ideas and with a reasonable amount of work could be modified to the new situation.

Hafedh Abdelmelek and collaborators [J15] have found evidence for effective super-conductivity in the sciatic nerves of both endotherms (rabbit) and poikilotherms (frog). The basic finding is that the resistance of the sciatic nerve is reduced by a factor of about ten below a critical temperature at the lower edge of the range of the physiological temperatures. The reduction of the temperature occurs inside a narrow temperature range ΔT , $\Delta T/T_c \sim .04$. This suggests effective super-conductivity. Furthermore, the critical temperature T_c for the breaking of the effective super-conductivity raises from 240 K to 300 K in the transition from poikilotherms (say frog) to endotherms (say rabbit).

These findings seem to be consistent with the following view.

1. Nerve pulse generation involves a mechanism inducing a flow of ions between axonal interior and exterior and induces at the same time the breaking of super-conductivity [K37] . At too low temperatures nerve pulses cannot be generated because the breaking of the super-conductivity is not possible. Therefore the critical temperature must be below the range of physiological temperatures and explains the difference between poikilotherms and endotherms.
2. In myelin sheathed regions the breaking of the effective super conductivity does not occur or the critical temperature is higher and the signal carried by the nerve pulse is transformed to an effective or genuine supra current. A small pulse like perturbation of the membrane potential could propagate still.
3. Poikilotherms can survive only if nerve pulse conduction is possible down to about 240 K which represents lower bound for the temperature of environment. Endotherms can keep the body temperature above 300 K and so that T_c can be as high as 300 K. This is good for survival purposes since high T_c minimizes ohmic losses related to nerve pulse conduction.

The recent model for nerve pulse generation favors somewhat different view. The melting temperatures T_m of the axon and microtubular surface and quantum critical temperature T_c of high T_c super-conductivity are the critical parameters. The generation of the nerve pulse is possible only if T is slightly above T_m . T_m can vary in a wide range and can be controlled genetically. Same could be true for T_c since external perturbations amplified by quantum criticality are expected to affect it. This would explain different values of T_c for poikilotherms and endotherms. The critical temperature for super-conductivity would pose only an upper bound for the temperatures

at which organisms can survive whereas quantum criticality of various membranes would constrain this temperature to a narrow range.

D.4.1 Many-Sheeted Space-Time And Connection Between Thermal De-Broglie Wavelength And Size Of The Space-Time Sheet

The concept many-sheeted space-time is needed to understand super-conductivity and breaking of super-conductivity. Parallel space-time sheets with distance about 10^4 Planck lengths form a hierarchy. Each material object (... , atom, molecule, ... , cell, ...) corresponds to this kind of space-time sheet. The p-adic primes $p \simeq 2^k$, k prime or power of prime, characterize the size scales of the space-time sheets in the hierarchy. The p-adic length scale $L(k)$ can be expressed in terms of cell membrane thickness as

$$L(k) = 2^{(k-151)/2} \times L(151) , \quad (\text{D.4.1})$$

where the p-adic length scale $L(151)$ and all p-adic length scales above electron length scale $L(127)$ were identified erratically in all writings about TGD before 2014. This deserves some comments.

1. The wrong identification was $L(151) \simeq 10$ nm implying wrong identification of other scales above $L(127)$ since I have calculated them by scaling $L(151)$ by an appropriate power of two. What I have denoted by $L(151)$ is actually obtained by scaling the Compton length $L_e(127) = \hbar/m_e$ by $2^{(151-127)/2}$ and therefore electrons Compton scale if it would correspond to $k = 151$. Since the mass of electron from p-adic mass calculations is given by $m_e = \sqrt{5+X}\hbar/L(127)$, the correct identification of $L(151)$ would be

$$L(151) = 2^{(151-127)/2} L(127) = 2^{(151-127)/2} L_e(151)/\sqrt{5+X} = 10/\sqrt{5+X} \text{ nm} , \quad 0 \leq X \leq 1 .$$

Here X denotes the unknown second order contribution of form $X = n/M_{127}$, n integer, to the electron mass, and in the first approximation one can take $X = 0$ - the approximation is excellent unless n is very large. In the sequel I will try to use the shorthand $L_e(k) = \sqrt{5}L(k)$ but cannot guarantee that the subscript "e" is always present when needed: it is rather difficult to identify all places where the earlier erratic definition appears. I can only apologise for possible confusions.

2. This mistake has no fatal consequences for TGD inspired quantum biology. Its detection however provides a further support for the speculated central role of electron in living matter. Since the scales obtained by scaling the electron Compton scale seem to be important biologically (scaled up Compton scale $\sqrt{5}L(151)$ corresponds to cell membrane thickness), the conclusion is that electrons - or perhaps their Cooper pairs - play a fundamental role in living matter. The correct value of $L(151)$ is $L(151) = 4.5$ nm, which is slightly below the p-adic length scale $L_e(149) = 5$ nm assigned with the lipid layer of cell membrane.
3. I have also assigned to electron the time scale $T = .1$ seconds defining a fundamental biorhythm as a secondary p-adic time scale $T_2(127) = \sqrt{M_{127}}T(127)$. The correct assignment of $T = .1$ seconds is as the secondary Compton time $T_{2,e}(127) = \sqrt{M_{127}}T_e(127)$ of electron: secondary p-adic time scale is $T_2(127) = \sqrt{M_{127}}T(127)$ and corresponds to $T_{2,e}(127)/\sqrt{5} = .045$ seconds and to $f(127) = 22.4$ Hz.

These are so called primary p-adic length scales but there are also n-ary p-adic length scales related by a scaling of power of $\sqrt{p}$ to the primary p-adic length scale.

The characteristic temperature scale for particles of mass M in a thermal equilibrium at the space-time sheet characterized by $L(k)$ is given in terms of the zero point kinetic energy associated with the space-time sheet

$$T(k) = n \times E_0(k) = n \times n_1 \times \frac{\pi^2}{2ML^2(k)} , \quad (\text{D.4.2})$$

where n and n_1 are numerical constants not far from unity (for convenience the units $k_B = 1$, $\hbar = 1$, $c = 1$ are used). $T(k)$ decreases very rapidly as a function of the p-adic length scale $L(k)$. This equation relates the p-adic prime of space-time sheet to T and M of particles present in the sheets forming join along boundaries condensate. Of course, the size L of space-time sheet characterized by k can vary in the range $[L(k), L(k_>)]$ and $T \propto 1/L^2$ is an attractive guess for the dependence of the temperature on the size of the space-time sheet. One can interpret $T(k)$ as a critical temperature at which the p-adic prime characterizing the space-time sheet changes.

D.4.2 Magnetic Flux Tubes As Effective Super-Conductors And Breaking Of Super-Conductivity

The model for bio-superconductivity and its breaking relies on the following picture.

1. Magnetic flux tubes of Earth's magnetic field (in particular) characterized by $k = 169$ and having a minimal thickness about $5 \mu\text{m}$ correspond to tubular space-time sheets. The magnetic flux tubes of endogenous magnetic field $B = .2$ with $n = 5$ characterizing the value of the scaled up Planck constant $\hbar = n\hbar_0$ [K77] and the unit $n\hbar_0$ of magnetic field magnetic flux and $k = 169$ characterizing the p-adic length scale define second option consistent with the identification of 15 Hz as cyclotron frequency of Ca^{+2} . In this case the value of magnetic flux is $2\hbar_5$ and the scaled down magnetic field $B_{\text{end}}/2$ required by the sleep time EEG would correspond to single flux quantum. Flux tubes would have thickness of about $25 \mu\text{m}$ corresponding to a size of a large neuron.

In the absence of both larger and smaller space-time sheets, the flux quanta can act as 1-D super-conductors since cyclotron energy scale, which by the quantization of the magnetic flux behaves also as $1/L^2(k)$, is larger than de Broglie temperature for sufficiently high values n of the magnetic flux (implying thicker flux tube). More generally, one can consider the possibility of a hierarchy of magnetic flux tubes inside magnetic flux tubes corresponding to the sequence $k = 167, 163, \dots$ as especially interesting candidate since $k = 151, 157, 163, 167$ define Gaussian Mersennes $(1+i)^k - 1$. Each of these flux tubes can be a super-conductor. Bio-super-conductivity is assumed to be due to this mechanism. Of course, only space-time sheets corresponding to only some of these p-adic length scales could be present and this would be crucial as far as super-conductivity and its breaking is considered. The study of the effects of external magnetic fields on the axonal conductivity might provide valuable information about the role of magnetic fields.

2. Super-conductivity can be broken by a temporal leakage of the Cooper pairs to larger space-time sheets if present. These Cooper pairs are kicked back by thermal photons. System is an effective super-conductor in the sense that Cooper pairs are not destroyed in the breaking of super-conductivity and an effective ohmic conductor in the sense that dissipation is present. Super-conductivity can be also broken by thermal kicking of the Cooper pairs to smaller space-time sheets. In this case there is however a restriction posed by the fact that the zero point kinetic energy of the particle increases from $E_0(k)$ to $E_0(k_<)$, where $k_<$ ($k_>$) is the largest (smallest) the prime smaller (larger) than k . Thermal energy is needed to achieve this. For the leakage to occur, one must have

$$T > nE_0(k) = T(k) . \quad (\text{D.4.3})$$

Some numerical constant n is involved here. Note that the temperature at super-conducting space-time sheets is much lower than the critical temperature and the temperature at atomic space-time sheets.

3. The prediction is that the conductivity decreases in a stepwise manner at temperatures $T = T(k)$ as the temperature increases, and that the smallest value of k for current carrying space-time sheets gradually decreases as $k = 169 \rightarrow 167 \rightarrow 163 \rightarrow 157 \rightarrow 151 \rightarrow \dots$. The behavior of the conductivity in the sciatic nerve seems to represent one particular step of this kind. The primes $k = 167, 163, 157, 151$ are expected to be especially important in living

matter since they corresponds to the so called Gaussian Mersennes and p-adic length scales in the range 10 nm-2.56 μm [K8, K9].

4. For a space-time sheet having $k = k_0$, the leakage of supra-current is induced by the formation of flux tubes between $k = k_0$ space-time sheets and $k \geq k_0$ space-time sheets. The leakage to the smaller space-time sheets can be also induced by radiation with frequency corresponding to the increment of the zero point kinetic energy and the transversal electric field involved with radiation can be regarded as inducing the force driving the particles to smaller space-time sheets or back.
5. The strange findings indicating that DNA can behave like a super-conductor [I12], an ohmic conductor [I17], or an insulator could be perhaps understood in terms of the local architecture of the many-sheeted space-time. If only atomic space-time sheet is present, DNA would behave as insulator. If larger space-time sheets are present DNA behaves as an effective ohmic conductor in the sense that dissipative effects are present. If only single larger space-time sheet is present, super-conductivity is possible so that the manufacturing of super-conductors should reduce to space-time engineering.

D.4.3 Quantitative Model For The Breaking Of Super-Conductivity

The dropping (or leakage) of electronic Cooper pairs from $k = k_0$ (say $k_0 = 151$ corresponding to cell membrane thickness) space-time sheet to larger space-time sheets possibly present and followed by a thermal kicking back to $k = k_0$ space-time sheet is a good candidate for the mechanism causing the breaking of magnetic super-conductivity.

The conductivity as a function $\sigma(k)$ of the p-adic length scale $L(k)$ should characterize the mechanism quantitatively. If the thermal energy $E_{th} = T$ satisfies the condition

$$\begin{aligned} E_0(k) - E(k_{>}) &< T < E_0(k_{<}) - E(k) , \\ E_0(k) &= n_1 \times \frac{\pi^2}{4m_e L^2(k)} , \end{aligned} \quad (\text{D.4.4})$$

one can say that the space-time sheet k is the effective carrier of the current.

The mechanism predicts that the increase of the temperature is accompanied by a sequence of phase transitions in which the value of k characterizing the effective carrier of the current decreases in a stepwise manner: $k = 169 \rightarrow 167 \rightarrow 163 \rightarrow 157 \rightarrow 151 \rightarrow \dots$. These transitions occur at temperatures $T(k) = n \times E_0(k)$, n a numerical constant. This picture is consistent with the observation that the reduction of resistance occurs in a very short temperature interval ΔT : $\Delta T/T \sim .04$.

A more concrete picture is obtained by decomposing the friction force to a sum of forces resulting from dropping from say $k = 151$ to $k = 157163, 167, \dots$ and being kicked back. This gives

$$\begin{aligned} F &= K(k)v , \\ K(k) &= \sum_{k_i > k} \kappa(k_i) = \kappa(k_{>}) + K(k_{>}) . \end{aligned} \quad (\text{D.4.5})$$

The condition $F = qE$, $q = 2e$, gives for the conductivity defined by $j = nv = \sigma(k)E$, E electric field, the expression

$$\frac{1}{\sigma(k)} = \frac{K(k)}{nq} = \frac{\kappa(k_{>})}{nq} + \frac{1}{\sigma(k_{>})} . \quad (\text{D.4.6})$$

What this means that the space-time sheets correspond effectively to resistors in series.

From the experimental findings for frog, for the transition from $k = 157$ to $k = 151$ the term $\kappa(157)$ must be by about a factor 10 larger than the sum of terms term $\kappa(k)$, $k > 157$. The fractal scaling

$$K(k) \propto \frac{1}{L^\alpha(k)} \propto 2^{-\alpha k/2} \quad (\text{D.4.7})$$

with $\alpha \simeq 1.1$, suggests itself.

The standard classical model for the dissipative force implies that the force is inversely proportional to the free path $l(k)$ of the particle and by naïve scaling symmetry l would be naturally proportional to the p-adic length scale $l \propto L(k)$ giving $\alpha = 1$. $\alpha > 1$ for $K(k)$ means that the free path has a fractal dimension slightly larger than one. The anomalous dimension is due to the many-sheeted nature of the free paths implying the presence of the higher order terms in the expansion of $K(k)$. Indeed, in the lowest order the model based on the naïve scaling dimension -1 for $\kappa(k)$ predicts

$$\frac{\sigma(151)}{\sigma(157)} \simeq 1/8 - 1/64 \simeq .11 \quad (\text{D.4.8})$$

in consistency with the measured reduction of the resistivity. Needless to say, this prediction provides a strong support for the p-adic length scale hypothesis and the notion of many-sheeted space-time.

D.4.4 Application At Axonal Level

It is interesting to apply the model for the breaking of super-conductivity in the case of axon.

Understanding the critical temperature

The model for the nerve pulse generation predicts that “bridges” are formed between $k = k_0 > 151$ (say $k_0 = 169$) and $k = 151$ space-time sheets making possible the flow of ions between cell interior and exterior. Super conductivity is broken provided that the temperature is sufficiently high. For electron Cooper pairs ($M = 2m_e$) the zero point kinetic energy at the cell membrane space-time sheet is from Eq. D.4.4

$$E_0(k = 151) = n_1 \times 312.25 \text{ K} . \quad (\text{D.4.9})$$

n_1 is some numerical constant not too far from unity. $n_1 = 1$ corresponds to a temperature 42.25 C. The identification as the critical temperature gives quite satisfactory agreement with the experimental values varying from 240 K to 300 K. Note that the requirement $T > T_{cr}$ for the physiological temperatures means that $k = 151$ cell membrane space-time sheet is the effective current carrier in the presence of larger space-time sheets.

If the flux tube connecting $k = 169$ and $k = 151$ space-time sheets contains a strong enough transversal electric field, the supra current can flow only in one direction. It seems that in the case of cell membrane the leakage of electronic Cooper pairs to the negatively charged cell interior is forbidden by this mechanism. The absence of the flux tubes between cell membrane and cell exterior assumed to be generated during the nerve pulse in the TGD based model of the nerve pulse [K37] in turn implies that the leakage cannot occur to or from $k = 169$ space-time sheets at all. Therefore both $k = 151$ and $k = 169$ space-time sheet might be genuinely super-conducting and only nerve pulse conduction would be accompanied by the breaking of super-conductivity.

Predictions for the critical temperature and resistance

Fractality allows to make definite quantitative predictions for the critical temperature.

1. For $k = 163$ conductivity the critical temperature is predicted to be by a factor $2^{157-151} = 64$ lower than for $k = 157$ conductivity. This gives $T_c(163) = 4.9 \text{ K}$ for $T_c(157) = 300 \text{ K}$. The upper bound $T_c = 4 \text{ K}$ for the critical temperature for super-conductivity in molecular crystals is reported in [D95]. This would correspond to $T(157) = 240 \text{ K}$ measured in the case of frog. The predicted lowering of the resistance at this critical temperature for nerve conduction might be testable.

2. The observation that DNA attached between carbon and rhenium electrodes becomes super-conducting below the critical temperature of about 1 K for rhenium [I12] allows the possibility that DNA becomes super-conducting already at about $T_c(163) \simeq 4-5$ K but that the rhenium acts as the weak link in the super-conducting circuit.
3. Cell membrane thickness L might vary and the natural guess is that the critical temperature is inversely proportional to $1/L^2$. If this is the case, the ratio of cell membrane thicknesses for frog and rabbit should be

$$\frac{L(frog)}{L(rabbit)} = \sqrt{\frac{T(rabbit)}{T(frog)}} = \sqrt{5/4} = 1.12 \quad (D.4.10)$$

for $T(rabbit) = 300$ K and $T(frog) = 240$ K.

4. A further prediction following from the fractal model for the conductance (Eq. D.4.7) is that also the $k = 157 \rightarrow 163$ at about 4-5 K involves a 10-fold reduction of resistance. Also this prediction might be testable for nerves.

What happens in saltation?

An interesting question is what happens in the saltation over the myelin sheathed portions of the nerve. According to the TGD based model of nerve [K36] [K37], the ME (“massless extremal”, “topological light ray” moving with effective velocity equal to the conduction velocity of nerve pulse acts as a bridge between cell membrane ($k = 151$) and cell exterior ($k = 169$) space-time sheets and in this manner allows the leakage of ions from cell interior to exterior and vice versa inducing the physiological effects of nerve pulse. ME could propagate along the myelin sheath rather than along the axon inside. Therefore nerve pulse would not be generated. The following picture about saltation suggests itself.

1. The transformation of the nerve pulse to an electronic $k = 151$ or $k = 169$ supra current propagating rapidly through the myelin sheathed portion would make possible a rapid signal transmission without physiological effects. Inside myelin sheathed portions of the axon the leakage to $k = 169$ space-time sheets would be impossible by the mechanism described above irrespective of the value of the critical temperature.
2. Nerve pulse conduction involves also communication and interaction between different space-time sheets and therefore necessitates the leakage of electronic Cooper pairs from $k = 151$ cell membrane space-time sheet. Therefore the critical temperature must be below the range of the physiological temperatures. Endotherms have an evolutionary advantage since the higher critical temperature implies that the dissipative effects associated with the nerve pulse conduction are weaker.

Whether electronic supra current in the myelin sheathed portions of the axon propagates along $k = 151$ or $k = 169$ space-time sheet or along both plus possibly along some other space-time sheets, remains unclear. Note that the critical temperature in myelin sheathed regions could be higher than the physiological temperature. The endogenous magnetic field $B = .2$ Gauss suggested by the work of Blackman and others corresponds to a flux tube radius $L = \sqrt{5}/2 \times L_e(169) \simeq 1.58L_e(169) = 17.7L(169) \sim L(177) = 2^{(5)}L(127)$.

It is interesting to notice that Evan Harris [J14] [J14] has developed a quantitative theory in which the tunnelling of electrons through the synaptic contact is the basic step of synaptic transfer. The theory applies also to ephapses in which electric transfer of the nerve pulse takes place. Theory explains the differences between ephapses and synapses and also the morphology of synapses and ephapses finds natural explanation. This kind of tunnelling might be induced by the formation of 151-169 ME contacts at presynaptic cell and 169-151 ME contacts at the postsynaptic cell.

D.5 Quantum Model For The Direct Currents Of Becker

Robert Becker [J10] proposed on basis of his experimental work that living matter behaves as a semiconductor in a wide range of length scales ranging from brain scale to the scale of entire body. Direct currents flowing only in preferred direction would be essential for the functioning of living manner in this framework.

One of the basic ideas of TGD inspired theory of living matter is that various currents, even ionic currents, are quantal currents. The first possibility is that they are Josephson currents associated with Josephson junctions but already this assumption more or less implies also quantal versions of direct currents.

TGD inspired model for nerve pulse assumes that ionic currents through the cell membrane are quantal currents. If they are Josephson currents, the situation is automatically stationary and dissipation is small as various anomalies suggest. One can criticize this assumption since the Compton length of ions for the ordinary value of Planck constant is so small that magnetic flux tubes carrying the current through the membrane look rather long in this length scale. Therefore either Planck constant should be rather large or one should have a non-ohmic quantum counterpart of a direct current in the case of ions and perhaps also protons in the case of neuronal membrane: electronic and perhaps also protonic currents could be still Josephson currents. This would conform with the low dissipation rate.

In the following the results related to laser induced healing, acupuncture, and DC currents are discussed first. The obvious question is whether these direct currents are actually supracurrents and whether they could be universal in living matter. A TGD inspired model for quantal direct currents is proposed and its possible implications for the model of nerve pulse are discussed.

Whether the model for quantum direct currents is consistent with the proposed vacuum extremal property of the cell membrane remains an open question but both options explain the special role of Ca^{++} currents and current of Na^+ Cooper pairs in the generation of nerve pulse as in would take place in TGD Universe. In fact, it is not clear what one exactly means with the vacuum extremal property of cell membrane. Many-sheeted space-time (see **Fig.** <http://tgdtheory.fi/appfigures/manysheeted.jpg> or **Fig. 9** in the appendix of this book) allows to consider space-time sheets which can be both almost vacuum extremals and far from vacuum extremals. Also space-time sheets for which Planck constant is so large that both electronic and protonic Josephson currents become possible. Various pumps and channels could actually correspond to magnetic flux tubes along which various ionic supra currents or even Josephson currents can flow. The condition that both electronic and protonic supra currents are possible in same length scale leads to the hierarchy of Planck constants coming approximately as powers of $m_p/m_e \simeq 2^{11}$ proposed originally as a general truth. Radiation at Josephson frequency serves as a signature for Josephson currents.

In the following a TGD inspired quantum model for the direct currents of Becker as direct quantum currents is developed and shown to be consistent with what is known about nerve pulse generation.

D.5.1 Connection Between Laser Induced Healing, Acupuncture, And Association Of DC Currents With The Healing Of Wounds

The findings of Robert Becker (the book “The Body Electric: Electromagnetism and the Foundation of Life” by Becker and Selden, which can be found from web (see <http://tinyurl.com/y8rbgebw>) [J10], meant a breakthrough in the development of bioelectromagnetics. One aspect of bioelectromagnetic phenomena was the discovery of Becker that DC currents and voltages play a pivotal role in various regeneration processes. Why this is the case is still poorly understood and Becker’s book is a treasure trove for anyone ready to challenge existing dogmas. The general vision guiding Becker can be summarized by a citation from the introduction of the book.

Growth effects include the alteration of bone growth by electromagnetic energy, the restoration of partial limb regeneration in mammals by small direct currents, the inhibition of growth of implanted tumors by currents and fields, the effect upon cephalocaudal axis development in the regenerating flatworm in a polarity-dependent fashion by applied direct currents, and the production of morphological alterations in embryonic development by manipulation of the electrochemical species present in the environment. This partial list illustrates the great variety of known bioelectromagnetic phenomena.

The reported biological effects involve basic functions of living material that are under remarkably precise control by mechanisms which have, to date, escaped description in terms of biochemistry. This suggests that bioelectromagnetic phenomena are fundamental attributes of living things, ones that must have been present in the first living things. The traditional approach to biogenesis postulates that life began in an aqueous environment, with the development of complex molecules and their subsequent sequestration from the environment by membranous structures. The solid-state approach proposes an origin in complex crystalline structures that possess such properties as semiconductivity, photoconductivity, and piezoelectricity. All of the reported effects of electromagnetic forces seem to lend support to the latter hypothesis.

Observations relating to CNS

The following more quantitative findings, many of them due to Becker, are of special interest as one tries to understand the role of DC currents in TGD framework.

1. CNS and the rest of perineural tissue (tissue surrounding neurons including also glial cells) form a dipole-like structure with neural system in positive potential and perineural tissue in negative potential. There is also an electric field along the neuron in the direction of nerve pulse propagation (dendrites correspond to - and axon to +) (note that motor nerves and sensory nerves form a closed loop). Also microtubules within axon carry electric field and these fields are probably closely related by the many-sheeted variants of Gauss's and Faraday's laws implying that voltages along two different space-time sheets in contact at two points are the same in a static situation.
2. A longitudinal potential along front to back in the brain with the frontal lobes in negative potential with respect to occipital lobes and with a magnitude of few mV was discovered. The strength of the electric field correlates with the level of consciousness. As the potential becomes weaker and changes sign, consciousness is lost. Libet and Gerard observed traveling waves of potentials across the cortical layers (with speeds of about 6 m/s: TGD inspired model of nerve pulse predicts this kind of waves [K36]). Propagating potentials were also discovered in glial cells. The interpretation was in terms of electrical currents.
3. It was found that brain injury generated positive polarization so that the neurons ceased to function in an area much larger than the area of injury. Negative shifts of neuronal potentials were associated with incoming sensory stimuli and motor activity whereas sleep was associated with a positive shift. Very small voltages and currents could modulate the firing of neurons without affecting the resting potential. The "generating" potentials in sensory receptors inducing nerve pulse were found to be graded and non-propagating and the sign of the generating potential correlated with sensory input (say increase/reduction of pressure). Standard wisdom about cell membrane has difficulties in explaining these findings.
4. The natural hypothesis was that these electric fields are accompanied by DC currents. There are several experimental demonstrations for this. For instance, the deflection of assumed DC currents by an external magnetic field (Hall effect) was shown to lead to a loss of consciousness.

Observations relating to regeneration

The second class of experiments used artificial electrical currents to enhance regeneration of body parts. These currents are nowadays used in clinical practice to induce healing or retard tumor growth. Note that tissue regeneration is a genuine regeneration of an entire part of the organism rather than mere simple cell replication. Salamander limb generation is one of the most studied examples. Spontaneous regeneration becomes rare at higher evolutionary levels and for humans it occurs spontaneously only in the fractures of long bones.

1. An interesting series of experiments on Planaria, a species of simple flatworm with a primitive nervous system and simple head-to-tail axis of organization, was carried out. Electrical measurements indicated a simple head-tail dipole field. The animal had remarkable regenerative powers; it could be cut transversely into a number of segments, all of which would

regenerate a new total organism. The original head-tail axis was preserved in each regenerate, with that portion nearest the original head end becoming the head of the new organism. The hypothesis was that the original head-tail electrical vector persisted in the cut segments and provided the morphological information for the regenerate. The prediction was that the reversal of the electrical gradient by exposing the cut surface to an external current source of proper orientation should produce some reversal of the head-tail gradient in the regenerate. While performing the experiment it was found that as the current levels were increased the first response was to form a head at each end of the regenerating segment. With still further increases in the current the expected reversal of the head-tail gradient did occur, indicating that the electrical gradient which naturally existed in these animals was capable of transmitting morphological information.

2. Tissue regeneration occurs only if some minimum amount of neural tissue is present suggesting that CNS plays a role in the process although the usual neural activity is absent. The repeated needling of the stump had positive effect on regeneration and the DC current was found to be proportional to innervation. Hence needling seems to stimulate innervation or at least inducing formation of DC currents. Something like this might occur also in the case of acupuncture.
3. Regeneration involves de-differentiation of cells to form a blastema from which the regenerated tissue is formed. Quite early it was learned that carcinogens induce de-differentiation of cells because of their steric properties and by making electron transfer possible and that denervation induces tumor formation. From these findings Becker concluded that the formation of blastema could be a relatively simple process analogous to tumor growth whereas the regeneration proper is a complex self-organization process during which the control by signals from CNS are necessary and possibly realized in terms of potential waves.
4. Regeneration is possible in salamanders but not in frogs. This motivated Becker and collaborators to compare these situations. In an amputated leg of both salamander and frog the original negative potential of approximately -1 mV was raised first to a positive value of about +10 mV. In the frog it returned smoothly to its original value without regeneration. In the salamander it returned over a period of three days to the original base line and then went to a much higher negative value around -20 mV (resting potential is around -70 mV) followed by a return to the original value once regeneration had occurred. Thus the large negative potential is necessary for the regeneration and responsible for the formation of blastema. Furthermore, artificial electron current also induced regeneration also in the case of the frog, even in the denervated situation. Thus the flow of electrons to the stump seems to be necessary for the formation of blastema and the difference between salamander and frog is that frog is not able to provide the needed electronic current although positive potential is present.
5. It was also learned that a so called neuroepidermal junction (NEJ) formed in the healing process of salamander stump was responsible for the regeneration in the presence of denervation. The conclusion was that the DC voltage and electronic current relevant for regeneration could be assigned the interface between CNS and tissue rather than to the entire nerve and the regeneration seemed to be a local process, perhaps a feed of metabolic energy driving self-organization. Furthermore, NEJ seemed to make possible the flow of electrons from CNS to the stump.
6. The red blood cells of animals other than mammals are complete and thus possess nuclei. Becker and collaborators observed that red blood cells also dedifferentiated to form blastemas. Being normally in a quiescent state, they are ideal for studying de-differentiation. It was found that the electric current acted as a trigger at the level of cell membrane inducing de-differentiation reflected as an increased amount of mRNA serving as marker of gene expression. Also pulsed magnetic field was found to trigger the de-differentiation, perhaps via induced electric field. By the way, the role of the cell membrane fits nicely with the TGD inspired view about DNA-cell membrane system as topological quantum computer with magnetic flux tubes that are assumed to connect DNA and cell membrane and serve as braid strands in TGD inspired model of DNA as topological quantum computer [K58].

7. The experiments of Becker and collaborators support the identification of the charge carriers of DC currents responsible for the formation of the stump's large negative potential as electrons. The test was based on the different temperature dependence of electronic and protonic conductivities. Electronic conductivity increases with temperature and protonic conductivity decreases and an increase was observed.

Gene activation by electrostatic fields?

The basic question concerns the method of activation. The discovery of chemists Guido Ebner and Guido Schuerch [J4] raises the hope that these ideas might be more than over-active imagination and their work also provides a concrete proposal for the activation mechanism. Ebner and Schuerch studied the effect of electrostatic fields on the growth and morphogenesis of various organisms. Germ, seeds, or eggs were placed between conducting plates creating an electric field in the range 5-2 kV/m: note that the Earth's electric field is in the range .1 – 4 kV/m and of the same order of magnitude.

The outcome was rather surprising and in the year 1989 their employer Ciba Geigy (now Novartis) applied for a patent "Method of enhanced fish breeding" [J4] for what is called Ciba Geigy effect. The researchers describe how fishes (trouts) develop and grow much better, if their eggs have been conditioned in an electrostatic field. The researchers also reported [J4] that the morphology of the fishes was altered to what seems to represent an ancient evolutionary form: this was not mentioned in the patent.

The chemists founded their own Institute of Pharmaceutical Research near Basel, where Guido Ebner applied for another very detailed patent, which was never granted. In the patent he describes the effect of electrostatic fields on several life forms (cress, wheat, corn, fern, micro-organisms, bacteria) in their early stage of development. A clear change in the morphogenesis was observed. For instance, in one example fern had all sort of leaves in single plant apparently providing a series of snapshots about the evolution of the plant. The evolutionary age of the first leaf appeared to be about 300 million years whereas the last grown-up leaf looked close to its recent form.

If one takes these finding seriously, one must consider the possibility that the exposure to an electrostatic field can activate passive genes and change the gene expression so that older morphologies are expressed. The activation of not yet existing morphologies is probably more difficult since strong consistency conditions must be satisfied (activation of program requires activation of a proper hardware). This would suggest that genome is a kind of archive also containing also older genomes even potential genomes or that topological quantum computer programs [K58] determine the morphology to a certain extent and that external conditions such as electric fields determine the self-organization patterns characterizing these programs.

It is known that the developing embryo has an electric field along the head-tail axis and that this field plays an important role in the control of growth. These fields are much weaker than the fields used in the experiment. p-Adic length scale hierarchy however predicts an entire hierarchy of electric fields and living matter is indeed known to be full of electret structures. The strength of the electric field in some p-adic length scale related to DNA might somehow serve as the selector of the evolutionary age. The recapitulation of phylogeny during ontogeny could mean a gradual shift of the activated part of both genome and "memone" (as a menetic analog of genome: for a proposal of memetic code see [K17]), perhaps assignable to topological quantum computer programs realized as braidings, and be controlled by the gradually evolving electric field strength.

The finding that led Ebner to his discovery was that it was possible to "wake up" ancient bacteria by an exposure to an electrostatic field. The interpretation would be in terms of loading of metabolic batteries. This would also suggest that in the case of primitive life forms like bacteria the electric field of the Earth has served as metabolic energy source whereas in higher life forms endogenous electric fields have taken the role of Earth's electric field.

A TGD based model for the situation

On the basis of these observations one can try to develop a unified view about the effects of laser light, acupuncture, and DC currents. It is perhaps appropriate to start with the following - somewhat leading - questions inspired by a strong background prejudice that the healing process -

with control signals from CNS included - utilises the loading of many-sheeted metabolic batteries by supra currents as a basic mechanism.

The first series questions, observations, and ideas relates to the connection of DC currents with metabolism and ordinary biochemistry. The hierarchy of Planck constant is expected to be involved somehow.

1. How the DC currents relate to metabolism and ordinary biochemistry? For what purpose they are needed? The crucial point is that the energy of order 1 meV gained by electron in the electric field is much below the metabolic energy quantum and also thermal energy so that the interpretation in terms of metabolic energy quantum does not look promising. This forces to consider the possibility that the basic role of electric field is to drive electrons to where they are needed, say wounded part of tissue in positive potential and thus attracting electrons. Electrons are indeed needed by the electron transport cycle appearing in both photosynthesis and cell respiration since the transport cycle induces leakage of electrons due to the formation of ROS (reactive oxygen species) such as O_2^- . The purpose of electronic Becker currents would be therefore the re-establishment of metabolism.

The change of the sign of the Becker potential to positive induce a loss of electrons and reduced metabolism. This could explain why consciousness is lost when the sign of Becker potential is changed or electrons are deviated by Hall effect. Wound damages the connections of the tissue to the organism and the transfer of electrons compensating for leaked electrons is prevented since Becker potential changes sign. The regeneration induced by an artificial Becker potential of correct sign would induce healing by re-establishing the electron feed.

The crucial question concerns the role of electrons. It seems that in all situations electron flow to the damaged tissue induces healing. Why electrons generating negative potential should help in healing? The first input is TGD model [K48] [L14] for the findings of Pollack [L14] involves the connection of dark matter hierarchy $h_{eff} = n \times h$ with negentropic entanglement characterized by density matrix reducing to $n \times n$ unit matrix for entanglement matrix proportional to a unitary matrix. In infinite-dimensional case the divisor is infinite unless one uses von Neumann's hyperfinite factor of type II_1 for which the normalization factor can be taken to be unity: in the case of quantum groups this corresponds to using quantum trace instead of the ordinary one. A further input is the observation that the gravitational Planck constant h_{gr} explaining planetary Bohr quantization rules can be equal to h_{eff} in living matter for microscopic systems like elementary particles, atoms, and ions, even molecules [K91, K34].

1. Pollack's findings about fourth phase of water formed when external energy feed induces formation of negatively charged exclusion zones of water obeying stoichiometry $H_{1.5}O$ with 1/4: th of protons going to the complement of exclusion zone. Something similar might happen also now.
2. In TGD framework this process is explained as a formation dark phase of protons at the magnetic flux tubes associated with the exclusion zone with dark protons realizing genetic code so that one obtains what might be regarded as primitive primordial life form.
3. There is evidence for a huge anomalous gravimagnetic Thomson field in rotating super conductors. Thomson field is proportional to square of Planck constant h_{eff} and TGD explanation is that large h_{gr} phase is formed at gravitational flux tubes. The assumption $h_{gr} = h_{eff}$ in elementary particle and atomic scales is possible and is consistent with the hypothesis that bio-photons in visible and UV energy range correspond to decay products of dark EEG photons.
4. h_{gr} can be generalized to $h_{em} = -Z_1 Z_2 e^2 / v_0$: v_0 would be typical rotational velocity in a system with opposite charges Z_1 and Z_2 . Exclusion zone would be good example. For ATP v_0 would be rotational velocity of ATP. For exclusion zone v_0 could be rotational velocity of Cooper pairs in magnetic field associated with flux tubes or walls or rotational velocity of magnetic body. $Z_2 = -Z_1$ is natural assumption by charge neutrality.
5. In this framework the feed of electrons would increase the value of h_{eff} by increasing the negative charge associated with the analog of exclusion zone accompanying the wound and

induce also a flow of dark protons to the magnetic flux tubes associated with the magnetic body of the analog of exclusion zone.

6. The DC currents would be needed because the damage of the tissue means that the $\hbar_{eff} = \hbar_{em} = Z^2 e^2 / v_0$ is reduced for a pair formed by damaged system and its complement. Healing would be essentially attempt to increase $\hbar_{eff}$ to its original value. The parameter Z^2 is reduced and must be increased to its original value and perhaps even to a higher value since the larger $\hbar_{eff}$ is, the richer the negentropic resources of system are. The transfer of electrons to the system analogous to exclusion zone induces transfer of dark protons to the magnetic flux quanta of the magnetic body of the system. Recall that dark proton strings at flux tubes could be analogs of dark nuclei and that the model for dark nucleons allows to identify nucleon states as counterparts of DNA, RNA, amino-acids and even tRNA. This leads to a model of prebiotic lifeforms [K18].
7. ATP synthase transforming ADP to ATP involves rotating shaft and one can ask whether the velocity parameter v_0 appearing in the expression for $\hbar_{em}$ equals to the rotation speed of the shaft. This predicts that the value of $\hbar_{em}$ to be same order as $\hbar_{eff}$ and $\hbar_{gr}$ for Earth-electron system assuming that v_0 corresponds to the rotation velocity at the surface of Earth. The assumption $\hbar_{eff} = \hbar_{gr} = \hbar_{em}$ makes it possible for the gravitational and em flux tubes to reconnect.
8. The original guess was that electrons to provide energy giving rise to the formation of ATP in cell respiration and photosynthesis. Electrons themselves receive their energy either from the oxidation of molecules or from solar photons. This model is consistent with the model above since electron transport chain is crucial for cell transpiration and needs both electrons and dark protons located at the dark flux tubes associated with the exclusion zones. Dark protons would flow through the ATP synthase attached to mitochondrial membrane and liberate dark cyclotron energy if the value of the magnetic fields associated with the flux tube is different for the interior and exterior portions of the flux tube [K13, K32].

The experimental support for the role of bio-photons in living matter is accumulating and a natural question concerns their role in metabolism. In TGD framework dark photons with large value of $\hbar_{eff}$ with energy of visible photon can transform to ordinary photons of same energy with some - presumably rather small - probability, and would be interpreted as bio-photons. Could dark photons take the role of solar photons and provide in some situations energy to the electrons in the electron transport cycle? This would mean a non-conventional non-local mechanism of metabolism. The effects of laser light on tissue suggest that laser light indeed takes the role of solar light and feed energy to the electron transport cycle transforming it to the energy of high energy phosphate bond of ATP. A more detailed TGD inspired view about what might happen is discussed in [K21].

One can consider also the possibility that quantum credit card mechanism (remote metabolism) could be at work in some the situations when chemical metabolic energy sources are absent. Damaged tissue might define this kind of exceptional situation. This brings in mind the strange ability of plants suffering under-nutrition to attract insects responsible for their pollination observed by Callahan, who has also reported that plants and insects communicate using infrared light which according to his findings serves as a sensor input in insect olfaction [I3]: also in this case quantum credit card mechanism building magnetic flux tube bridges guiding the insects to the plant might be at work. The electrons which have gained 1 meV energy during travel along pairs formed by MEs and parallel magnetic flux tubes (meridians), could send negative energy dark photons with energy of order -5 eV to gain same positive energy allowing to get over the semiconductor junction after they have arrived to the damaged tissue. These negative energy photons would be absorbed by a metabolic energy store (ATP in mitochondria transforming to ADP) in the healthy part of the organism.

$\hbar_{eff} = \hbar_{em}$ implies that the spectrum of bio-photons originating from dark cyclotron photons is universal having no dependence on ion mass and in visible and UV range, which is also the range for molecular excitation energies. Dark cyclotron photons decaying to bio-photons would therefore allow magnetic body to control biochemistry by resonant absorption inducing transitions of molecules.

The original model for the charging of the metabolic batteries and for effective semiconductor junction assumed that the electrons of supra current are transferred to smaller space-time sheets.

1. For ground state electrons this requires energy which is at least the difference of zero point kinetic energies of electron at the two space-time sheets. This energy should be of the order of fundamental metabolic energy quantum of about .5 eV.

For Cooper pairs of electrons the sheet should correspond to p-adic length scale of order $L_e(k_e = 149) = 10$ nm, the thickness of lipid layer of cell membrane. For single proton corresponding scale would be $L_e(k_p = 139) \simeq 2^{-12} L_e(151)$ from $m_p/2m_e \simeq 2^{10}$ and $E_{0,p}/E_{0,2e} = (2m_e/m_p) \times (L_e(k_e)/L_e(k_p))^2 = (2m_e/m_p) \times 2^{k_e - k_p} \sim 1$.

This suggests that electron Cooper pair is kicked to a smaller space-time sheet assignable to a mitochondrial lipid layer having $k_e = 149$. The larger space-time sheet could be that of cell membrane with $k = 151$. For protons the zero point kinetic energies at these space-time sheets are by a factor $2m_e/m_p$ lower and of the order of .5 meV. This happens to be of the same order of magnitude as the energy gained by proton or electron in the Becker potential. Maybe this is not an accident.

There is also a second intriguing quantitative co-incidence. In the absence of an action potential, acetylcholine vesicles spontaneously leak into the synaptic junction and cause very small de-polarizations in the postsynaptic membrane known as miniature end plate potentials (see <http://tinyurl.com/y98zhxzh>) (mEPSP) of magnitude .5 mV. These potentials are too small to generate action potential but together they can sum up to the needed action potential. Maybe the interpretation in terms of proton kicked to lipid layer space-time sheet might make sense.

2. The re-charging mechanism should relate directly to ADP $\rightarrow$ ATP process occurring during electronic transport cycle in mitochondrial membrane. The connection with metabolism forces to ask how the formation of high energy phosphate bond in the addition of phosphate to ADP relates to the transfer of electrons to smaller space-time sheet. Somehow the energy of electrons must go to the formation of this bond: perhaps the dropping of electron back to larger space-time sheet transfers the energy to the high energy phosphate bond.

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.

3. The transfer of particles between space-time sheets with different p-adic length scales is not the only one that one can consider, and recently a more elegant mechanism has emerged [K21]. If the particles are free, a phase transition in which the p-adic prime of the space-time sheet containing particles decreases adiabatically increases the scale of kinetic energy but leaves particle quantum numbers unchanged. If the same happens for charge particles at magnetic flux tubes, similar increase of cyclotron energy scale takes place since magnetic field strength increase to conserve magnetic flux. The predictions are in good approximation the same as for the original model. If the phase transition reducing p-adic length scale is accompanied by a compensating increase of Planck constant, the size scale of space-time sheet remains unaffected but metabolic batteries are loaded. The reversal of this phase transition liberates metabolic energy. What is important that metabolic energy and negentropic entanglement (measured in terms of the value of Planck constant) are closely correlated for this mechanism. The loading/liberation of energy is also a quantum coherent process.
4. Acupuncture and the application of DC current are known to induce the generation of endorphins. Do endorphins contribute to well-being by reducing the pain? In TGD framework the deeper level interpretation of metabolism is as a provider of negentropic entanglement in

turn giving rise to well-being. Are endorphins kind of negentropy packets or just conscious signals about the improved situation?

Second series of questions, observations, and ideas relates to the meridians, acu points, and “chi”.

1. A permanent potential difference of same sign between head and tail could mean an accumulation of positive and negative charges to the ends of the of the system if only electron currents are present. If both electron and proton currents with opposite directions are present, there is no accumulation of charge but there is an accumulation of protons and electrons. Probably there exists a pumping mechanism forcing the electrons (and possibly also protons) to move against the potential gradient from the tail back to the head. This however requires metabolic energy and the simplest source of this energy would be just the energy of electrons otherwise used to generate ATP. If so, the leakage would not be an unavoidable dissipative effect but a manner to avoid charge accumulation.

If the pumping mechanism is not at work, this situation cannot continue for ever and the sign of the potential difference must eventually change and induce loss of consciousness. The simplest possibility is that the potential difference changes sign rhythmically. A natural question is whether the sleep-awake rhythm is unavoidable and corresponds to the oscillatory behavior of the head-to-tail voltage.

“Chi” would correspond electrons or their Cooper pairs in this picture. Abnormal chi flow (reduced flow, flow in wrong direction, accumulation of chi) would cause various problems including also insomnia in which too much electron charge tends to accumulate.

3. What is the nature of acupuncture meridians, what kind of currents flow along them, and why are they not directly observed? The most natural identification in TGD Universe would be in terms of magnetic flux tubes accompanied by parallel massless extremals (MEs) making possible also the propagation of dark photons used for control purposes and perhaps even in metabolism as already discussed. Dark currents along pairs of MEs and magnetic flux tubes are ideal for the transfer of particles and energy.

If the length of the superconducting “wire” is long in the scale defined by the appropriate quantum scale proportional to $\hbar$, the classical picture makes sense and charge carriers can be said to accelerate and gain energy ZeV . For large values of $\hbar_{eff}$ an oscillating Josephson current would be in question. Since Becker currents are associated with CNS, it would be natural to associate the meridians with neural pathways although this assignment is not necessary. Magnetic flux tube system defined kind of magnetic circulation which could serve as a template for the neural pathways. The transfer of energy with minimal dissipation would explain why a semiconductor like property is needed and why acupuncture points have a high conductivity value.

4. What about acu-points? Acu points are known to be in negative potential normally. This suggests that the density of electrons or their Cooper pairs at them is higher than elsewhere in the meridian. Could they server as kind of electron stores providing electrons to their environment to compensate for losses caused by ROS. This would make possible higher metabolic activity in presence of nutrient molecules since the rate for the electron transform cycle should be proportional to the density of energizable electrons, “chi”.

When the potential of the acu-point is reduced or become positive, under-nutrition follows. This should relate to various symptoms like pain at acupuncture points. Acupuncture needle as an electronic conductor would develop a charge distribution with a concentration of electrons to the acu-point, and would re-establish the metabolic activity. Pain would be signature of lack of negentropic entanglement (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig.** ?? in the appendix of this book) and positive/negative coloring of emotions and sensations would quite generally correlate with the amount of negentropic entanglement.

5. Nanna Goldman et al have provided empirical evidence (see <http://tinyurl.com/4to42pc>) [I11] for the expectation that the healing effect of the acupuncture involves metabolism (see the popular article in Sciencedaily (see <http://tinyurl.com/3734uub>) [I4]).

The group has found that adenosine is essential for the pain killing effects of acupuncture. For mice with a normal adenosine level acupuncture reduced discomfort by two-thirds. In special “adenosine receptor knock-out mice” acupuncture had no effect. When adenosine was turned on in the tissues, the discomfort was reduced even in the absence of acupuncture. During and after an acupuncture treatment, the level of adenosine in tissues near the needles was 24 times higher than before the treatment. In the abstract of the article it is stated that it is known for long time that acupuncture generates signals which induce brain to generate natural pain killing endorphins but that also adenosine acts as a natural pain killer.

Adenosine is the basic building block of AXP, $X=M, D, T$ (adenosine-X-phosphate, $X=\text{mono, di, tri}$). Therefore the findings suggest that the flow of electrons from the needle to acupuncture point loads metabolic batteries by providing electrons to electron transport cycle needed to generate ATP. Adenosine could be partially generated as decay products of AXPs. Tissue itself could increase adenosine concentration to make possible its transformation to AXP utilizing electric field energy. From the popular article one cannot conclude whether the authors propose a connection with metabolism. The results are consistent with the assumption that the AXPs generated from adenosine accompany negentropic entanglement. This can occur in the scale of entire body and meridians could also make possible direct signalling with brain.

How can understand the semiconducting character of Becker’s DC currents?

1. Becker assigns to the system involved with DC currents an effective semiconductor property. Could the effective semiconductor property be due the fact that the transfer of charge carriers to a smaller space-time sheet by first accelerating them in electric field is analogous to the transfer of electrons between conduction bands in semiconductor junction? If so, semiconductor property would be a direct signature of the realization of the metabolic energy quanta as zero point kinetic energies. For metabolic energy quantum of order .5 eV this however makes sense only if the electrons transferred to the smaller space-time sheet have energy slightly below the minimum energy for the transfer to the smaller space-time sheet in absence of the Becker potential. The situation would be critical and 1 mV voltage could serve as a kind of control knob.

One can imagine the analog of this mechanism also when the external energy feed corresponds to a phase transition reducing p-adic length scale and increasing Planck constant so that the size of the space-time sheet remains unaffected. Again 1 mV voltage would have the role of control knob.

2. Supra currents flowing along magnetic flux tubes would make possible dissipation-free loading of metabolic energy batteries. This even when oscillating Josephson currents are in question since the transformation to ohmic currents in semiconductor junction makes possible energy transfer only during second half of oscillation period. Could this be a universal mechanism applying to various stages of the regeneration process? In quantal situation the metabolic energy quanta have very precise values as indeed required.
3. The findings of Becker provide support for electronic DC currents. The Cooper pairs of electrons are indeed the best candidates for the carriers of supra current by their small mass. In the minimal situation the currents defined by leaked electrons moving against potential gradient (utilising the energy used otherwise to generate ATP) could compensate the Becker currents and give rise to closed current loops without charge accumulation. If the electronic DC currents observed by Becker are much stronger than needed to compensate for the local electron leakage, a larger metabolically driven return current is needed to guarantee local charge neutrality. These currents seem to be assignable to CNS: maybe the two electron currents could be associated with sensory and motor pathways. An interesting question whether sympathetic-parasympathetic dichotomy also relates to electron currents in opposite directions.
4. Could also dark protonic and even ionic DC currents be present and running along their own flux tubes and perhaps defining cyclotron Bose-Einstein condensates? How large the scale of flux tubes can be: could it be much larger than that of biological body (by simple argument magnetic body should have layers with even size scale of Earth). What is the

possible connection with cell respiration? When single ATP is generated, three protons are pumped through the mitochondrial membrane utilising the energy liberated in electron transport cycle. This does not however require protonic currents in longer scales.

5. In regeneration process NEJs are formed. They could consist of pairs of MEs and magnetic flux tube mediating the electronic DC current during blastema generation and regeneration proper during which also control signals from CNS would be present. Since NEJs seems to resemble cell membranes in some respects, the ideas inspired by the model of cell membrane and DNA as TQC can be used. The model for nerve pulse and the model for DNA as topological quantum computer suggest that dark ionic currents flowing along magnetic flux tubes characterised by a large value of the effective Planck constant are involved with both meridians and NEJs. Magnetic flux tubes can act as DC current wires or Josephson junctions generating oscillatory supra currents of ions and electrons. Also for large values of the effective Planck constant meridians look short in the relevant dark length scale and could act as Josephson junctions carrying oscillatory Josephson currents.

One can raise also questions about the relationship between DC currents and de-differentiation.

1. Could cell de-differentiation be caused by the presence of Becker's DC current? Also acupuncture is known to induce de-differentiation. Could the mere ability to charge metabolic energy batteries provided by electron feed induce de-differentiation, which manifests as an increased genetic expression? Can one see differentiation as an eliminative process forced by the reduction of the electron feed and inducing a selective reduction of gene expression? If this were the case, de-differentiation could be induced by a feed of surplus electrons to the system using either external electron current or additional electric field. Local electron density would correlate negatively with the degree of differentiation.
2. In this framework it might be possible to understand the claimed effects of external electric fields on the development of plants and fishes. In this case rejuvenation means return to the earlier evolutionary stages. Maybe ontogeny-recapitulates-phylogeny principle might allow to understand this if genome in some sense contains archive about earlier stages of evolution. This archive might be virtual and realised by an epigenetic mechanism selecting different patterns of gene expression using the same genome.

If this is the case, the density of electrons or their Cooper pairs - "chi" - possessed by the cell would serve as a measure for the biological age of the cell and the meridian system feeding "chi" would serve as a rejuvenating agent with respect to gene expression. The average density of dark electrons would serve as a measure for the age of cell: the larger the density the higher the metabolic activity and the lower the biological age.

D.5.2 Quantum Model For Effective Semiconductor Property

Becker [J10] summarizes his findings by stating that living matter is an effective semiconductor. There are pairs of structures in positive and negative potential in various scales and the current between the plates of this effective capacitor flows when above some minimum potential difference. The current flows from positive to negative pole and could be an electron current. Also proton current in the opposite direction can be considered but the electron current is experimentally favored. For instance consciousness is lost when a magnetic field is used to deflect the current.

In TGD framework natural carriers of these currents would be magnetic flux tubes also carrying electric fields. A very simple deformation of the imbedding of a constant longitudinal magnetic field also gives longitudinal electric field. With a slight generalization one obtains helical electric and magnetic fields. A crucial difference is that these currents would be quantal rather than ohmic currents even in the length scale of the biological body and even longer scales assignable to the magnetic body.

The following argument allows us to understand the physical situation.

1. A precise everyday analogy is vertical motion in the gravitational field of the Earth between surface and some target at given height h . If the kinetic energy is high enough, the particle reaches the target. If not, the particle falls back. In the quantum case one expects that the

latter situation corresponds to a very small probability amplitude at the target (tunnelling to classically forbidden kinematic region).

2. Now the electric field replaces the gravitational field. Suppose that the classical electric force experienced by the particle is towards the capacitor plate taking the role of the surface of Earth. Below critical field strength the charged particle cannot reach the target classically and quantum mechanically this occurs only by tunnelling with vanishingly small probability.
3. Particles with opposite value of charge experience a force which accelerates them and classically they certainly reach the second plate. What happens in a quantum situation? It seems that this situation is essentially identical with the first one: one has linear potential in finite interval and wave functions are localized in this range. One can equivalently regard these states as localized near the second capacitor plate.
4. A good analogy is provided by atoms: classically the electron would end down at the nucleus but quantization prevents this. One can imagine also now stationary solutions for which the electric currents for individual charges vanish at the plates although classically there would be a current in another direction. Also quantum mechanically non-vanishing conserved current is possible: all depends on boundary conditions.

Basic model

Consider now the situation at more quantitative level.

1. One can assign complex order parameters Ψ_k to various Bose-Einstein condensates of supra phases and obey Schrödinger equation

$$i\partial_t \Psi_k = \left(-\frac{\hbar^2}{2m_k} \partial_z^2 + q_k E z \right) \Psi_k . \quad (\text{D.5.1})$$

Here it is assumed that the situation is effectively one-dimensional. E is the value of constant electric field.

2. The Schrödinger equation becomes non-linear, when one expresses the electric field in terms of the total surface charge density associated with the plates of effective capacitor. In absence of external electric field it is natural to assume that the net surface charge densities σ at the plates are of opposite sign so that the electric field inside the capacitor is proportional to

$$\sigma = E = \sum_i \sigma_i = \sum_i q_i \bar{\Psi}_i \Psi_i . \quad (\text{D.5.2})$$

This gives rise to a non-linear term completely analogous to that in non-linear Schrödinger equation. A more general situation corresponds to a situation in which the region interval $[a, b]$ bounded by capacitor plates a and b belongs to a flux longer tube like structure $[A, B]$: $[a, b] \subset [A, B]$. In this case one has

$$E_{tot} = E + E_0 . \quad (\text{D.5.3})$$

This option is needed to explain the observations of Becker that the local strengthening of electric field increases the electron current: this would be the case in the model to be discussed if this field has a direct opposite to the background field E_0 . One could also interpret E as quantized part of the electric field and E_0 as classical contribution.

3. The electric currents are given by

$$j_k = \frac{i\hbar q_k}{2m_k} \bar{\Psi}_k \partial_z^{\leftrightarrow} \Psi_k . \quad (\text{D.5.4})$$

In stationary situation the net current must vanish:

$$\sum_k j_k = 0 . \quad (\text{D.5.5})$$

A stronger condition is that individual currents vanish at the plates:

$$j_k = 0 . \quad (\text{D.5.6})$$

It must be emphasized that this condition does not make sense classically.

Explicit form of Schrödinger equation

Consider now the explicit form of Schrödinger equation in a given electric field.

1. The equation is easy to solve by writing the solution ansatz in polar form (the index k labelling the charge particle species will be dropped for notational convenience).

$$\Psi = R(a \exp(iU) + b \exp(-iU)) \exp(-iE_n t) \quad (\text{D.5.7})$$

For real solutions current vanishes identically and this is something which is not possible classically. It is convenient to restrict the consideration to stationary solutions, which are energy eigen states with energy value E_n and express the general solution in terms of these.

2. The Schrödinger equation reduces with the change of variable

$$\begin{aligned} z &\rightarrow \frac{(z - z_0)}{z_1} \equiv x , \\ z_0 &= \frac{E_n}{qE} , \quad z_1 = \left(\frac{\hbar^2}{2mqE} \right)^{1/3} . \end{aligned} \quad (\text{D.5.8})$$

to

$$(\partial_x^2 + x)\Psi = 0 . \quad (\text{D.5.9})$$

The range $[0, z_0]$ for z is mapped to the range $[-z_0/z_1, 0]$. z_0/z_1 has positive sign as is easy to verify. The value range of x is therefore negative irrespective of the sign of qE . This is the differential equation for Airy functions (see <http://tinyurl.com/6b8yh7>) [B1]. Airy functions are encountered in WKB approximation obtained by linearizing the potential function: $V(x) = ax + b + O(x^2)$.

The change of variable leads automatically to solutions restricted near the plate where the situation is completely analogous to that in the gravitational field of the Earth. For stationary solutions a test charge in a given background field would be localized near the capacitor plate with opposite sign of charge. A strong background field could be created by charges which do not correspond to the ionic charges defining ionic currents. Electrons and protons could define this field possibly associated with flux tubes considerably longer than the distance between capacitor plates.

3. Using the polar representation $\Psi = R \exp(iU)$ Schrödinger equation reduces to two equations

$$\begin{aligned} [(\partial_x^2 - U_x^2 + x)R] \cos(U) + [U_{xx} + 2\partial_x R \partial_x U] \sin(U) &= 0, \\ [(\partial_x^2 - U_x^2 + x)R] \sin(U) - [U_{xx} - 2\partial_x R \partial_x U] \cos(U) &= 0. \end{aligned} \quad (\text{D.5.10})$$

Note that both (R, U) and $(R, -U)$ represent solutions for given value of energy so that the solution can be chosen to be proportional to $\cos(U)$ or $\sin(U)$. The electric current j is conserved and equal to the current at $x = 0$ and given by

$$j = \frac{\hbar}{2m} \frac{U_x}{z_1} R^2, \quad z_1 = \left(\frac{\hbar}{2mqE} \right)^{1/3}. \quad (\text{D.5.11})$$

The current vanishes if either U_x is zero or if the solution is of form $\Psi = R \sin(U)$.

Semiclassical treatment

In semiclassical approximation the potential is regarded as varying so slowly that it can be regarded as a constant. In this situation one can write the solution of form $R \exp(iU)$ as

$$\Psi = R_0 \exp \left(\frac{i}{\hbar} \int_0^z \sqrt{2m} \sqrt{E - qEz} dz \right) = R_0 \exp \left(i \int_0^x x^{1/2} dx \right). \quad (\text{D.5.12})$$

The plate at which the initial values are given can be chosen so that the electric force is analogous to gravitation at the surface of Earth. This requires only to replace the coordinate z with a new one, vanishing at the plate in question - and gives to the energies a positive shift $E_0 = qE_0 h$.

1. The semiclassical treatment of the equation leads to Bohr rules

$$\frac{\oint p_z dz}{\hbar} = \frac{2}{\hbar} \int_0^h p_z dz = n. \quad (\text{D.5.13})$$

This gives

$$\frac{\oint p_z dz}{\hbar} = \frac{2\sqrt{2m}}{\hbar} \int_0^h \sqrt{E_n - qEz} dz = 2 \int_0^{x_0} x^{1/2} = \frac{4}{3} x_0^{3/2} = n. \quad (\text{D.5.14})$$

Note that the turning point for classical orbit corresponds to $z_{max} = E_n/qE$.

2. One obtains

$$E_n = \frac{1}{2} \left(\frac{nqE\hbar^2}{r\sqrt{m}} \right)^{2/3}, \quad r = \int_0^1 (1-u)^{1/2} du = \frac{2}{3}. \quad (\text{D.5.15})$$

The value of z_{max} is

$$z_{max} = \frac{E_n}{qE} = \frac{n^{2/3}}{2r^{2/3}} \left(\frac{\hbar^2}{qEm} \right)^{1/3}. \quad (\text{D.5.16})$$

3. The approximation $R = R_0 = \text{constant}$ can make sense only if the position of the second plate is below z_{max} . This is possible if the value of n is large enough ($n^{2/3}$ proportionality), if the mass m of the charged particle is small enough ($m^{-1/3}$ proportionality) raising the electron and also the proton to a special position, or if the strength of the electric field is small enough ($E^{-1/3}$ proportionality). The value z_{max} is proportional to $\hbar^{2/3}$ so that a phase transition increasing Planck constant can induce current flow.

Possible quantum biological applications

The proposed model for quantum currents could provide quantum explanation for the effective semiconductor property of Becker's DC currents.

1. The original situation would be stationary with no currents flowing. The application of an external electric field in the correct direction would reduce the voltage below the critical value and currents would start to flow. This is consistent with Becker's findings if there is a background electric field E_0 with direction opposite to that of the applied field has a direction opposite to E_0 so that the field strength experienced by charged particles is reduced and it is easier for them to reach the second plate.
2. Becker's DC currents appear in several scales. They are assigned with the pairs formed by CNS and perineural tissue (this includes also glia cells) and by frontal and occipital lobes. Acupuncture could involve the generation of a DC supra current. The mechanism would be essential in the healing. Also the mechanism generating qualia could involve generation of supra currents and dielectric breakdown for them. The role of the magnetic flux tubes in TGD inspired biology suggests that the mechanism could be universal. If this were the case one might even speak about a Golden Road to the understanding of living matter at the basic level.

Even the generation of nerve pulse [K36] might be understood in terms of this mechanism. One can argue that neurons have a higher evolutionary level than the system pairs to which only electron currents or electron and proton currents can be assigned. This is because the value of the effective Planck constant is higher for the magnetic flux tubes carrying the quantal ionic currents.

1. For Bose-Einstein condensate the simplest choice is $n = 1$ at both plates. The energy eigenvalues would naturally differ by the shift $E_0 = qE_0h$ at the two plates for a given particle type. Under these assumptions the current can flow appreciably only if the voltage is below the minimum value. This is certainly a surprising conclusion but brings in mind what happens in the case of neuronal membrane. Indeed, hyper-polarization has a stabilizing - something difficult to understand classically but natural quantum mechanically.
2. The reduction of membrane potential slightly below the resting potential generates nerve pulse. Also a phase transition increasing the value of the effective Planck constant might give rise to quantal direct currents and generate flow of ionic currents giving rise to nerve pulse. Stationary solutions are located near either capacitor plate. What comes to mind is that the nerve pulse involves a temporary change of the capacitor plate with this property.
3. If the electron and proton currents flow as direct currents, one encounters a problem. Nerve pulse should begin with direct electronic currents and be followed by direct protonic currents and only later ions should enter the game if at all. The existing model for nerve pulse however assumes that at least electrons flow as oscillating Josephson currents rather than direct quantal currents. This is quite possible and makes sense if the cell membrane thickness is small - that is comparable to electron Compton length as assumed in large $\hbar$ model for the nerve pulse. This assumption might be necessary also for proton and would make sense if the Planck constant for protonic flux tubes is large enough. For ions the Compton length would be much smaller than the thickness of cell membrane and direct currents would be natural.

If the value of the effective Planck constant is the same for biologically important ions, direct quantum currents would be generated in definite order since in $\hbar < z_{max}$ one has $z_{max} \propto m^{-1/3} \propto A^{-1/3}$. The lightest ions would start to flow first.

- (a) Nerve pulses can be generated by voltage gated channels for potassium and calcium. Voltage gated channels would correspond to magnetic flux tubes carrying electric field. For voltage gated channels Na^+ ions with atomic weight $A = 23$ and nuclear charge $Z = 11$ start to flow first, then K^+ ions with atomic weight $A = 39$ and $Z = 19$ follow. This conforms with the prediction that the lightest ions flow first. The nerve pulse duration is of the order of 1 millisecond at the most.

- (b) Nerve pulses can be also generated by voltage gated Ca^{+2} channels. In this case the duration can be 100 ms and even longer. Ca has $A = 40$ and $Z = 20$. The proper parameter is $x = r^2/qA$, $r = \hbar/\hbar_0$. One has

$$\frac{x(Ca^{++})}{x(Na^+)} = \left(\frac{r(Ca^{++})}{r(Na^+)}\right)^2 \times \frac{23}{2 \times 40} . \quad (D.5.17)$$

$r^2(Ca_{++}) \sim 2r^2(Na_+)$ would allow to compensate for the increased weight and charge of Ca_{++} ions.

4. The objection is that Na^+ and K^+ are not bosons and therefore cannot form Bose-Einstein condensates. The first possibility is that one has Cooper pairs of these ions. This would imply

$$\frac{x(Ca^{++})}{x(2Na^+)} = \left(\frac{r(Ca^{++})}{r(Na^+)}\right)^2 \times \frac{23}{20} .$$

Ca^{++} and Na^+ pair would be in very similar position for a given value of Planck constant. This is a highly satisfactory prediction. Another manner to circumvent the problem is more science fictive and assumes that the Na^+ ions are exotic nuclei behaving chemically as Na^+ but having one charged color bond between nucleons [L4].

It remains to be seen whether this model is consistent with the model of cell membrane as almost vacuum extremal or whether the vacuum extremal based model could be modified by treating ionic currents as direct currents. In the vacuum extremal model classical Z^0 gauge potential is present and would give a contribution to the counterpart of Schrödinger equation. The ratio $x(Ca^{++})/x(2Na^+)$ for the parameter $x = r^2/q(A - Z)A$ (em charge q is replaced with neutron number in good approximation) equals to 1.38 and is not therefore very far from unity.

The many-sheetedness of space-time is expected to play a key role and one should precisely specify which sheets are almost vacuum extremals and which sheets are far from vacuum extremals. One expects that magnetic flux tubes are far from vacuum extremals and if voltage gated ionic channels are magnetic flux tubes, the proposed model might be consistent with the model of cell membrane as almost vacuum extremal.

The effects of ELF em fields on vertebrate brain

The effects of ELF em fields on vertebrate brain occur both in frequency and amplitude windows. Frequency windows can be understood if the effect occur at cyclotron frequencies and correspond to absorption of large $\hbar$ photons. A finite variation width for the strength of magnetic field gives rise to a frequency window. The observed quantal character of these effects occurring at harmonics of fundamental frequencies leads to the idea about cyclotron Bose-Einstein condensates as macroscopic quantum phases. The above considerations support the assumption that fermionic ions form Cooper pairs.

I have tried to understand also the amplitude windows but with no convincing results. The above model for the quantum currents however suggests a new approach to the problem. Since ELF em fields are in question they can be practically constant in the time scale of the dynamics involved. Suppose that the massless extremal representing ELF em field is orthogonal to the flux tube so that the ions flowing along flux tube experience an electric force parallel to flux tube. What would happen that the ions at the flux tube would topologically condensed at both the flux tube and massless extremal simultaneously and experience the sum of two forces.

This situation is very much analogous to that defined by magnetic flux tube with longitudinal electric field and also now quantum currents could set on. Suppose that semiconductor property means that ions must gain large enough energy in the electric field so that they can leak to a smaller space-time sheet and gain one metabolic quantum characterized by the p-adic length scale in question. If the electric field is above the critical value, the quantum current does not however reach the second capacitor plate as already found: classically this is of course very weird. If the

electric field is too weak, the energy gain is too small to allow the transfer of ions to smaller space-time sheet and no effect takes place. Hence one would have an amplitude window.

The amplitude window occur in widely separate ranges 1-10 V/m and around 10^{-7} V/m. Of course, also other ranges might be possible. Fractality and the notion of magnetic body suggests a possible explanation for the widely different frequency ranges. Both p-adic length scale hypothesis and the hierarchy of Planck constants suggest that some basic structures associated with the cell membrane have fractal counterparts in a wide length scale range and correspond to binary structures. Magnetic flux tubes carrying quantal DC currents of Becker would be the most natural candidate in this respect since these currents appear in several length scales inside organism. Also the counterparts of lipid layers of cell membrane could be involved. If so, one must include to the hierarchy of amplitude windows also fields in the range corresponding to the cell membrane resting potential of about 6×10^6 V/m. This is of course only a rough order of magnitude estimate since perturbations of these field are in order.

Fractality motivates some guess for voltage and electric field.

1. The voltage along the flux tube could be invariant under the scaling of Planck constant. The interpretation could be that the charges at the ends of the linear structure generate an electric flux running along the structure do not depend on the length L of the structure so that the electric field along linear structure behaves as $1/L \propto 1/h_{eff}$ as a function of the length scale $L \propto h_{eff}$ so that voltage between the ends does not depend on the length of the structure. This would give rise to a universal amplitude window for voltage rather than potential. The cell membrane electric field of 6×10^6 V/m would correspond to the field 6 mV/m. This kind of voltages could be associated with Becker's DC currents and the order of magnitude would be around few mV.

Note that if the electric flux is like that between point charges, the scaling law $E \propto 1/h_{eff}^2$ holds true.

2. There could be also a constant electric field along microtubular structures due to polarization - most naturally tubulin polarization. This field strength serves as a candidate for a universal amplitude window for electric field.

The idea that the direct currents of Becker run between lipid layers of cell does not conform with the hypothesis about generalized Josephson currents between them. There are electric fields along microtubules and one could wonder whether the DC voltages of Becker could relate to the voltages between the ends of linear structures formed by axonal and dendritic microtubules connected to each other by MAPs - single MT can have a length up to about 1 cm. The longitudinal electric field due to the dipole moments of tubulins and confined to tubulin structure does not depend on its length L , and the electric field of 1 mV/m would correspond 10^3 V/ μ m, which is by order of magnitude larger than the constant longitudinal dipole electric field of order 10^2 eV/ μ m generated by tubulin dipoles estimated to have strength 337 Debye in [I16] (note that MT has radius of $R = 25$ nm, thickness of $\Delta R = 4$ nm and length of $d = 8$ nm and the volume of MT fragment defined by 13 parallel tubulins is given by $V = 13 \times 2\pi R^2 \Delta R$ and that electric is $E = p/V$). If Becker's direct currents correspond to electric fields due to the charge difference between the ends of tubulins, one can consider the possibility that Becker's longitudinal electric fields have micro.tubular origin.

3. Electric field in the range $E = 1 - 10$ V/m assignable to EEG would correspond to field of $(1 - 10) \times 10^3$ V/ μ m and seems to be too large to be assigned with microscopic structures. DNA is a possible candidate since the smaller thickness of DNA would increase the dipole moment density by a factor of order 10^3 from that for MTs. The electric field of 10^{-7} eV/m seems to be associated with much larger structure than organism.

Effects of 50 Hz magnetic fields on living matter

The vision about the role of cyclotron Bose-Einstein condensates was inspired by the effects of ELF em fields on vertebrate brain. The magnetic field strength explaining the effects was about 2 Tesla, 2/5 of the nominal value for the strength of Earth's magnetic field.

There are also other experiments have demonstrated that oscillating electromagnetic fields have effects on living matter. In particle oscillatory magnetic fields with frequency of 50 Hz and

with field strengths typically in the range .1-1 mT are used: these effects are summarized in [J24]. Even fields of order .14 Tesla are used.

It is interesting to look at the values of basic parameters associated with these fields.

1. For 50 Hz oscillation frequency the wave length λ is 6000 km to be compared with the radius of Earth which is 6371 km. If one takes seriously the notion of magnetic body this need not be an accident. I do not know how essential it is to have just 50 Hz frequency. The magnetic field is nearby oscillating dipole field (see <http://tinyurl.com/36c4pfg>) up to distances of order λ and radiation field at much longer distances. Therefore the field in question is in good approximation nearby field as far as biological body is considered. For magnetic body the radiation field could dominate
2. For the endogenous magnetic field $B_{end} = .2$ Gauss cyclotron frequencies of ions are in EEG range: Ca^{++} cyclotron frequency is 15 Hz. The scaling up to $r = .1-1$ mT means scaling of cyclotron frequencies by a factor 5 – 50. For Ca^{++} this would give frequency range 75-750 Hz. For K^+ and Cl^+ ions the frequency range would be about 35-375 Hz.
3. The magnetic length $r = \sqrt{2/eB}$ characterizing flux tube thickness for flux quantization with minimum value of flux is for $B = .05$ mTesla equal to $5 \mu m$. For the fields in the range .1-1 mTesla it is in the range $3.5 \mu m - 1.1 \mu m$. $2.5 \mu m$ corresponds to p-adic length scales $L_e(k)$ associated with Gaussian Mersenne $M_{G,k} = (1+i)^k - 1$, $k = 167$, and Gaussian Mersenne corresponding to $k = 163$ would correspond to p-adic length scale $.36 \mu m$. .14 Tesla corresponds to magnetic length of 9.4 nm rather near to cell membrane thickness of 10 nm which corresponds to p-adic length scale $L_e(151)$ assignable to Gaussian Mersenne $M_{G,151}$.

The effects of polarized light on living matter

Polarized light is known to have effects on living matter [J24]. For instance, Peter Gariaev has found that the polarized light generated by living matter sample irradiated by polarized laser light has effects on distant organism and there are even indications that genetic code might be realized in terms of radiation patterns [K102]. The quantum model for Becker currents suggest that these effects result as a modification of the voltage between the ends of magnetic flux tubes. If the flux tubes are near criticality for the generation of quantal DC currents, polarized light could be utilized both communication and control purposes whereas the acceleration in the electric fields along flux tubes would serve as a provider of metabolic energy allowing to load metabolic batteries. This process could be initiated by an electromagnetic signal inducing generation of quantal currents. The same basic mechanism could be at work also in DNA transcription, replication and other similar processes.

If the polarized low frequency radiation corresponds to a massless extremal (ME) orthogonal to the flux tube such that the polarization of the radiation is parallel to the flux tube, the voltage is affected by a contribution given by $\Delta V = Ed$, d the thickness of ME. If the flux tube is near criticality to a generation of quantal currents this change of voltage could serve as a signal inducing the generation of quantal currents.

The maximal effect is obtained for the flux tubes having direction parallel to the electric polarization so that the effect is highly selective. In the case of DNA double strand the direction of flux tube changes so that the effect would be maximal on DNAs which correspond to the same angular position on the super-coil of radius of order 10 nm formed by DNA double helix. This allows to imagine signals for which temporal variation of polarization direction means scanning of DNA.

It is known that the energy of radiation can be transformed to metabolic energy. For instance, IR light for which photons have energies of order metabolic quantum has biological effects [I28]. The mechanism could be following. Suppose that the electric field of IR photon is parallel to the flux tube which carries an electric field and is near criticality for the generation of quantal DC currents. If the direction of polarization is correct, the additional contribution to electric field induces direct current and acceleration of electrons and protons and their transfer to smaller space-time sheets and therefore loading of metabolic batteries. This could also make generation of ATP possible.

Suppose that one takes seriously the model for remote replication of DNA [K102] involving flux tubes connecting identical DNA nucleotides and that the radiation propagating along them induces quantal currents along the receiving DNA inducing replication and perhaps even transcription. The direction of polarization for the emitted radiation should be parallel to the DNA strand locally and during its travel to the target the polarization should remain orthogonal to the flux tube so that one would have what might be called polarization window. Parallel translation of the polarization vector in the induced metric suggests itself.

Support for the proposed interaction mechanism of em radiation fields with flux tubes

The basic prediction of the interaction mechanism is that the effects of em field with a given frequency occur only at the second half period when the direction of electric field is “correct”. This prediction might be testable. In fact, there is evidence for this interaction mechanism in the case of theta waves of EEG. The memory storage occurs only at the second half of the theta wave. This is discussed from different point of view in [K58].

The place coding by phase shifts was discovered by O’Reefe and Recce [J23]. In [J26, J25]. Y. Yamaguchi describes the vision in which memory formation by so called theta phase coding is essential for the emergence of intelligence. It is known that hippocampal pyramidal cells have “place property” being activated at specific “place field” position defined by an environment consisting of recognizable objects serving as landmarks. The temporal change of the percept is accompanied by a sequence of place unit activities. The theta cells exhibit change in firing phase distributions relative to the theta rhythm and the relative phase with respect to theta phase gradually increases as the rat traverses the place field. In a cell population the temporal sequence is transformed into a phase shift sequence of firing spikes of individual cells within each theta cycle.

Thus a temporal sequence of percepts is transformed into a phase shift sequence of individual spikes of neurons within each theta cycle along linear array of neurons effectively representing time axis. Essentially a time compressed representation of the original events is created bringing in mind temporal hologram. Each event (object or activity in perceptive field) is represented by a firing of one particular neuron at time τ_n measured from the beginning of the theta cycle. τ_n is obtained by scaling down the real time value t_n of the event. Note that there is some upper bound for the total duration of memory if scaling factor is constant.

One can say that neurons in ensemble provide a representation for the external world and the location of the rodent in the external world is represented as a firing of a neuron in this landscape. Besides this also temporal scaling down by a factor about ten is carried out so that actual event is represented as much shorter copies of it. Obviously this represents temporal fractality.

This scaling down - story telling - seems to be a fundamental aspect of memory. Our memories can even abstract the entire life history to a handful of important events represented as a story lasting only few seconds. This scaling down is thought to be important not only for the representation of the contextual information but also for the memory storage in the hippocampus. Hierarchy of Planck constants and phase transitions changing Planck constant make this story building possible.

The finding of Yamaguchi and collaborators relevant in the recent context is that the gradual phase shift occurs at half theta cycle whereas firings at the other half cycle show no correlation [J26]. The proposed model for the interaction of theta waves with flux tubes could explain this naturally. The relevant neural sub.system would be critical to the generation of quantal DC current only when the direction electric field of synchronizing theta wave generated by magnetic body is correct. Hence synchronous neural activity would be induced only at second half cycle of theta wave and firing would be random during the other half cycle.

D.5.3 A Model For Remote Gene Expression Based On Becker Currents

If one accepts the notion of magnetic body as intentional agent, the basic challenge is to understand how magnetic body realizes its intents as remote mental interactions on biological body. This model must of course apply also to the more conventional remote mental interactions such as remote realization of intent.

The hypothesis is that electromagnetic and possibly also other massless classical fields assignable to so called massless extremals are in a key role. Also cyclotron frequencies characteriz-

ing magnetic bodies play a key role. The vision is that magnetic flux sheets traverse many-sheeted DNA in various scales giving rise to a hierarchy of genomes and coherent gene expression in scales of cell, organelles, organism, and even population, and species. Hierarchy of Planck constants is in an essential role in realizing this hierarchy in terms of photons with energies above the thermal energy at physiological temperature and having spectrum of wavelengths coming as multiples $\lambda = n\lambda_0$, $n = \hbar/\hbar_0$.

The findings of Benveniste and followers relating to water memory and homeopathy, the recent work of group led by HIV Nobelist Luc Montagnier coupling the findings with genetics and suggesting a new nanoscale realization of genetic code [L5]), the work of the group of Popp with bio-photons identified as decay produces of large $\hbar$ photons with visible energies (in particular dark EEG photons), and the work of Peter Gariaev and collaborators supporting remote gene expression and replication discussed [K102] suggest that electromagnetic radiation is indeed involved. In the case of water memory and homeopathy the spectrum of cyclotron frequencies for the chemical invader characterizes it and induces immune response trying to eliminate it. I have also proposed a model for how genes coding for proteins eliminating the invader could be generated almost automatically: the model is based on the predicted realization of vertebrate genetic code in terms of dark proton states [K18]. DNA would like an animal which sniffs the invaders magnetic body and automatically reacts to the smell.

The discussions with Lian Sidorov and people who have realized that new era is beginning in biology have served as a driving force in the attempts to formulate in more detail TGD inspired view about how remote mental interactions - which are basic element of the model in TGD framework - might be realized. As a matter fact, I have added to my homepage a new book summarizing briefly the recent view about quantum TGD and its applications to quantum consciousness, quantum biology, to quantum neuroscience, and to remote mental interactions with some proposals for possible tests [K50]).

To start with, suppose that in the case of biological target realization of intent in the simplest situation reduces to expression of genes. This is of course a strong limitation to the type of remote mental interactions. The challenge is to develop a model for remote realization of genetic activities like replication, and transcription. For some time ago I proposed a model with Peter Gariaev [K102] but it was still too clumsy since it required too much of information transfer between the genomes of sender and receiver. Much simpler model involving only sending of simple commands initiating genetic programs suggests itself. The following proposal tries to achieve this and involves three basic ideas.

1. The idea of password and addressing is familiar from ordinary computers. Collection of frequencies as password/address allows to reach tuned targets without specific targeting of the command. This is a dramatic improvement to the previous model.
2. Password and fractal addressing realized in terms of frequencies coupling resonantly (already in the original model: I did not however realize the implications of resonant coupling!) and the hierarchy of Planck constants to realize the hierarchical addressing. I have discussed analogous addressing based on information molecules and their receptors at the biochemical level to realize magnetic flux tube connections between sender and target inside organism (hormonal action would be very analogous to what I am proposing here).
3. Becker's DC currents as supra currents flowing along DNA and activated optimally when the incoming laser light has polarization parallel to DNA's local direction, activation of super currents would mean activation of the gene. This is second new element to the original model.

In the following I discuss this with more details.

The analogy with ordinary computer

Consider first the analog of remote mental interactions for ordinary computer. Computer sends a password to the other computer and after that it can use it to run programs of the other computer. Whistling to a dog is another example: extremely simple command activates arbitrary complex programs.

In the recent case electromagnetic radiation with a given frequency coupling resonantly like radio signal to a tuned radio receiver would be the simplest command activating the target. There

would no need to specify the direction or distance of the target precisely since essentially mass communications would be in question: intent would be enough. Password could consist of several frequencies which must be received simultaneously by the target before it would activate and tunes to receive more frequencies representing simple commands - perhaps acting on the intronic portion of DNA and activating the genome to remote gene expression or something else such as activating DNAs of other cells by sending similar em addresses!

I have discussed topological quantum computer programs (see <http://tinyurl.com/y84g3tk7>) based on braiding could look like in this framework [L8]. Also here addressing but now realized as information molecule-receptor pair would play a key role.

Hierarchy of Planck constants and hierarchical addressing

Fractal hierarchy of frequencies (in Peter's experiment laser light induced generation of radiation at frequencies down to about 10 kHz) would allow to transform passwording to addressing. Very naïvely, the longest wavelengths: about 10^4 meters would reach the tuned receivers in nearly the same phase in a region of this size. One would have some subregions in tune. The shorter wavelengths would allow to pinpoint the tuned receivers inside each of these subregions and so on. This would be fractal addressing with most significant bits correspond to the longest wavelengths. Only those receivers which would be tuned to all frequencies would start to express the gene in the case of AND logic. Of course, also other Boolean functions of tuned-not tuned bits can be considered.

A good guess is that all photons correspond to the same energy of visible photon and only Planck constant varies. For ordinary value of Planck constant one would have a photon with wavelength of order size scale of single cell, and the frequencies in this range would select single gene in the genome of a particular kind of cell, say neuron within particular region of brain.

In Peter Gariaev's experiment involving 2 eV incoming red laser light the outgoing photons would have same energy but larger Planck constant so that also wavelengths would be longer and range down to at least 3×10^4 meters corresponding to radiofrequency scale of 10 kHz. What is interesting that 2 eV is 4 times the nominal value of the metabolic energy quantum of 0.5 eV identifiable as zero point kinetic energy of electron or proton for the p-adic length scale $L_e(151)$ corresponding to cell membrane thickness and Gaussian Mersenne $M_{151} = (1 + i)^{151} - 1$. Could it be that 2 eV could be preferred photon energy or is its use simply due to the unavailability of continuous frequency spectrum for laser light. And why the laser light induces the generation of the command inducing remote gene expression?

This picture conforms with Peter's experiment and with the reports of Benveniste and followers about the possibility of representing homeopathic remedy using very low frequency spectrum - presumably cyclotron frequencies - assignable to remedy. These frequencies would be addresses for genes activating genes transcribing building bricks of biomolecules of immune response eliminating the substance from the organism. The proposal could be seen as a generalization of Benveniste's observation and realization of wave DNA proposal.

DNA supra currents and activation of genes by Becker mechanism

The third building brick of the model would be quantum model for Becker currents (see <http://tinyurl.com/ybnjk9bq>) [L9] as supra currents or quantal DC currents: also this element is new. Assume - in accordance with the general vision - that these supra currents can flow also along the strands of many-sheeted DNA (flux sheets associated with the strand, entire hierarchy labelled by the values of $\hbar$). Assume also that the interaction of polarized photons addressing for genes with DNA is such that the electric fields of DNA flux tube and "massless extremal" representing laser beam superpose and charges (electrons) experience the superposition of field already present and the field of ME. If the net electric field is near criticality originally (think as analog neuronal membrane) and becomes over-critical, quantal Becker current starts to flow and the machinery responsible for gene activation is activated.

This means also the activation of metabolic machinery since the acceleration of electrons in the electric field gives them energy making possible a transfer to smaller space-time sheets where they form Cooper pair like states with negentropic entanglement. Metabolic energy corresponds to zero point kinetic energy and negentropic entanglement is relevant from the point of view

of consciousness: in the case of healing understood as a regeneration of negentropic resources this aspect is especially important. This mechanism generates high energy phosphate bonds in ATP and the decay $\text{ATP} \rightarrow \text{ADP}$ liberates the metabolic energy and destroys the negentropic entanglement possibly associated with ATP so that the second law in generalized form (see <http://tinyurl.com/yakmqhz6>) [L6] allowing local generation of genuine negentropy (but assigned to information carried by entanglement defining a quantum rule) wins after all.

It could also happen that the decay of ATP generates dark photon or photons absorbed by cyclotron condensate at magnetic flux tube. The excited state is non-local single particle excitation and involves very simple negentropic entanglement between the particles of the condensate. In this case the negentropy of ATP would be transformed to the negentropy of the magnetic flux tube or even several of them if large value of Planck constant is associated with the photon. This mechanism could allow the generation of negentropic entanglement associated with attention. The storage of metabolic energy in photosynthesis could involve similar excitation of cyclotron state at the first step. The most plausible candidate is cyclotron condensate for electron Cooper pairs. Also electrons filling state up to some Fermi energy could be in question. In this case the excitations would be excitation in longitudinal degrees of freedom of the flux tube generating current.

D.6 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 [K36].

D.6.1 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 [I20] 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 0.07 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 vision 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]

$$\gamma = 3J - \frac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = \sin^2(\theta_W) \quad (D.6.1)$$

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 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 implies $\hbar \sim 10^{13} \hbar_0$ 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 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 source- 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

$$f_\nu = \frac{m_e}{m_\nu} \frac{1}{2\sin^2(\theta_W)} f_e \quad .$$

From $f_e \simeq .57 \times \text{MHz}$ and $p = \sin^2(\theta_W) = .23$ one obtains $E_\nu = 1.7 \times 10^{-2} \text{ eV}$, 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 conclude 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 $E_\nu = .41 \text{ eV}$, 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

$$E = \sqrt{g_Z Q_Z B_Z 2\pi} \simeq .48 \text{ eV}$$

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

$$E = \sqrt{n} r^{1/2} \sqrt{g_Z Q_Z B_Z 2\pi} \simeq r^{1/2} \times .48 \text{ eV} , \quad r = \sqrt{\hbar/\hbar_0} .$$

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 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 expectation 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 [J5] 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 neutron (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

$E(Ion)/eV$	$V = -40 \text{ mV}$	$V = -60 \text{ mV}$	$V = -70 \text{ mV}$
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 D.1: Values of the Josephson energy of cell membrane for some values of the membrane voltage for $p = .23$. The value $V = -40 \text{ mV}$ corresponds to the resting potential for photoreceptors and $V = -70 \text{ mV}$ to the resting state of a typical neuron.

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

$$\begin{aligned} \left(\frac{Z - N}{4} - pZ \right) Z^0 + q_{em} \gamma &= Q_{eff} \gamma, \\ Q_{eff} &= -\frac{Z - N}{2p} + 2Z + q_{em}. \end{aligned} \quad (D.6.2)$$

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 D.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.

D.6.2 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 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 wavelength 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 [J3, J5]. 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 D.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 [J5] 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 D.2**.

1. The resting potential for photoreceptors is $V = -40$ mV [J7]. 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^+ correspond to the peak energies for cones 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 [J7], 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.

Ion	Na^+	Cl^-	K^+	Ca^{++}
$E_J(.04 \text{ mV}, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065 \text{ V}, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40 \text{ mV}, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50 \text{ mV}, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55 \text{ mV}, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65 \text{ mV}, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70 \text{ mV}, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75 \text{ mV}, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80 \text{ mV}, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90 \text{ mV}, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95 \text{ mV}, p = .0295)/eV$	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 D.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.

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 D.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

$Na^+ \leftrightarrow 2.19 \text{ eV (R) and } eV = 86.8 \text{ eV,}$
 $Cl^- \leftrightarrow 2.32 \text{ eV (G) and } eV = 65.8 \text{ eV,}$
 $K^+ \leftrightarrow 2.49 \text{ eV (W) and } eV = 60.2 \text{ eV,}$
 $Ca^{++} \leftrightarrow 3.06 \text{ eV (B) and } eV = 67.3 \text{ meV.}$

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 $E_J = .04 \text{ eV}$ 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 $E_J = V_{rest}/2p = 2.086 \times V_{rest}$.

D.6.3 Water Electric As Protocell

Ulla Matfolk sent to me some interesting material at the web page of Dr. Mae-Wan Ho which provides further insights into the model of cell. The articles are “Water electric” [D80] and “Making Fuel from Water” [D78]. The articles summarize an experimental discovery which could be called Pollack-Zheng effect [D101, D84]. Both articles relate closely to what might be called the holy grail of artificial photosynthesis. The unreasonable effectiveness of photosynthesis in the sense that the waste of energy during the process is extremely small, makes artificial photosynthesis an excellent candidate for the final solution of energy problems as far energy sources and minimization of wastes are considered. In the following I comment only the first paper in detail from TGD viewpoint.

How photosynthesis manages to be so effective is one of the mysteries of biology. TGD based view about metabolic energy involves two ideas.

1. TGD predicts a hierarchy of metabolic energy quanta [K4, K20]. The basic quanta come as $E(k) = 2^k E_0$, where k is positive or negative integer and $E_0 \simeq .5 \text{ eV}$ holds true. For instance, 2 eV metabolic energy quantum corresponding to red light corresponds to $k = 3$. This is actually oversimplification since there is a cascade of quanta $E(k, n) = (1 - 2 < sup > - n < /sup >)E(k)$ converging to $E(k)$ for each p-adic length scale. These energies correspond to

energies liberated when electron or proton drops to a larger space-time sheet at the limit when second space-time becomes very large and the particle starts from rest and remains to rest: this is second idealization as also the particle in a box geometry. The idea is that these universal metabolic energy quanta preceded the metabolism based on chemical storage of energy and that the primary step in photosynthesis is kicking of proton or electron to a smaller space-time sheet.

2. Second idea relies on the hierarchy of Planck constants.

- (a) The rate of dissipation - that this the energy wasted per unit time - is inversely proportional to $\hbar$ in the first naïve guess and means that macroscopically quantum coherent dark matter dissipates very little. Could photon kick charged dark particles to smaller space-time sheet where they dissipate very little? Or could photosynthesis capture ordinary or dark photons of sunlight to some layer of the onion like structure formed by the magnetic body of the organism, where it kicks particles to smaller space-time sheets. This light could correspond to bio-photons liberated as the biological body of the organism dies.
- (b) Could this storage of photons have preceded chemical storage of energy in living matter? And could this energy reserve explain some rather mysterious findings about the ability of some people to survive without ordinary metabolic energy feed (usually saints and this kind of people telling that light is enough for them to survive. Also animals are capable to these metabolic miracles [I7] : see the article “Researchers Seek to Demystify the Metabolic Magic of Sled Dogs” in Science. Of course, the storage of energy to that of dark matter or dark photons confined to the net defined by magnetic flux tubes could be the eventual manner to avoid energy waste and associated entropy growth inducing environmental problems. Hierarchy of Planck constants would allow the storage in arbitrary long length scales for given energy of photon so that even a community of organisms could have collective metabolic energy resources: maybe synergy has something to do with this.

The first article summarizing the Pollack-Zheng effect gives quantitative support for this picture. I have formatted the text as comments to the summary represented in the article of Mae-Wan Ho [D80].

Exclusion zones

The article summarizes the sequence of events initiated by the discovery of Gerald Pollack and his student Jian-ming Zheng [D101, D84]. As a matter fact, the fascinating findings described in detail by Gerald Pollack in his book were absolutely crucial for the recent TGD based view about quantum biology in which dark matter plays key role.

1. Pollack and his student discovered that suspensions of colloids and dissolved substances are excluded from a region extending some hundreds of micrometres from the surfaces of hydrophilic gels. An “exclusion zone” (EZ) of this magnitude conflicts the belief that interfacial water forming at liquid-solid, or liquid-air interfaces can be no more than a few layers of molecules thick. What’s observed is a million layers or more! “Exclusion” means that the water suspension of micro-spheres moved away from the surface of gel with constant velocity and behaving like single structural unit.

Comment: The sizes of cells vary up to hundreds of micrometers and cells are by definition structures which are isolated from the environment. Maybe EZs represent protocells or their predecessors. Pollack and coauthors have indeed proposed that their finding might relate to the origin of life [D84]. That the surface was that of gel might be important. In TGD based model of living matter gels have magnetic bodies and their presence might relate to the formation of the thick water layer in non-standard phase.

2. Similar exclusion zones were found next to any hydrophilic surface including surfaces coated with a monolayer of hydrophilic molecules, and around ion exchange resin beads. Electric charge appears to be important, as EZ failed to form around charge-exhausted resin beads.

Although EZ can form in pure water, it is enhanced and stabilized by low concentrations of buffer (2 to 10 mM at pH 7).

Comment: Hydrophily could correspond to the formation of magnetic flux tubes connecting the hydrophilic surface to water molecules as assumed in the model of protein folding and bio-catalysis [K61].

3. The EZ phase is very different from the bulk water. An unusually ordered crystalline phase where the molecules are less free to move is suggestive. The UV and visible absorption spectrum gave a single absorption peak at $\lambda \simeq 270$ nm in the UV region completely absent in the bulk phase. The infrared emission record showed that the EZ radiates very little compared with bulk water, as would be expected on account of the reduced mobility of water molecules. The magnetic resonance imaging mapping similarly gave a transverse relaxation time (T2) of 25.4 ± 1 ms, which is shorter than the 27.1 ± 0.4 ms recorded for the bulk water phase, again indicative of restricted motion.

Comment: The reduced radiation might mean that part of photons are dark and bound inside magnetic flux tubes defining a structure responsible for the formation of gel like phases inside cell and perhaps also inside EZ. The interpretation as bio-photons is suggestive. This phase of water could be predecessor of the water in cell interior since in the crystalline phase long bio polymers like DNA and amino-acid sequences would be stable against hydration.

4. EZ had a different electrical potential from the bulk phase, by as much as 100–200 mV, depending on the hydrophilic surface. With a negatively charged surface such as polyacrylic acid or Nafion (widely used as a proton exchange membrane), the potential is negative compared with the bulk water away from the EZ. Simultaneously, the hydrogen ion (proton, H^+) concentration is high just outside the EZ, decreasing in a gradient away from it. This indicates that the formation of the EZ is accompanied by a separation of positive and negative electrical charges, which led to the build up of electrical potential between the EZ and the bulk water. In effect, the water has become an electrical battery, and can provide electricity through an external circuit.

Comment: Cell membrane is also a battery and the potential is around 50-80 mV to be compared with 100–200 mV, and the size scale of cell varies from 5 micrometer to hundreds of micrometers so that EZs could be involved with the formation of cell and cell membranes. The kicking of electrons or protons to smaller space-time sheet could be the mechanism inducing electric potential at a given space-time sheet. The formation of battery would mean that water could some day used to store very effectively the energy of solar radiation.

A connection with photosynthesis

Separating H^+ from e^- (electron) is the first step of photosynthesis in green plants which provides energy for most of the biosphere. In this case the energy comes from solar radiation. The separation of charges requires energy also in the case of EZ and the question is where this energy comes from in the case of EZ.

1. A clue came after having inadvertently left the experimental chamber with the EZ on the microscope overnight. Next morning, the EZ had shrunk considerably. But after turning on the microscope lamp, it began to immediately grow again, restoring itself within minutes to its former size. The energy for EZ formation comes from light, as in photosynthesis, but it can use the low energy part of the solar spectrum that photosynthesis cannot.

Comment: Could one consider the possibility that photosynthesis involves unknown step and this step is just the kicking of electrons or protons to a smaller space-time sheet. This step would also induce the separation of charges and the generation of electric potential.

2. Although the entire spectrum of visible light appeared effective in making the EZ grow, the most effective part is in the infrared region, peaking at $\lambda \simeq 3100$ nm. A 10 minute exposure at that wavelength expanded the width of an EZ 3.7 times, and after an hour of exposure, the expansion was more than 6 times. After the light was turned off, the EZ remained constant

for about 30 minutes before beginning to shrink, reaching halfway to its baseline level in about 15 minutes.

Comment: $\lambda = 3100$ nm corresponds to .4 eV. The nominal value of the fundamental metabolic energy quantum is around $E_0 = .5$ eV and one has $E(k = 0, n = 3) = 0.4375$ eV for this value of E_0 . Perhaps the photons indeed kick electrons or protons to a smaller space-time sheet.

- (a) In the case of protons the smaller space-time sheet would correspond to atomic space-time sheets characterized by $p \simeq 2^{137}$: the larger one would correspond to $k = 141$.
 - (b) For electrons the size of the smaller space-time sheet would be by a factor $m_p/m_e = 940/.5 = 1880 \simeq 2^{11}$ larger and would correspond to $k = 137 + 11 = 148$. This served as one motivation for the original $\hbar/\hbar_0 = 2^{11k}$ hypothesis for the preferred values of Planck constant. This is one half of the thickness of the lipid layer of cell membrane. The larger space-time sheet would correspond to cell membrane thickness $L(151) = 10$ nm and perhaps the dark space-time sheet serving as a template for the formation of the cell membrane! If $E = .4$ eV corresponds to electron, then proton would correspond to $E(0, 3) = .44$ eV giving for the metabolic energy quantum the value $E_0(p) = 0.5029$ eV in the case of proton and $E_0(e) = 0.4616$ eV in the case of electron.
3. When the UV and visible range was tested, a peak in the degree of EZ expansion was detected at $\lambda = 270$ nm in the UV region, corresponding to the characteristic absorption peak of EZ that was identified before. However, as the optical power used in the UV and visible region was 600 times that in the IR, the most profound effect was identified in the IR region, particularly at 3 100 nm.

Comment: $\lambda = 270$ nm corresponds to the energy 4.5926 eV. $E = 4$ eV is the nearest metabolic energy quantum. This energy does not correspond directly to any metabolic energy quantum assignable to .4 eV or .43 eV. One must be however cautious with conclusions since the model is very rough.

4. The mechanism of EZ formation is still unknown. But the two wavelengths that expand the EZ most effectively may offer some hint. The UV wavelength 270 nm is close to the 250 nm ($\simeq 5$ eV) required to ionize water under standard state conditions and taking into account the hydration of the resulting ions. The 3 100 nm peak, on the other hand is close to the OH stretch of the ring hexamer identified as the most abundant species in infrared predissociation spectroscopy of large water clusters, and also in neon matrices by infrared spectroscopy. These results suggest that photoexcitation of ring hexamers and photoionisation followed by ejection of protons play synergistic roles in the assembly of the EZ phase. Pollack and colleagues believe that the infrared radiation, though normally insufficient to break OH bonds, can nevertheless work via resonance induced dissociation of large hydrogen-bonded networks.

Comment: Ring hexamers bring in mind the crucial role of aromatic cycles in TGD inspired model of DNA as topological quantum computer which leads also to a model of $ADP \leftrightarrow ATP$ transition involving reconnection of magnetic flux tubes and having also information theoretic interpretation as a change of the topology of the braid structure defining topological quantum computer program [K58]. Magnetic flux tubes carrying dark electrons begin from these and can end up to other bio-molecules or water. Just a guess: could they end on ring hexamers?

Summary

The findings suggest additional details to the TGD based view about living matter.

1. The kicking of electrons or protons or both of them to a larger space-time sheet would be the first step in photosynthesis as I indeed suggested for years ago. The energy of 3100 nm photons indeed corresponds to that for the fundamental metabolic energy quantum. I have also proposed this process to be a fundamental step also in bio-catalysis: the temporary dropping of electron or proton of the catalyst molecule could provide the energy helping the reacting molecules to overcome the potential wall preventing the reaction from running. This

metabolic coin could be returned to catalyst with high enough probability or the photons exchanged could be virtual.

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 $\hbar_{eff}$ so that cyclotron energy would be liberated.

2. The findings suggest also a mechanism for how solar radiation generates proto cells or their predecessors. The resulting phases of water have size extending to those for largest cells and the water could involve a gel like phase in which magnetic flux tubes containing dark matter could play a key role and eventually lead to quantum computer like behavior [K58]. The kicking of electrons (or protons) to smaller space-time sheet would induce ionization at given space-time sheet so that electric potential difference would result. The magnitude of the potential difference is of a correct order of magnitude. Cell membrane scale is present as a p-adic length scale for the space-time sheet of electrons before the kicking to the smaller space-time sheet and these space-time sheets could act as templates for the formation of cell membrane.
3. Interestingly, TGD based model of high T_c super conductivity predicts that both cell membrane length scale and size scale of cell are involved with the super-conductivity [K8]. Cell membrane acts as a Josephson junction in TGD based model of cell membrane, nerve pulse, and EEG.

D.7 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.

D.7.1 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 [L14].

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 $H_{1.5}O$. 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 [H4, 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 [H4, 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...

D.7.2 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 $H_{1.5}O$ blob. The model for the proto-variants of photosynthesis and metabolism remain as such. Also now genetic code would be realized [K18, 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 multiples of cyclotron frequency: this prediction is consistent with that in the original model for the findings of Blackman and others [J11].

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 [H4, 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).

D.7.3 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 $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2(g) + 6H_2O(l) + \text{heat}$ 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.

$$i\hbar_1 \frac{\partial \Psi_1}{\partial t} = ZeV\Psi_1 + k_1\Psi_2 \quad ,$$

$$i\hbar_2 \frac{\partial \Psi_2}{\partial t} = k_2\Psi_1 \quad .$$

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 $\Phi_1 = eVt/h_{eff}$. This gives

$$R_2(t) = \sin(\Phi_0) + \frac{k_1}{\hbar_1} \sin\left(\frac{eVt}{\hbar_1}\right) \quad .$$

R_2 oscillates around $\sin(\Phi_0)$ and the concentration difference is coded by Φ_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:

$$R = \sin(\phi_0) = \exp\left(\frac{ZeV(t)}{2T}\right) .$$

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 $\hbar_{eff}$ 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 $\hbar_{eff}$ and B_{end} . The scales of ionic chemical potential and ion concentrations would also depend on value of $\hbar_{eff}$.
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 [K15] 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 Weinberg 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 $\hbar_{eff} = n \times h$ to h .

In the modified model the sum $f_c + f_{J,n}$ ($f_{J,n} = E_J/n \times h$) of $\hbar_{eff}$ -independent cyclotron frequency and Josephson frequency proportional to $1/\hbar_{eff}$ 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

$$\frac{\Delta f}{f} \simeq \frac{2f_{J,n}}{f_c + f_{J,n}} = \frac{2f_{J,1}}{nf_c + f_{J,1}} .$$

If dark photons correspond to biophotons the energy of cyclotron photon is in visible and UV range one has $nf_c = E_{bio}$ and

$$\frac{\Delta f}{f} \simeq \frac{2ZeV}{E_{bio} + ZeV} .$$

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 equilibrium 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 [K91] explaining anomalously large gravimagnetic effect claimed by Tajmar et al [E2, E4] 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 three 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 $h_{em} = Z_1 Z_2 e^2 / v_0$ 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 $h_{eff} = h_{em} = Z^2 e^2 / v_0$.
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 [K21] 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.

$h_{eff}(ATP\text{synthase}) = h_{gr}(2e, \text{Earth})$ would make possible reconnection of electromagnetic flux tubes with gravimagnetic flux tubes [K34].

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>) [?]eorting 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 [K18, 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.

D.7.4 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 electrodes. 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/8xqsab>) consists 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 electrochemical 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 electrolytic 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 exceeds the energy needed for ionization and the situation becomes more stable.

5. This model could also allow to understand the effect of anesthetes [K49] [L20]. 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 anesthetic correlates with its solubility to the lipid membrane. This is the case if the presence of anesthetic 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 [K36]. 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.

D.8 Implications Of Strong Gravimagnetism For TGD Inspired Quantum Biology

Physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity [E2]. If the findings are replicable they mean a revolution in the science of gravity and, as one might hope, force a long-awaited serious reconsideration of the basic assumptions of the dominating super-string approach.

Tajmar et al have proposed [E4] the gravimagnetic effect as an explanation of an anomaly related to the superconductors. The measured value of the mass of the Cooper pair is slightly larger than the sum of masses whereas theory predicts that it should be smaller. The explanation would be that actual London field is larger than it should be because of gravimagnetic contribution to quantization rule used to deduce the value of London field.

TGD explanation of the discrepancy accepting the theory of Tajmar et al comes from the proposal inspired by Nottale's observations [E1] suggesting that Bohr's rules apply in planetary system with Planck constant replaced by $\hbar_{gr} = GMm/v_0$. Here M and m are the masses of Sun and planet. $v_0/c \simeq 2^{-11}$ holds true for the 3 inner planets and $v_0 \rightarrow v_0/5$ for the outer planets. The rotation velocities of the planets are related to v_0 by Bohr rules. $\hbar_{gr}$ clearly characterizes the pair Sun-planet rather than being fundamental constant whereas the gravitational Compton length GM/v_0 depends on M only. In TGD framework one assigns gravitational Planck constant to the flux tube connecting the masses and along which the gravitational massless extremals mediating the gravitational interaction are mediated. By Equivalence Principle it is possible to apply the hypothesis only in elementary particle length scales (this does not exclude its application in longer scales) and in these scales $\hbar_{eff} = \hbar_{gr}$ makes sense.

Gravimagnetic London field is proportional to the square of Planck constant and the obvious guess is that the replacement $\hbar$ with $\hbar_{gr}$ could explain the enormous discrepancy with GRT if gravimagnetism is in question. This predicts correctly the magnitude of the effect and one also ends up with the identification of the $\hbar_{gr} = \hbar_{eff}$ in elementary particle scales.

Also a vision about the fundamental role of quantum gravitation in living matter emerges. The earlier hypothesis that dark EEG photons decay to biophotons with energies in visible and ultraviolet range [K52, K51] receives strong quantitative support. This leads also to a simple model for how magnetic bodies control molecular transitions via dark cyclotron radiation with varying frequencies vary but universal energy spectrum since for a given magnetic field all charged particles gives rise to biophotons with same energy. The values of $\hbar_{gr}/m$ and endogenous magnetic field $B_{end} \simeq .2$ Gauss are such that the spectrum of biophotons is in the range of molecular binding energies. This vision would conform with Penrose intuitions about the fundamental role of gravitation in quantum biology.

D.8.1 The Theory of Tajmar et al for the Anomaly of Cooper Pairs Mass

The starting point of the theory of Tajmar and Matos [E4] is the so called London magnetic moment generated in rotating charged super-conductors adding a constant contribution to the exponentially damped Meissner contribution to the magnetic field. This contribution can be understood as being due to the massivation of photons in super-conductors. The modified Maxwell equations are obtained by just adding scalar potential mass term to Gauss law and vector potential mass term to the equation related the curl of the magnetic field to the em current.

The expression for the London magnetic field is given by

$$B = 2\omega_R n_s \times \lambda_\gamma^2, \quad (D.8.1)$$

where ω_R is the angular velocity of superconductor, n_s is charge density of super-conducting particles and $\lambda_\gamma = \hbar/m_\gamma$ is the wave length of a massive photon at rest. In the case of ordinary superconductor one has $\lambda_\gamma = \sqrt{m^*/q^*n_s}$, where $m^* \simeq 2m_e$ and $q^* = -2e$ are the mass and charge of Cooper pair. Hence one has

$$B = -2 \frac{m^*}{2e} \omega_R. \quad (D.8.2)$$

Magnetic field extends also outside the super-conductor and by measuring it with a sufficient accuracy outside the super-conductor one can determine the value of the electron mass. Instead of the theoretical value $m^*/2m_e = .999992$ which is smaller than one due to the binding energy of the Cooper pair the value $m^*/2m_e = 1.000084$ was found by Tate [E3]. This inspired the theoretical work generalizing the notion of London field to gravimagnetism and the attempt to explain the anomaly in terms of the effects caused by the gravimagnetic field.

Note that in the case of ordinary matter the equations would lead to an inconsistency at the limit $m_\gamma = 0$ since the value of London magnetic field would become infinite. The resolution of the problem proposed in [E4] is based on the replacement of rotation frequency ω with electron's spin precession frequency $\omega_L = -eB/2m$ so that the consistency equation becomes $B = -B = 0$ for a unique choice $1/\lambda_\gamma^2 = -\frac{q}{m}n$. One could also consider the replacement of ω with electron's cyclotron frequency $\omega_c = 2\omega_L$. To my opinion there is no need to assume that the modified Maxwell's equations hold true in the case of ordinary matter.

Gravimagnetic field

The perturbative approach to the Einstein equations leads to equations, which are essentially identical with Maxwell's equations. The g_{tt} component of the metric plays the role of scalar potential and the components g_{ti} define gravitational vector potential. Also the generalization to the super-conducting situation in which graviphotons develop a mass is straightforward. Just add the scalar potential mass term to the counterpart of Gauss law and vector potential mass term to the equation relating the curl of the gravimagnetic field to the gravitational mass current.

In the case of a rotating superconductor London magnetic field is replaced with its gravimagnetic counterpart

$$B_{gr} = -2\omega_R \rho_m \lambda_{gr}^2. \quad (D.8.3)$$

Obviously this formula would give rise to huge gravimagnetic fields in ordinary matter approaching infinite values at the limit of vanishing gravitational mass. Needless to say, these kind of fields have not been observed.

Equivalence Principle however suggests that the gravimagnetic field must be assigned with the rotating coordinate frame of the super-conductor. Equivalence principle would state that seeing the things in a rotating reference frame is equivalent of being in a gravimagnetic field $B_{gr} = -2\omega_R$ in the rest frame. This fixes the graviphoton mass to

$$\frac{1}{\lambda_{gr}^2} = \left(\frac{m_{gr}}{\hbar}\right)^2 = G\rho_m. \quad (D.8.4)$$

For a typical condensed matter density parameterized as $\rho_m = Nm_p/a^3$, $a = 10^{-10}$ m this gives the order of magnitude estimate $m_{gr} \sim N^{1/2}10^{-21}/a$ so that graviton mass would be extremely small.

If this is all what is involved, gravimagnetic field should have no special effects. In [E4] it is however proposed that in superconductors a small breaking of Equivalence Principle occurs. The basic assumptions are following.

1. Super-conducting phase and the entire system obey separately the gravitational analogs of Maxwell field equations.
2. The ad hoc assumption is that for super-conducting phase the sign of the gravimagnetic field is opposite to that for the ordinary matter. If purely kinematic effect were in question so that graviphotons were pure gauge degrees of freedom, the value of m_{gr}^2 should be proportional to ρ_m and $\rho_m - \rho_m^*$ respectively.
3. Graviphoton mass is same for both ordinary and super-conducting matter and corresponds to the net density ρ_m of matter. This is essential for obtaining the breaking of Equivalence Principle.

With these assumptions the gravimagnetic field giving rise to acceleration field detected in the rest system would be given by

$$B_{gr}^* = \frac{\rho_m^*}{\rho} \times 2\omega \quad (D.8.5)$$

This is claimed to give rise to a genuine acceleration field

$$g^* = -\frac{\rho_m^*}{\rho} a \quad (D.8.6)$$

where a is the radial acceleration due to the rotational motion.

Explanation for the too high value of measured electron mass in terms of gravimagnetic field

A possible explanation of the anomalous value of the measured electron mass [E3] is in terms of gravimagnetic field affecting the flux Bohr quantization condition for electrons by adding to the electromagnetic vector potential term $q^* A_{em}$ gravitational vector potential $m^* A_{gr}$. By requiring that the quantization condition

$$\oint (m^* v + q^* A_{em} + m^* A_{gr}) dl = 0 \quad (D.8.7)$$

is satisfied for the superconducting ring, one obtains

$$B = -\frac{2m}{e}\omega - \frac{m}{e}B_{gr} \quad (D.8.8)$$

This means that the magnetic field is slightly stronger than predicted and it has been known that this is indeed the case experimentally.

The higher value of the magnetic field could explain the slightly too high value of electron mass as determined from the magnetic field. This gives

$$B_{gr} = \frac{\Delta m_e}{m_e} \times 2\omega = \frac{\Delta m_e}{m_e} \times e m_e \times B \quad (D.8.9)$$

The measurement implies $\Delta m_e/m_e = 9.2 \times 10^{-5}$. The model discussed in [E4] predicts $\Delta m_e/m_e \sim \rho^*/\rho$. The prediction is about 23 times smaller than the experimental result.

D.8.2 Is The Large Gravimagnetic Field Possible In TGD Framework?

TGD allows to consider several alternative solutions for the claimed effect.

Many-sheeted space-time could be an essential part of the effect (if real!).

1. In TGD framework both induced metric and various gauge fields are expressible in terms of CP_2 coordinates and their gradients. Hence the gravimagnetic field would be very probably accompanied by an ordinary magnetic field and could be even proportional to it.
2. The ordinary London magnetic field could be accompanied by analogous magnetic field at different space-time sheet playing the same role as gravimagnetic field in the proposed model. Cooper pair would experience both fields by forming topological sum contacts to both space-time sheets carrying ordinary London magnetic field $B = m_e/ew_R$ and much smaller London magnetic field $\Delta B = \Delta m/ew_R$? There would be no need to introduce gravitation but one should explain why the value of the parameter $\epsilon = \Delta m_e/m_e$ is what it is.
3. In many-sheeted space the gravimagnetic field and accompanying magnetic field would be associated with the flux tubes mediating gravitational interaction with dark matter fraction of Earth's mass. It would not be surprising if the size of the parameter ϵ might be determined by this fraction. Pioneer and Flyby effects [K88] allow to make a rough estimate for the size of this fraction and the outcome is about 2×10^{-4} which is not far from $\epsilon \cdot 9 \times 10^{-4}$.

An alternative explanation is that the experiments probe single space-time sheet and that also other Z^0 magnetic field contributes below weak scale which is scaled up for $h_{eff} = n \times h$ and can be macroscopic.

1. TGD predicts the possibility of classical electro-weak fields at larger space-time sheets. If these couple to Cooper pairs generate exotic weak charge at super-conducting space-time sheets the Bohr quantization conditions modify the value of the magnetic field. Exotic weak charge would however mean also exotic electronic em charge so that this option is excluded. It would also require that the Z^0 charge of test bodies used to measure the acceleration field is proportional to their gravitational mass.
2. According to the simplest recent view about Kähler-Dirac action [K45] the modes of Dirac operator are confined to 2-D string world sheets at which classical W boson fields vanish. This guarantees that em charge is well-defined for the modes. The stronger condition that also classical Z^0 field vanishes makes also sense and should hold at least in the length scales in which weak bosons do not appear. This guarantees the absence of axial couplings and parity breaking effects. In living matter parity breaking effects are large and one could consider the possibility that weak length scale is scaled up for $h_{eff} > h$ and that classical Z^0 fields are present below the weak scale.
3. One cannot exclude the possibility that the classical weak fields vanish for entire space-time surface. In this case spinor modes can still be seen as continuous superpositions of 2-D ones. In principle one can consider also other options - such as vanishing of induced Kähler form or classical em field besides that of W fields.

The conservative option is that classical weak fields vanish in the situation considered so that there is room for the strong gravimagnetic field. The following model starts from the model of Tajmar et al and generalizes it by replacing Planck constant with its gravitational counterpart.

Modification of the model of Tajmar et al by replacing h with h_{gr}

Gravimagnetic London field is proportional to the square of Planck constant and the obvious guess is that the replacement h with h_{gr} could explain the enormous discrepancy with GRT if gravimagnetism is in question. This predicts correctly the magnitude of the effect and one also ends up with the identification of the $h_{gr} = h_{eff}$ in elementary particle scales.

One can of course develop an objection against the gravimagnetic field proportional h_{eff}^2 : also ordinary London magnetic field should be scaled in the same manner due to the proportionality to λ_γ^2 . The resulting magnetic field would be enormous. One can however argue that the increase

of Planck constant cannot affect the value of the ordinary London magnetic field. The scaling up of length scales by h_{eff} and flux conservation suggest that the value of B scales down like $1/h_{eff}^2$. This factor is compensated by the h_{eff}^2 factor in the expression of London magnetic field coming from the expression of magnetic penetration length in terms of mass of photon. One can of course ask why magnetic and gravimagnetic London field are different.

1. The formula used by Tajmar et al [E4] for the gravimagnetic variant of London magnetic field is direct generalization for the London field for ordinary super-conductor. The gravimagnetic field is proportional to the product $B_g = \omega_R r^2$ of the rotation frequency ω_R of super-conductor and square of the ratio $r = (\lambda_g/\lambda_{g,T})$, where $\lambda_g = \hbar/m_g$ is graviton wave length and $\lambda_{g,T}$ is gravimagnetic penetration length obtained as generalization of the magnetic penetration length for super-conductors by replacing charge with mass. The latter is purely classical quantity whereas graviton wave length depends on Planck constant. Graviton mass can be argued to result in gravitational Meissner effect and can be estimated from the value of cosmological constant Λ being essentially its square root. The resulting value of B_g is too small by 28 orders of magnitude.
2. Tajmar et al [E4] suggests that graviton mass is larger by a factor of order 10^{14} in conflict with the experimental upper bound of order 10^{55} kg for m_g . TGD proposal is that it is Planck constant which should be replaced with effective Planck constant $h_{eff} = nh$ equal to gravitational Planck constant h_{gr} for electron Cooper pair in Earth's gravitational field. The model for planetary orbits as Bohr orbits together with Equivalence Principle implies $h_{gr} = GMm/v_0$ at flux tubes connecting particle with mass m to Sun with mass M . v_0 has dimensions of velocity and has order of magnitude correlating with a typical rotation velocity of planetary orbit by Bohr quantization rules.
3. In the recent case the rotation velocity v_0 is the rotation velocity of Earth at its surface: $v_0(E)/c = 2.16 \times 10^{-6}$ to be compared with $v_0(S)/c \simeq .5 \times 10^{-3}$ for Sun-Earth system. The scaling of λ_g is given by $h_{gr}(E, pair)/h = (h_{gr,S, pair}/h) \times (M_E/M_S) \times v_0(S)/v_0(E)$. This gives

$$r \equiv \frac{h_{gr,S, pair}}{h} = \frac{\lambda(h_{gr,S, pair})}{\lambda(h, pair)} = \frac{\frac{GM}{v_0(S)}}{\lambda_c(pair)} = \frac{\frac{r_S}{v_0(S)}}{\lambda_c(e)} .$$

Using $r_S = 3km$ and $\lambda_e = .243 \times 10^{-12}$ m and $v_0(S) \simeq 2^{-11}$, $M_E/M_S = 3.0 \times 10^{-6}$ one obtains $r \simeq 3.6 \times 10^{14}$. This happens to be correct order of magnitude! Maybe the model might have something to do with reality. Even better, also the value of h_{eff} is consistent with its value spectrum appearing in EEG if one requires that the energy of dark EEG photon with frequency of order 10 Hz is that of biophoton with frequency of about 5×10^{14} Hz. If this picture is correct the values of $h_{eff} = h_{gr}$ would come as proportional to the masses of particles and cyclotron energies proportional to $h_e B/m$ would not depend on the mass of the particle at all.

4. What is nice that the model unifies the notions of gravitational Planck constant and dark Planck constant. The basic observation is that Equivalence Principle allows to understand the effects of h_{gr} by reducing it to elementary particle level interpreted in terms of flux tubes connecting particle to the bigger system. This allows to avoid gigantic values of h_{gr} and gives connection with TGD inspired quantum biology. The new quantum physics associated with gravitation would also become key part of quantum biology.

Could $h_{gr} = h_{eff}$ hold true?

The obvious question is whether the gravitational Planck constant deduced from the Nottale's considerations and the effective Planck constant $h_{eff} = nh$ deduced from ELF effects on vertebrate brain and explained in terms of non-determinism of Kähler action could be identical. At first this seems to be non-sensical idea since $h_{gr} = GMm/v_0$ has gigantic value.

It is however essential to realize that by Equivalence Principle one describe gravitational interaction by reducing it to elementary particle level. For instance, gravitational Compton lengths

do not depend at all on the masses of particles. Also the radii of the planetary orbits are independent of the mass of particle mass in accordance with Equivalence Principle. For elementary particles the values of h_{gr} are in the same range as in quantum biological applications. Typically 10 Hz ELF radiation should correspond to energy $E = h_{eff}f$ of UV photon if one assumes that dark ELF photons have energies of biophotons and transform to them. The order of magnitude for n would be therefore $n \simeq 10^{14}$.

The experiments of M. Tajmar et al [E2, E4] discussed in [K91] provide a support for this picture. The value of gravimagnetic field needed to explain the findings is 28 orders of magnitude higher than theoretical value if one extrapolates the model of Meissner effect to gravimagnetic context. The amazing finding is that if one replaces Planck constant in the formula of gravimagnetic field with h_{gr} associated with Earth-Cooper pair system and assumes that the velocity parameter v_0 appearing in it corresponds to the Earth's rotation velocity around its axis, one obtains correct order of magnitude for the effect requiring $r \simeq 3.6 \times 10^{14}$.

The most important implications are in quantum biology and Penrose's vision about importance of quantum gravitation in biology might be correct.

1. This result allows by Equivalence Principle the identification $h_{gr} = h_{eff}$ at elementary particle level at least so that the two views about hierarchy of Planck constants would be equivalent. If the identification holds true for larger units it requires that space-time sheet identifiable as quantum correlates for physical systems are macroscopically quantum coherent and gravitation causes this. If the values of Planck constant are really additive, the number of parallel space-time sheets corresponding to non-determinism evolution for the flux tube connecting systems with masses M and m is proportional to the masses M and m using Planck mass as unit. Information theoretic interpretation is suggestive since hierarchy of Planck constants is assumed to relate to negentropic entanglement very closely in turn providing physical correlate for the notions of rule and concept.
2. That gravity would be fundamental for macroscopic quantum coherence would not be surprising since by EP all particles experience same acceleration in constant gravitational field, which therefore has tendency to create coherence unlike other basic interactions. This in principle allows to consider hierarchy in which the integers $h_{gr,i}$ are additive but give rise to the same universal dark Compton length.
3. The model for quantum biology relying on the notions of magnetic body and dark matter as hierarchy of phases with $h_{eff} = n \times h$, and biophotons [K52, K51] identified as decay products of dark photons. The assumption $h_{gr} \propto m$ becomes highly predictable since cyclotron frequencies would be independent of the mass of the ion.
 - (a) If dark photons with cyclotron frequencies decay to biophotons, one can conclude that biophoton spectrum reflects the spectrum of endogenous magnetic field strengths. In the model of EEG [K13] it has been indeed assumed that this kind spectrum is there: the inspiration came from music metaphors suggesting that musical scales are realized in terms of values of magnetic field strength. The new quantum physics associated with gravitation would also become key part of quantum biophysics in TGD Universe.
 - (b) For the proposed value of h_{gr} 1 Hz cyclotron frequency associated to DNA sequences would correspond to ordinary photon frequency $f = 3.6 \times 10^{14}$ Hz and energy 1.2 eV just at the lower limit of visible frequencies. For 10 Hz alpha band the energy would be 12 eV in UV. This plus the fact that molecular energies are in eV range suggests very simple realization of biochemical control by magnetic body. Each ion has its own cyclotron frequency but same energy for the corresponding biophoton.
 - (c) Biophoton with a given energy would activate transitions in specific bio-molecules or atoms: ionization energies for atoms except hydrogen have lower bound about 5 eV (<http://tinyurl.com/233vcad>). The energies of molecular bonds are in the range 2-10 eV (<http://tinyurl.com/bfsy4ft>). If one replaces v_0 with $2v_0$ in the estimate, DNA corresponds to 62 eV photon with energy of order metabolic energy currency and alpha band corresponds to 6 eV energy in the molecular region and also in the region of ionization energies.

Each ion at its specific magnetic flux tubes with characteristic palette of magnetic field strengths would resonantly excite some set of biomolecules. This conforms with the earlier vision about dark photon frequencies as passwords.

It could be also that biologically important ions take care of their ionization self. This would be achieved if the magnetic field strength associated with their flux tubes is such that dark cyclotron energy equals to ionization energy. EEG bands labelled by magnetic field strengths could reflect ionization energies for these ions.

- (d) The hypothesis means that the scale of energy spectrum of biophotons depends on the ratio M/v_0 of the planet and on the strength of the endogenous magnetic field, which is 2 Gauss for Earth (2/5 of the nominal value of the Earth's magnetic field). Therefore the astrophysical characteristics of planets should be tuned for molecular life. Taking v_0 to be rotational velocity one obtains for the ratio $M(\text{planet})/v_0(\text{planet})$ using the ratio for Earth as unit the following numbers for the planets (Mercury, Venus, Earth, Mars, Jupiter, Saturnus, Uranus, Neptune): $M/v_0 = (8.5, 209, 1, .214223, 1613, 6149, 9359)$. If the energy scale of biophotons is required to be the same, the scale of endogenous magnetic field should be divided by this ratio in order to obtain the same situation as in Earth. For instance, in Mars the magnetic field should be roughly 5 times stronger: in reality the magnetic field of Mars is much weaker. Just for fun one can notice that for Sun the ratio is 1.4×10^6 so that magnetic field should be by the inverse of this factor weaker.
4. An interesting question is how large systems can behave as coherent units with $\hbar_{gr} = GMm/v_0$. In living matter one might consider the possibility that entire organism might be this kind of system. Interestingly, for larger masses the gravitational quantum coherence would be easier. For particle with mass m $\hbar_{gr}/h > 1$ requires larger mass to satisfy $M > M_P^2/m_e$. The first guess that life has evolved from long to shorter scales and reached elementary particle last. Planck mass is the critical mass corresponds to the mass of water blob with volume of size scale of 10^{-4} m (big neuron) is the limit.
 5. The Universal gravitational Compton wave length of $GM/v_0 \simeq 864$ meters gives an idea about largest possible living matter system if Earth is the second body. Of course, also other large bodies are possible. In the case of solar system this length is 3×10^3 km. The radius of Earth is 6.37×10^3 km - roughly twice the Compton length. The radii of Mercury, Venus, Earth, Mars, Jupiter, Saturnus, Uranus, Neptunus are (.38, .99, .533, 1, 10.6, 8.6, 4.0, 3.9) using Earth radius as unit the value of $\hbar_{gr}$ is by factor 5 larger than for three inner planets so that the values are reasonably near to gravitational Compton length or twice it. Does this mean that dark matter associated with Earth and maybe also other planets is in macroscopic quantum state at some level of the hierarchy of space-time sheets? Does this mean that Mother Gaia as conscious entity might make sense. One can of course make same question in the case of Sun. The universal gravitational Compton length in Sun would be 18 per cent of the radius of Sun if v_0 is taken to be the rotational velocity at the surface of Sun. The radius of solar core, where fusion takes place, is 20-25 per cent of solar radius.
 6. There are further interesting numerical co-incidences. One can for a moment forget the standard hostility of scientist towards horoscopes and ask whether Sun and Moon could have somehow affect our life via astroscopic quantum coherence. The gravitational Compton length for particle-Moon or particle-Sun system multiplied by the natural value of magnetic field is the relevant parameter. For Sun the parameters in question are mass of Sun, and rotational velocity of Earth with respect to Sun, plus magnetic fields of Sun at flux tubes associated with solar magnetic field measured to be about 5 nT at the position of Earth and 100 times stronger than expected from dipole field behavior. This gives that the range of biophoton energies is scaled down with factor of 1/4 in good approximation so that Father Sun might affect terrestrial biology! If one uses for the rotational velocity of particle at surface of Moon as parameter v_0 (particle would be at Moon), biophoton energy scaled scaled up by factor 1.2.

The general proposal discussed above is testable. In particular, a detailed study of molecular energies with those associated with resonances of EEG could be highly rewarding and reveal the

speculated spectroscopy of consciousness.

What about $h_{em} = h_{eff}$?

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 $h_{em} = Z_1 Z_2 e^2 / v_0$ is large. Pollack's exclusion zone [L14] (<http://tinyurl.com/oyhstc2>) and its complement define this kind of system and TGD inspired identification is as prebiotic life form. I have proposed a TGD inspired model for the fourth phase of water [K46] [L14].

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. The rotating shaft of a molecular motor associated with ATP synthase is proposed to play a key role.
2. What comes in mind is that the rotational velocity v_0 of the shaft appears in the formula for h_{em} . The electric field over the mitochondrial membrane generates charge separation and the product of charges of shaft and its complement should appear in the expression for h_{em} .
3. 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 lower bound for the magnitude for h_{em} is same as for h_{gr} associated with Earth-particle system.

Rotating magnetic systems are claimed to exhibit anomalous effects such as spontaneous acceleration and over unity energy production. I have discussed these in [K3].

1. The proposal is that rotating magnetic systems give rise to dark matter at magnetic flux tubes and sheets associated with the system and that the metabolic energy is needed to rotate the motor to generate the dark matter, which in turn makes possible negentropic entanglement characterized the density matrix proportional to unit matrix. This kind of matrix results if entanglement coefficients form a unitary S-matrix characterizing also quantum computation as unitary process.
2. The parameter v_0 appearing in the general formula for h_{eff} assigned with either em - or gravitational flux tubes is identifiable as the rotation velocity. One has $v_0/c \simeq 3 \times 10^{-8}$.
3. Since these systems are strongly charged, a natural guess is that large h_{em} system is in question.

D.8.3 Gravitational Mother Gaia And Life

Negentropic entanglement (NE) is one of the key notions of TGD inspired quantum biology. For instance, it would seem that NE would look more natural metabolic resource than energy. Nutrients should carry it. NE is however not single particle property but between nutrient and some other system in the recent case. What can one say about this system? Can it be part of nutrient? Could it correspond to oxygen molecules? Or could it be Mother Gaia identified in some sensible manner?

If one believes on the presence of gravimagnetic flux tubes and their role as generator of macroscopic quantum coherence in biology then one is forced to consider seriously also NE between its ends. If this is the case then the view of religions about life might be nearer to truth than that of hard-born materialists.

To make this more concrete, let us first look what the transfer of NE could mean.

1. Suppose that nutrient N has NE with unknown system A which a priori could be part of nutrient. Assume that the transfer of NE of nutrient with A is formed by reconnection of U-shaped flux tubes associated with N (or glucose G produced from it) and A so that two parallel flux tubes connecting N and A are formed.
2. The basic operation allowing transformation of $N - A$ NE to $P - A$ NE is following. The two flux tube portions of U-shaped flux associated with the receiver R are reconnected with the two parallel flux tubes connecting N and A so that two flux tubes connecting R to A are formed. NMP strongly suggests that the entanglement remains negentropic in the process.

3. NE is first transferred to P using this process so that P and A are now NE-connected. After this P attaches to ADP to yield ATP and ATP attaches to B and the transfer process leads to NE between B and A .

For ATP synthase the h_{em} consisting two elementary charges is of the same order as h_{gr} . This is probably not an accident. Could this mean that this kind of flux tube can reconnect with gravitational flux tube? Could this make possible a reconnection transforming N-Earth NE to P-Earth NE? This looks plausible.

Consider now the identification of A .

1. If one assumes that the negentropic entanglement (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig. ??** in the appendix of this book) corresponds to gravitational flux tubes for N -Earth system then A should be gravitational Mother Gaia, whatever its precise definition might be. N (and glucose) molecules would be alive in the sense that they have NE with Mother Gaia.
2. Could oxygen have some deeper role? For instance, could O_2 molecules serve as analogs of cell membrane receptors for Mother Gaia meaning that gravitational flux tubes go through O_2 molecules? This does not look plausible since metabolism is possible also as fermentation involving no oxygen.
3. In this picture the role of breathing and fermentation would be to make possible the transfer of NE from nutrients to the living system.

This picture allows to imagine about what might happen in biological death. Biological death takes first place only at the highest level of self hierarchy assignable to the our biological body. Cells continue for some time their life even after the last breath. The notion of h_{gr} together with Equivalence Principle suggests that the living biological body has negentropic flux tube connections to both electromagnetic magnetic body (personal magnetic body) and to gravitational Mother Gaia (MG) representing collective consciousness in the scale of Earth. Also personal magnetic body has flux tube connections to MG. The latter especially during sleep. Also connections to higher levels in hierarchy are possible. At the moment of biological death the negentropic flux tube pairs connecting the personal magnetic body to biological body are split and only those with MG remain or are generated in this process. This would happen later at lower levels of biological self hierarchy such as organ and organelles and eventually for cells and biopolymers. On the other hand, new life forms using the decay products as nutrients would take the available NE to use during the decay process.

The quantum model for metabolism allows to understand life as a process in which negentropic entanglement of gravitational Mother Gaia with nutrients is transformed to that of molecules of biological body with personal magnetic body and further processed and enriched. At the moment of biological death this information returns to the gravitational Mother Gaia. By NMP information is not lost but increases steadily giving rise to “Akashic records”. This view conforms with the core ideas of spiritual and religious teachings.

D.9 Quantitative Model Of High T_c Super-Conductivity And Bio-Super-Conductivity

I have developed already earlier [K8, K9, K33, K34] a rough model for high T_c super conductivity [D63, D64, D66, D21, D9, D72]. 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 be 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).

D.9.1 A More Detailed Flux Tube Model For Super-Conductivity

The following little calculations support the above vision and lead to quite predictive model.

D.9.2 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

$$B = \frac{\mu_0}{4\pi a^3} \times (3nn \cdot \mu - \mu) . \quad (\text{D.9.1})$$

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

$$E = \frac{1}{4\pi a^3} \times (-3\mu_1 \cdot n \mu_2 \cdot n + \mu_1 \cdot \mu_2) . \quad (\text{D.9.2})$$

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

$$H_{s-s} = \frac{1}{4\pi a^3} \times \left(\frac{ge\hbar}{2m}\right)^2 \times O , \quad O = -3(m_1)_x(m_2)_x + m_1 \cdot m_2 . \quad (\text{D.9.3})$$

m_i refers to spin in units of $\hbar$. x refers 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

$$(m_1)_x(m_2)_x = \frac{1}{4} \sum_{i=\pm, j=\pm} (m_i)_1(m_j)_2 . \quad (\text{D.9.4})$$

$m_1 \cdot m_2$ 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 $m_1 \cdot m_2(\text{singlet}) = -3/4$ and $m_1 \cdot m_2(\text{triplet}) = 1/4$

The outcome is an expression for the spin-spin interaction Hamiltonian

$$\begin{aligned} H_{s-s} &= E_{s-s} \times O , \quad E_{s-s} = \frac{1}{4\pi a^3} \times (ge\hbar/2m)^2 \times O , \\ O &= O_1 + O_2(S) , \quad O_1 = -\frac{3}{4} \sum_{i=\pm, j=\pm} (m_i)_1(m_j)_2 , \\ O_2(\text{singlet}) &= -\frac{3}{4} , \quad O_2(\text{triplet}) = \frac{1}{4} . \end{aligned} \quad (\text{D.9.5})$$

2. The total interaction Hamiltonian of magnetic moment with the magnetic field of flux tube can be deduced as

$$\begin{aligned} H_{s-flux} &= -(\mu_Z)_1 B_1 - (\mu_Z)_2 B_2 = \frac{ge}{\hbar 2m} (m_1)_z B_1 + (m_2)_z B_2 \\ &= E_{s-flux} \times ((m_1)_z + \epsilon(m_2)_z) \quad , \quad E_{s-flux} = \frac{ge\hbar B}{2m} \quad . \end{aligned} \quad (D.9.6)$$

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

$$O = \begin{pmatrix} \frac{1}{4} & 1 \\ 1 & \frac{1}{4} \end{pmatrix} \quad . \quad (D.9.7)$$

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

$$\begin{aligned} H(anti, S_z = 0) &= -\frac{E_{s-s}}{2} \begin{pmatrix} 1 & x \\ x & 0 \end{pmatrix} \\ x &= -\frac{4E_{s-flux}}{E_{s-s}} = -32\pi \frac{ma^3}{ge\hbar B} \quad , \\ E_{s-s} &= \frac{1}{8\pi} \left(\frac{ge\hbar}{2m}\right)^2 \frac{1}{a^3} \quad . \end{aligned} \quad (D.9.8)$$

The eigenvalues $H(anti, S_z = 0)$

$$E_{\pm} = -\frac{E_{s-s}}{4} (1 \pm \sqrt{1 + 4x^2}) \quad . \quad (D.9.9)$$

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 $\hbar_{eff}$ so that singlet approximation improves for large values of $\hbar_{eff}$.

D.9.3 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 anti-symmetrization 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 $n = \hbar_{eff}/\hbar$. 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 $\hbar_{eff}$. 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.

D.9.4 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

$$E = E_{s-s} \times \lambda \ ,$$

$$\lambda \in \left\{ \frac{5}{4}, -\frac{3}{4}, -\frac{1}{4}(1 \pm \sqrt{1 + 4x^2}) \right\} \ . \quad (\text{D.9.10})$$

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 $T^* = 300\text{K}$ and $T_c = 80\text{K}$. 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 $T_{min}^{**} = (2/3) \times 300 = 200\text{ K}$. 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.

D.9.5 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 $a = a_0 = 1\text{ nm}$ taken as the distance between flux tubes. For $h_{eff} = n \times h$ value of Planck constant one obtains $E_{s-s} = n^2(a/a_0)^3 \times E_0$. $E_0 = 1.7 \times 10^{-7}\text{ eV}$.

Taking $B = 1\text{ Tesla}$ one obtains for E_{s-flux} $E_{s-flux} = n \times E_{s-flux,0}$, $E_{s-flux,0} = 6.2 \times 10^{-7}\text{ eV}$. For $B = B_{end} = .2\text{ Gauss}$ suggested as an important value of dark endogenous magnetic field one obtains $E_{s-flux,0} = 2.5 \times 10^{-11}\text{ eV}$.

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 $B=1\text{ Tesla}$ its magnitude for electron is about $E_{s-flux,0} = 6.2 \times 10^{-7}\text{ eV}$ 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 $a \geq 2 \times 10^{-7}\text{ m}$ which belongs to the range of biologically most important length scales between cell membrane thickness and nucleus size.

4. The hypothesis $\hbar_{eff} = n \times \hbar = \hbar_{gr} = GMm/v_0$ [K85, K70] 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 $\hbar_{eff}^2/m^2a^3$, where a is minimum distance between members of the Cooper pair. It is invariant under the simultaneous scaling of $\hbar_{eff}$ 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 [K51]. This would be also consistent with the earlier explanation for the finding of Hu and Wu [J20] 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 [K13], and in the model for nerve pulse [K36]. 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 $\hbar_{eff}$ 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 $\hbar_{eff}$ 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 $\hbar_{eff}$ 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: $\hbar_{eff}/\hbar \simeq 10^5$ 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. Their ratio of these scales would be roughly 50.

D.9.6 Does Also Low T_c 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 T_c 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- T_c 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 [L17]. This is compete paradox and suggests in TGD framework that the flux tubes of external magnetic field serve as the wires [L17].
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 T_c 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 [K34].

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 T_c 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 T_c SC would only have larger h_{eff} and bio-superconductivity even larger h_{eff} !

3. Could it be that also in low T_c 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? $h_{eff} \rightarrow h$ 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 T_c 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 H_2S - 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 [D60] 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 [D20] (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 [D60] (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 [K34].

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 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 [L20].

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 [J9, J17] (see <http://tinyurl.com/ze366ny>). The transition to a state resembling superconductivity would occur at certain critical frequencies. For the TGD inspired model see [L13].

The TGD proposal for bio-superconductivity - in particular that appearing in microtubules - is same as that for high T_c superconductivity [K33, K34]. 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 microtubules 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 superconductivity 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 [K34].

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 reconnection. 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 superconductivity. 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>). Assume 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 [J9, J17] 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 [K31]. The general proposal is that h_{eff} equals to what I have called gravitational Planck constant $\hbar_{gr} = GMm/v_0$ [K70, K85]. 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 $h_{eff} = \hbar_{gr}$ 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.

D.9.7 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 T_c superconductivity [K33, K34] 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 superconductivity 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/y4wkzcq1>) 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 be 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.

The group of Suchitra Sebastian has discovered very unconventional condensed matter system, which seems to be simultaneously both insulator and conductor of electricity but only in

presence of magnetic field. Science article is entitled “Unconventional Fermi surface in an insulating state” [L17] (see <http://tinyurl.com/y79qo7lp>). There is also a popular article with title “Paradoxical Crystal Baffles Physicists” in Quanta Magazine summarizing the findings (see <http://tinyurl.com/qhwdmxj>). I learned about the finding first from the blog posting of Lubos Motl (see <http://tinyurl.com/yacm6bj7>).

Observations

The crystal studied at superlow temperatures was Samarium hexaboride - briefly SmB_6 . The high resistance implies that electron cannot move more than one atom’s width in any direction. Sebastian et al however observed electrons traversing over a distance of millions of atoms- a distance of order 10^{-4} m, the size of a large neuron. So high mobility is expected only in conductors. SmB_6 is neither metal or insulator or is both of them! The finding is described by Sebastian as a “big shock” and as a “magnificent paradox” by condensed matter theorists Jan Zaanen. Theoreticians have started to make guesses about what might be involved but according to Zaanen there is no even remotely credible hypothesis has appeared yet.

On basis of its electronic structure SmB_6 should be a conductor of electricity and it indeed is at room temperature: the average number conduction electrons per SmB_6 is one half. At low temperatures situation however changes. At low temperatures electrons behave collectively. In superconductors resistance drops to zero as a consequence. In SmB_6 just the opposite happens. Each Sm nucleus has the average 5.5 electrons bound to it at tight orbits. Below 223 degrees of Celsius the conduction electrons of SmB_6 are thought to “hybridize” around samarium nuclei so that the system becomes an insulator. Various signatures demonstrate that SmB_6 indeed behaves like an insulator.

During last five years it has been learned that SmB_6 is not only an insulator but also so called topological insulator. The interior of SmB_6 is insulator but the surface acts as a conductor. In their experiments Sebastian et al hoped to find additional evidence for the topological insulator property and attempted to measure quantum oscillations in the electrical resistance of their crystal sample. The variation of quantum oscillations as sample is rotated can be used to map out the Fermi surface of the crystal. No quantum oscillations were seen. The next step was to add magnetic field and just see whether something interesting happens and could save the project. Suddenly the expected signal was there! It was possible to detect quantum oscillations deep in the interior of the sample and map the Fermi surface! The electrons in the interior travelled 1 million times faster than the electrical resistance would suggest. Fermi surface was like that in copper, silver or gold. A further surprise was that the growth of the amplitude of quantum oscillations as temperature was decreased, was very different from the predictions of the universal Lifshitz-Kosevich formula for the conventional metals.

Could TGD Help To Understand The Strange Behavior Of SmB_6 ?

There are several indications that the paradoxical effect might reveal the underlying dynamics of quantum TGD. The mechanism of conduction must represent new physics and magnetic field must play a key role by making conductivity possible by somehow providing the “current wires”. How? The TGD based answer is completely obvious: magnetic flux tubes - one of the basic distinctions between electrodynamics of Maxwell and its TGD variant! Also the failure of Lifshitz-Kosevich formulas should be understood.

1. Single sheet of many-sheeted space-time resembles topological insulator

One should also understand topological insulator property at deeper level, that is the conduction along the boundaries of topological insulator. One should understand why the current runs along 2-D surfaces. In fact, many exotic condensed matter systems are 2-dimensional in good approximation. In the models of integer and fractional quantum Hall effect electrons form a 2-D system with braid statistics possible only in 2-D system. High temperature super-conductivity is also an effectively 2-D phenomenon. By strong form of holography these aspects are also key aspects of quantum TGD at the fundamental level of single space-time sheet when the approximation replacing many-sheeted space-time with that of GRT and standard model does not mask the simplicity of the fundamental dynamics.

1. Many-sheeted space-time is second fundamental prediction TGD. The dynamics of single sheet of many-sheeted space-time should be very simple by the strong form of holography implying effective 2-dimensionality. The standard model description of this dynamics masks this simplicity since the sheets of many-sheeted space-time are replaced with single region of slightly curved Minkowski space with gauge potentials sums of induced gauge potentials for sheets and deviation of metric from Minkowski metric by the sum of corresponding deviations for space-time sheets. Could the dynamics of exotic condensed matter systems give a glimpse about the dynamics of single sheet? Could topological insulator and anyonic systems [K86] provide examples of this kind of systems?
2. Second basic prediction of TGD is strong form of holography: string world sheets and partonic 2-surfaces serve as kind of “space-time genes” and the dynamics of fermions is 2-D at fundamental level. It must be however made clear that at QFT limit the spinor fields of imbedding space replace these fundamental spinor fields localized at 2-surface. One might argue that the fundamental spinor fields do not make them directly visible in condensed matter physics. Nothing however prevents from asking whether in some circumstances the fundamental level could make itself visible.

In particular, for large $\hbar_{eff}$ dark matter systems (, whose existence can be deduced from the quantum criticality of quantum TGD) the partonic 2-surfaces with CP_2 size could be scaled up to nano-scopic and even longer size scales. I have proposed this kind of surfaces as carriers of electrons with non-standard value of $\hbar_{eff}$ in QHE and FQHE [K86].

The long range quantum fluctuations associated with large, $\hbar_{eff} = n \times \hbar$ phase would be quantum fluctuations rather than thermal ones. In the case of ordinary conductivity thermal energy makes it possible for electrons to jump between atoms and conductivity becomes very small at low temperatures. In the case of large scale quantum coherence just the opposite happens as observed. One therefore expects that Lifshitz-Kosevich formula for the temperature dependence of the amplitude does not hold true.

The generalization of Lifshitz-Kosevich formula to quantum critical case deduced from quantum holographic correspondence by Hartnoll and Hofman [D57] (<http://tinyurl.com/ybednd85>) is expected to hold true qualitatively also for quantum criticality in TGD sense. The first guess is that by underlying super-conformal invariance scaling laws typical for critical systems hold true. In the proposed formula the dependence on temperature is via a power of dimensionless parameter $x = T/\mu$, where μ is chemical potential for electron system. As a matter fact, exponent of power of x appears and reduces to first for Lifshitz-Kosevich formula. Since magnetic field is important, one also expects that the ratio of cyclotron energy scale $E_c \propto \hbar_{eff} eB/m_e$ to Fermi energy appears in the formula. One can even make an order of magnitude guess for the value of $\hbar_{eff}/\hbar \sim 10^6$ from the facts that the scale of conduction and conduction velocity were millions times higher than expected.

Strings are 1-D systems and strong form of holography implies that fermionic strings connecting partonic 2-surfaces and accompanied by magnetic flux tubes are fundamental. At light-like 3-surfaces fermion lines can give rise to braids. In TGD framework AdS/CFT correspondence generalizes since the conformal symmetries are extended. This is possible only in 4-D space-time and for the imbedding space $H = M^4 \times CP_2$ making possible to generalize twistor approach [K94].

3. Topological insulator property means from the perspective of modelling that the action reduces to a non-abelian Chern-Simons term. The quantum dynamics of TGD at space-time level is dictated by Kähler action. Space-time surfaces are preferred extremals of Kähler action and for them Kähler action reduces to Chern-Simons terms associated with the ends of space-time surface opposite boundaries of causal diamond and possibly to the 3-D light-like orbits of partonic 2-surfaces. Now the Chern-Simons term is Abelian but the induced gauge fields are non-Abelian. One might say that single sheeted physics resembles that of topological insulator.
4. The effect appears only in magnetic field. I have been talking a lot about magnetic flux tubes carrying dark matter identified as large $\hbar_{eff}$ phases: topological quantization distinguishes TGD from Maxwell’s theory: any system can be said to possess “magnetic body”, whose

flux tubes can serve as current wires. I have predicted the possibility of high temperature super-conductivity based on pairs of parallel magnetic flux tubes with the members of Cooper pairs at the neighboring flux tubes forming spin singlet or triplet depending on whether the fluxes are have same or opposite direction.

Also spin and electric currents assignable to the analogs of spontaneously magnetized states at single flux tube are possible. The obvious guess is that the conductivity in question is along the flux tubes of the external magnetic field. Could this kind of conductivity explains the strange behavior of SmB_6 . The critical temperature would be that in which the parallel flux tubes are stable. The interaction energy of spin with the magnetic field serves as a possible criterion for the stability if the presence of dark electrons stabilizes the flux tubes.

2. Magnetic flux tubes as dark current carriers in quantum criticality

The following represents an extremely childish attempt of a non-specialist to understand how the conductivity might be understood. The current carrying electrons at flux tubes near the top of Fermi surface are current carriers. $h_{eff} = n \times h$ and magnetic flux tubes as current wires bring in the new elements. Also in the standard situation one considers cylinder symmetric solutions of Schrödinger equation in external magnetic field and introduces maximal radius for the orbits so that formally the two situations seem to be rather near to each other. Physically the large h_{eff} and associated many-sheeted covering of space-time surface providing the current wire makes the situation different since the collisions of electrons could be absent in good approximation so that the velocity of charge carriers could be much higher than expected as experiments indeed demonstrate.

Quantum criticality is the crucial aspect and corresponds to the situation in which the magnetic field attains a value for which a new orbit emerges/disappears at the surface of the flux tube: in this situation dark electron phase with non-standard value of h_{eff} can be generated. This mechanism is expected to apply also in bio-superconductivity and to provide a general control tool for magnetic body.

1. Let us assume that flux tubes cover the whole transversal area of the crystal and there is no overlap. Assume also that the total number of conduction electrons is fixed, and depending on the value of h_{eff} is shared differently between transversal and longitudinal degrees of freedom. Large value of h_{eff} squeezes the electrons from transversal to longitudinal flux tube degrees of freedom and gives rise to conductivity.
2. Consider first Schrödinger equation. In radial direction one has harmonic oscillator and the orbits are Landau orbits. The cross sectional area behaves like $\pi R^2 = n_T h_{eff} / 2m\omega_c$ giving $n_T \propto 1/h_{eff}$. Increase of the Planck constant scales up the radii of the orbits so that the number of states in cylinder of given radius is reduced. Angular momentum degeneracy implies that the number of transversal states is $N_T = n_T^2 \propto 1/h_{eff}^2$. In longitudinal direction one has free motion in a box of length L with states labelled by integer n_L . The number of states is given by the maximum value N_L of n_L .
3. If the total number of states is fixed to $N = N_L N_T$ is fixed and thus does not depend on h_{eff} , one has $N_L \propto h_{eff}^2$. Quanta from transversal degrees of freedom are squeezed to longitudinal degrees of freedom, which makes possible conductivity.
4. The conducting electrons are at the surface of the 1-D "Fermi-sphere", and the number of conduction electrons is $N_{cond} \simeq dN/d\epsilon \times \delta\epsilon \simeq dN/d\epsilon T = NT/2\epsilon_F \propto 1/h_{eff}^4$. The dependence on h_{eff} does not favor too large values of h_{eff} . On the other hand, if scattering of electrons at flux tubes could be absent. The assumption $L \propto h_{eff}$ increases the range over which current can flow.
5. To get a non-vanishing net current one must assume that only the electrons at the second end of the 1-D Fermi sphere are current carriers. The situation would resemble that in semiconductor. The direction of electric field would induce symmetry breaking at the level of quantum states. The situation would be like that for a mass in Earth's gravitational field treated quantally and electrons would accelerate freely. Schrödinger equation would give rise to Airy functions as its solution.

3. Quantum critical quantum oscillations

What about quantum oscillations in TGD framework?

1. Quantum oscillation refers to de Haas-van Alphen effect (<http://tinyurl.com/yaaljv9j>) - an oscillation of the induced magnetic moment as a function of $1/B$ with period $\tau = 2\pi e/\hbar A$, where A is the area of the extremal orbit of the Fermi surface, in the direction of the applied field. The effect is explained to be due to the Landau quantization of the electron energy. I failed to really understand the explanation of this source and in my humble opinion the following arguments provide a clearer view about what happens.
2. If external magnetic field corresponds to flux tubes, Fermi surface decomposes into cylinders parallel to the magnetic field since the motion in transversal degrees of freedom is along circles. In the above thought experiment also a quantization in the longitudinal direction occurs if the flux tube has finite length so that Fermi surface in longitudinal direction has finite length. One expects on basis of Uncertainty Principle that the area S of the cross section of Fermi cylinder in momentum space is given by $S \propto \hbar_{eff}^2/\pi R^2$. This follows also from the equation of motion of electron in magnetic field. As the external magnetic field B is increased, the radii of the orbits decrease inside the flux tube, and in momentum space the radii increase.
3. Why does the induced magnetic moment (magnetization) and other observables oscillate?
 - (a) The simplest manner to understand this is to look at the situation at space-time level. Classical orbits are harmonic oscillator orbits in radial degree of freedom. Suppose that the area of flux tube is fixed and B is increased. The orbits have radius $r_n^2 = (n + 1/2) \times \hbar/eB$ and shrink. For certain field values the flux $eBA = n\hbar$ corresponds to an integer multiple of the elementary flux quantum. A new orbit at the boundary of the flux tube emerges if the new orbit is near the boundary of Fermi sphere providing the electrons. This is clearly a critical situation.
 - (b) In de Haas-van Alphen effect the orbit $n + 1$ for B has same radius as the orbit n for $1/B + \Delta(1/B)$: $r_{n+1}(1/B) = r_n(1/B + \Delta(1/B))$. This gives approximate differential equation with respect to n and one obtains $(1/B)(n) = (n + 1/2) \times \Delta(1/B)$. $\Delta(1/B)$ is fixed from the condition the flux quantization. When largest orbit is at the surface of the flux tube the orbits are same for $B(n)$ and $B(n + 1)$, and this gives rise to the de Haas - van Alphen effect.
 - (c) It is not necessary to assume finite radius for the flux tube, and the exact value of the radius of the flux tube does not play an important role. The value of flux tube radius can be estimated from the ratio of the Fermi energy of electron to the cyclotron energy. Fermi energy about .1 eV depending only on the density of electrons in the lowest approximation and only very weakly on temperature. For a magnetic field of 1 Tesla cyclotron energy is .1 meV. The number of cylinders defined by orbits is about $n = 10^4$.
4. What happens in TGD Universe in which the areas of flux tubes identifiable as space-time quanta are finite? Could quantum criticality of the transition in which a new orbit emerges at the boundary of flux tube lead to a large $\hbar_{eff}$ dark electron phase at flux tubes giving rise to conduction?
 - (a) The above argument makes sense also in TGD Universe for the ordinary value of Planck constant. What about non-standard values of Planck constant? For $\hbar_{eff}/\hbar = n$ the value of flux quantum is n -fold so that the period of the oscillation in de Haas - van Alphen effect becomes n times shorter. The values of the magnetic field for which the orbit is at the surface of the flux tube are however critical since new orbit emerges assuming that the cyclotron energy corresponds is near Fermi energy. This quantum criticality could give rise to a phase transition generating non-standard value of Planck constant.
 What about the period $\Delta(1/B)$ For $\hbar_{eff}/\hbar = n$? Modified flux quantization for extremal orbits implies that the area of flux quantum is scaled up by n . The flux changes

by n units for the same increment of $\Delta(1/B)$ as for ordinary Planck constant so that de Haas-van Alphen effect does not detect the phase transition.

- (b) If the size scale of the orbits is scaled up by $\sqrt{n}$ as the semiclassical formula suggests the number of classical orbits is reduced by a factor $1/n$ if the radius of the flux tube is not changed in the transition $h \rightarrow h_{eff}$ to dark phase. n -sheetedness of the covering however compensates this reduction.
- (c) What about possible values of h_{eff}/h ? The total value of flux seems to give the upper bound of $h_{eff}/h = n_{max}$, where n_{max} is the value of magnetic flux for ordinary value of Planck constant. For electron and magnetic field for $B = 10$ Tesla and has $n \leq 10^5$. This value is of the same order as the rough estimate from the length scale for which anomalous conduction occurs.

Clearly, the mechanism leading to anomalously high conductivity might be the transformation of the flux tubes to dark ones so that they carry dark electrons currents. The observed effect would be dark, quantum critical variant of de Haas-van Alphen effect!

Also bio-superconductivity is quantum critical phenomenon and this observation would suggest sharpening of the existing TGD based model of bio-super-conductivity. Super-conductivity would occur for critical magnetic fields for which largest cyclotron orbit is at the surface of the flux tube so that the system is quantum critical. Quantization of magnetic fluxes would quantify the quantum criticality. The variation of magnetic field strength would serve as control tool generating or eliminating supra currents. This conforms with the general vision about the role of dark magnetic fields in living matter.

To sum up, a breakthrough of TGD is continuing. I have written about thirty articles during this year - more than one article per week. There is huge garden there and trees contain fruits hanging low! It is very easy to pick them: just shatter and let them drop to the basket! New experimental anomalies having a nice explanation using TGD based concepts appear on weekly basis and the mathematical and physical understanding of TGD is taking place with great leaps. It is a pity that I must do all alone. I would like to share. I can only hope that colleagues could take the difficult step: admit what has happened and make a fresh start.

D.10 A New Control Mechanism Of TGD Inspired Quantum Biology

The idea that TGD Universe is quantum critical, is the corner stone of quantum TGD and fixes the theory more or less uniquely since the only coupling constant parameter of the theory - Kähler coupling strength - is analogous to critical temperature. Also more than one basic parameters are in principle possible - maximal quantum criticality fixes the values of all of them - but it seems that only Kähler coupling strength is needed. TGD Universe is a quantum critical fractal: like a ball at the top of hill at the top of hill at.... Quantum criticality allows to avoid the fine tuning problems plaguing as a rule various unified theories.

D.10.1 Quantum Criticality

The meaning of quantum criticality at the level of dynamics has become only gradually clearer. The development of several apparently independent ideas generated for about decade ago have led to the realization that quantum criticality is behind all of them. Behind quantum criticality are in turn number theoretic vision and strong forms of general coordinate invariance and holography.

1. The hierarchy of Planck constants defining hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of super-symplectic algebra for which conformal weights are n -ples of those for the entire algebra, n corresponds to the value of effective Planck constant $h_{eff}/h = n$. These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question.

2. Quantum criticality in turn reduces to the number theoretic vision about strong form of holography. String world sheets carrying fermions and partonic 2-surfaces are the basic objects as far as pure quantum description is considered. Also space-time picture is needed in order to test the theory since quantum measurements always involve also the classical physics, which in TGD is an exact part of quantum theory.

Space-time surfaces are continuations of collections of string world sheets and partonic 2-surfaces to preferred extremals of Kähler action for which Noether charges in the sub-algebra of super-symplectic algebra vanish. This condition is the counterpart for the reduction of the 2-D criticality to conformal invariance. This eliminates huge number of degrees of freedom and makes the strong form of holography possible.

3. The hierarchy of algebraic extensions of rationals defines the values of the parameters characterizing the 2-surfaces, and one obtains a number theoretical realization of an evolutionary hierarchy. One can also algebraically continue the space-time surfaces to various number fields - reals and the algebraic extensions of p-adic number fields. Physics becomes adelic. p-Adic sectors serve as correlates for cognition and imagination. One can indeed have string world sheets and partonic 2-surfaces, which can be algebraically continued to preferred extremals in p-adic sectors by utilizing p-adic pseudo constants giving huge flexibility. If this is not possible in the real sector, fragment of imagination is in question! It can also happen that only part of real space-time surface can be generated: this might relate to the fact that imaginations can be seen as partially realized motor actions and sensory perceptions.

D.10.2 Quantum Criticality And TGD Inspired Quantum Biology

In TGD inspired quantum biology quantum criticality is in crucial role. First some background.

1. Quantum measurement theory as a theory of consciousness is formulated in zero energy ontology (ZEO) and defines an important aspect of quantum criticality. Strong form of NMP states that the negentropy gain in the state function reduction at either boundary of causal diamond (CD) is maximal. Weak form of NMP allows also quantum jumps for which negentropic entanglement is not generated: this makes possible ethics (good and evil) and morally responsible free will: good means basically increase of negentropy resources.
2. Self corresponds to a sequence state function reductions to the same boundary of CD and h_{eff} does not change during that period. The increase of h_{eff} (and thus evolution!) tends to occur spontaneously, and can be assigned to the state function reduction to the opposite boundary of CD in zero energy ontology (ZEO). The reduction to the opposite boundary means death of self and living matter is fighting in order to avoid this even. To me the only manner to make sense about basic myth of Christianity is that death of self generates negentropy.
3. Metabolism provides negentropy resources for self and hopefully prevents NMP to force the fatal reduction to the opposite boundary of CD. Also homeostasis does the same. In this process self makes possible evolution of sub-selves (mental images dying and re-incarnating) state function by state function reduction so that the negentropic resources of the Universe increase.

D.10.3 A New Mechanism Of Quantum Criticality

Consider now the mechanisms of quantum criticality. The TGD based model [L17] [K70] (<http://tinyurl.com/y8oblpl9>) for the recent paradoxical looking finding [L17] (<http://tinyurl.com/y79qo7lp>) that topological insulators can behave like conductors in external magnetic field led to a discovery of a highly interesting mechanism of criticality, which could play a key role in living matter.

1. The key observation is that magnetic field is present. In TGD framework the obvious guess is that its flux tubes carry dark electrons giving rise to anomalous currents running in about million times longer time scales and with velocity, which is about million times higher than expected. Also supra-currents can be considered.

The currents can be formed of the cyclotron energies of electrons are such that they correspond to energies near the surface of the Fermi sphere: recall that Fermi energy for electrons is determined by the density of conduction electrons and is about 1 eV. Interestingly, this energy is at the lower end of bio-photon energy spectrum. In the field of 10 Tesla the cyclotron energy of electron is .1 mV so that the integer characterizing cyclotron orbit must be $n \simeq 10^5$ if conduction electron is to be transferred to the cyclotron orbit.

2. The assumption is that external magnetic field is realized as flux tubes of fixed radius, which correspond to space-time quanta in TGD framework. As the intensity of magnetic field is varied, one observes so called de Haas-van Alphen effect (<http://tinyurl.com/hoywcng>) used to deduce the shape of the Fermi sphere: magnetization and some other observables vary periodically as function of $1/B$ (for a model for the quantum critical variant of the effect see [D57]).

This can be understood in the following manner. As B increases, cyclotron orbits contract. For certain increments of $1/B$ $n+1$:th orbit is contracted to n :th orbit so that the sets of the orbits are identical for the values of $1/B$, which appear periodically. This causes the periodic oscillation of say magnetization.

3. For some critical values of the magnetic field strength a new orbit emerges at the boundary of the flux tube. If the energy of this orbit is in the vicinity of Fermi surface, an electron can be transferred to the new orbit. This situation is clearly quantum critical.

If the quantum criticality hypothesis holds true, $h_{eff}/h = n$ dark electron phase can be generated for the critical values of magnetic fields. This would give rise to the anomalous conductivity perhaps involving spin current due to the spontaneous magnetization of the dark electrons at the flux tube. Even super-conductivity based on the formation of parallel flux tube pairs with either opposite or parallel directions of the magnetic flux such that the members of the pair are at parallel flux tubes, can be considered and I have proposed this a mechanism of bio-superconductivity and also high T_c super-conductivity.

D.10.4 A New Mechanism Of Quantum Bio-Control

The quantum criticality of the process in which new electron orbit emerges near Fermi surface suggests a new mechanism of quantum bio-control by generation of super currents or its reversal.

1. In TGD inspired quantum biology magnetic body uses biological body as motor instrument and sensory receptor and EEG and its fractal variants with dark photons with frequencies in EEG range but energy $E = h_{eff}f$ in the range of bio-photon energies make the necessary signalling possible.
2. Flux tubes can become braided and this makes possible quantum computation like processes [K58]. Also so called 2-braids - defined by knotted 2-surfaces imbedded in 4-D space-time surface - are possible for the string world sheets defined by flux tubes identified to be infinitely thin, are possible. As a matter fact, also genuine string world sheets accompany the flux tubes. 2-braids and knots are purely TGD based phenomenon and not possible in superstring theory or M-theory.
3. It is natural to speak about motor actions of the magnetic body. It is assumed that the flux tubes of the magnetic body connect biomolecules to form a kind of Indra's web explaining the gel like character of living matter. h_{eff} reducing phase transitions contract flux tubes connecting biomolecules so that they can find each other by this process and bio-catalysis becomes possible. This explains the mysterious looking ability of bio-molecules to find each other in the dense molecular soup. In fact the dark matter part is far from being soup! The hierarchy of Planck constants and $h_{eff} = h_{gr}$ hypothesis imply that dark variants of various particles with magnetic moment are neatly at their own flux tubes like books in shelf.

Reconnection of the U-shaped flux tubes emanating from two subsystems generates a flux tube pair between them and gives rise to supracurrents flowing between them. Also cyclotron radiation propagating along flux tubes and inducing resonant transitions is present. This would be the fundamental mechanism of attention.

4. I have proposed that the variation of the thickness of the flux tubes could serve as a control mechanism since it induces a variation of cyclotron frequencies allowing to get in resonance or out of it. For instance, two molecules could get in flux tube contact when the cyclotron frequencies are identical and this can be achieved if they are able to vary their flux tube thickness. The molecules of immune system are masters in identifying alien molecules and the underlying mechanism could be based on cyclotron frequency spectrum and molecular attention. This would be also the mechanism behind water memory and homeopathy (<http://tinyurl.com/yda3d6se> [K18] which still is regarded as a taboo by mainstreamers.
5. Finally comes the promised new mechanism of bio-control. The variation of the magnetic field induced by that of flux tube thickness allows also to control whether there is quantum criticality for the generation of dark electron supra currents of electrons. The Fermi energy of the conduction electrons at the top of Fermi sphere is the key quantity and dictated by the density of these electrons. This allows to estimate the order of magnitude of the integers N characterizing cyclotron energy for ordinary Planck constant and the maximal value of $h_{eff}/h = n$ cannot be larger than N .

D.11 TGD based model for graphene superconductivity

A highly interesting new effect associated with graphene is discussed in Phys.Org article (see <http://tinyurl.com/ydyqgk56>). The original research articles by Cao et al are published in Nature [D29, D30]. There is also a popular article In Nature (see <http://tinyurl.com/ya5jzadc>). What is found that a bilayer formed by parallel graphene sheets becomes superconducting for critical values of twist angle θ . The largest critical value of θ is $\theta = 1.1$ degrees.

The finding of Cao et al is believed to be highly significant concerning the understanding of high T_c super-conductivity and motivates the development of a model of Mott insulators based on TGD based views about valence bond inspired by the identification of dark matter as $h_{eff}/h = n$ phases of ordinary matter emerging naturally in adelic physics [L38] [L39]. Also a more detailed version about the model of high T_c superconductivity in TGD Universe developed in [K8, K9, K33, K34] emerges.

D.11.1 Basic observations

Consider first the basic facts. The surprising discovery was that graphene becomes unconventional superconductor at temperature 1.7 K. It was already earlier discovered that the coupling of graphene to a superconductor can make also graphene superconducting.

1. The system studied consists of two graphene (see <http://tinyurl.com/8os5eas>) layers twisted by angle θ with respect to each other (rotation of the second sheet by angle θ around the axis normal to sheets). For a generic value of θ the graphene layers behave as separate conductors. For certain critical twist angles below 1.1 degrees the two-layered system however behaves like single unit and Mott insulator (see <http://tinyurl.com/ybqblvc7>): this is due to the increase of the conduction band gap. In an applied electric field the system becomes a super conductor. The electric field provides the energy needed to kick the current carries to the conduction band, which for Mott insulators has higher energy than for the corresponding conductor: at the top of the band Cooper pairs are formed as in the case of ordinary superconductors.
2. A kind of Moire effect (see <http://tinyurl.com/qchunes>) is involved. The twist creates a superlattice with larger unit cell and the electrons associated with periodically occurring C-atom pairs above each other give rise to a narrow band where the superconducting electrons are. Electric field would kick the electrons to this band.
3. There are intriguing analogies with high T_c superconductivity. Electron density as function of temperature has a pattern similar to that for cuprates. Superconductivity occurs at electron density, which is 10^{-4} times that for conventional superconductors at the same temperature. The pairing of electrons cannot be due to phonon exchange since the density is so low. Unidentified strong interaction between electrons is believed to be the reason.

D.11.2 Mott insulators, transition metals, antiferromagnets, and high T_c superconductors in TGD framework

In 1937 Jan Hendrik de Boer and Evert Johannes Willem Verwey pointed out that a variety of transition metal oxides are insulators although they should be conductors since they have odd number of electrons per lattice cells. Nevill Mott and Rudolf Peierls predicted that the effect can be explained by taking into account the interaction between electrons neglected in the band theory of solids. These materials became known as Mott insulators (see <http://tinyurl.com/ybqblvc7>).

1. 1949 Mott proposed a model for NiO as insulator (Ni is transition metal). The conduction was based on the process $(Ni^{2+}O^{2-})^2 \rightarrow Ni^{3+}O^{2-} + Ni^{1+}O^{2-}$. In this process electron is transferred between the neighboring sites. For critical values of parameters NiO however becomes insulator.

The formation of energy gap preventing conduction can be understood as competition between Coulomb potential U between 3d electrons at the same site and the transfer integral t of 3d electrons between neighboring sites characterizing the transfer of electron between neighboring sites. The total energy gap is $U - 2zt$, where z is the total number of nearest-neighbor atoms. As U is increased by varying parameters a transition to insulator takes place when the energy gap becomes too large.

t is essentially the matrix element of atomic potential ΔU due to the neighboring atoms taken between two electronic orbitals associated with neighboring atoms. Usually this matrix element is small.

2. It is believed that ordinary quantum mechanics can explain the needed large magnitude of t . The calculations are however not first principle calculations and involve experimental input from chemical bond energy data. Therefore one can ask whether some new physics possible related to the notion of valence bond might be needed.

In TGD framework one indeed ends up to a model of valence bonds involving non-standard value of $h_{eff}/n = n$ for valence bonds. This could lead to a delocalization of electron wave functions and generate strong interaction between valence electrons of neighboring atoms. This mechanism might apply to all strongly interacting many-electron systems (such as that appearing in QHE and FQHE [K86]) so that the physics of dark matter would make itself visible in condensed matter physics thought to be thoroughly understood at the level of basic principles.

Remark: The original motivation for the hierarchy of Planck constants was the idea that Nature loves theoreticians [K77, K70]. The phase transition increasing the value of Planck constant reduces the large value of gauge coupling constant $\alpha = g^2/4\pi\hbar$ making perturbation theory impossible by factor $1/n$ and makes perturbation theory possible.

The TGD based picture about Mott insulators relies on $h_{eff}/h = n$ hierarchy giving rise to dark matter as phases of ordinary matter. In particular, one ends up with a model for valence bonds with valence electrons having value of n larger than for atoms. This in turn leads to a model of high T_c superconductivity generalizing to a model of Mott insulators. Also graphene superconductivity would rely on these mechanisms.

Dark matter as $h_{eff}/h = n$ phases

It is good to explain first the development of the ideas related to $h_{eff}/h = n$ hierarchy.

1. I ended up to the discovery of dark matter hierarchy and eventually to adelic physics [L39], where $h_{eff}/h = n$ has number theoretic interpretation along several roads starting from anomalous findings.

One of these roads began from the claim about the existence of strange form of matter by David Hudson [H2]. Hudson associated with these strange materials several names: White Gold, monoatomic elements, and ORMEs (orbitally re-arranged metallic elements). Any colleague without suicidal tendencies would of course refuse to touch anything like White Gold even with a 10 meter long pole but I had nothing to lose anymore. The basic feature is

that these elements would form metal like strongly correlates structure although the atoms are separate so that their is no lattice in the usual sense.

My question was how to explain these elements if they are actually real [K8, K76]. If all valence electrons of this kind of element are dark these element have effectively full electron shells as far as ordinary electrons are considered and behave like noble gases with charge in short scales and do not form molecules. Therefore “monoatomic element” is justified. Of course, only the electrons in the outermost shell could be dark and in this case the element would behave chemically and also look like an atom with smaller atomic number Z . So called Rydberg atoms for which valence electrons are believed to reside at very large orbitals could be actually dark atoms in the proposed sense.

Obviously also ORME is an appropriate term since some valence electrons have re-arranged orbitally. White Gold would be Gold but with dark valence electron. The electron configuration of Gold is $[Xe]4f^{14}5d^{10}6s^1$. There is single unpaired electron with principal quantum number $m = 6$ and this would be dark for White Gold and chemically like Platinum (Pt), which indeed has white color.

Remark:: The precious metals involved are also transition metals near the end point of the group along the row of the periodic table as are also Mott insulators.

The ability of ORMES consisting of single isolated atoms to behave like condensed matter system would be due to the presence of long magnetic flux tubes assignable to valence electrons with large n and connecting the atoms of ORMUS together. For ordinary valence bonds the flux tubes are short and one obtains ordinary metal lattice.

2. Developments at quantitative level began with the TGD based explanation [L37] (see <http://tinyurl.com/y8pqcc8s>) for the finding that in heating of a system involving transition metal unpaired valence electrons mysteriously disappear. The increase of $h_{eff} = n \times h$ for valence electrons in transition metals from their normal value would explain how they become dark matter in TGD sense. Since the binding energy associated with the bond increases with n , energy is required to kick electrons to the dark valence band and heating provides it. In TGD inspired quantum biology, metabolic energy increases the value of n for valence bonds and makes possible quantum coherence in unusually long length scales.
3. This model led soon to a TGD inspired model for valence bonds [L36] (see <http://tinyurl.com/ycg94xp1>). The value of n for valence bond depends on the valence of the atom having larger electronegativity (more towards right along the row of the Periodic Table) and increases as one moves along the row: this guarantees that the bond energies vary only weakly along the row of the periodic table. The simple expectation from ordinary quantum theory is that the dependence of bond energy should be rather strong.

The outcome is a vision about biochemistry and the roles of various valence bonds in metabolism. The valence bonds associated with atoms with high electronegativity carry especially larger metabolic energy identified as the difference of the bond energies for the actual value n_{bond} of n and its value n_{atom} for free atom. Catabolism would liberate this energy by reducing the values of n_{bond} .

Many-sheeted description of conductors

The first question is what electrons and elementary particles are at space-time level in TGD Universe.

1. In many-sheeted space-time elementary particles are two-sheeted structures consisting of two wormhole contacts, whose throats are connected by flux tubes at both sheets. The flux tubes at other sheet defining the magnetic body of the particle could have large value of $h_{eff}/h = n$ and be rather long. For instance, in atomic nucleus the flux tubes connecting nuclei to a nuclear string would be short with length L of order nucleon size but the flux tubes at the sheet defining magnetic body would be considerably longer - naturally given by nuclear length scale [L4, K66]. The length would be even longer for dark nuclei [L30].

2. Many-sheeted space-time predicts a hierarchy of space-time sheets and magnetic fields in various scales would correspond to these sheets and be represented as flux tubes. Flux tubes within flux tubes is what comes naturally in mind. Valence bonds would correspond to flux tubes defining only one level in this length scale hierarchy. Certainly this level is higher than elementary particle level, which corresponds to the Compton size of elementary particle.
3. Valence flux tubes could correspond to the magnetic body of the particle and have large value of n . In accordance with the TGD view about valence bonds [L36] (see <http://tinyurl.com/ycg94xpl>) the value of n for valence bonds making possible also conductivity is larger than for free atoms.

Remark: TGD Universe is fractal and this picture about elementary particles and their magnetic body is very similar to the view about galaxies as knots in long flux tube and having protuberances analogous to the flux loops and containing stars as sub-knots [L46] (see <http://tinyurl.com/ybbs9zhp>).

What makes the system a conductor?

1. Suppose that valence bonds indeed correspond to flexible loop like structures, which can be rather long for large values of n . Could the hopping of electrons between neighboring molecules (or atoms) be basically a topological process?

Could the valence flux loops of neighboring molecules (say NiO) temporarily reconnect to form a pair of flux tubes connecting the molecules so that electrons can propagate along the these flux tubes between molecules?

There would be no resistance during the flow along flux tube but the stopping at the end of the flux tubes would contribute to the resistance. In absence of electric field the currents are in random direction but the presence of electric field would make possible a net current.

2. One can try to relate this picture also to the standard description of conductivity obtained replacing many-sheeted space-time with that of special relativity so that all information about space-time topology is lost. What remains are the parameters U and t defined as matrix element of ΔU and the gap energy for the conduction band defined as $U - 2zt$.

A de-localization of electrons occurs in conductivity due to temporary reconnections inducing hopping of electrons between neighboring sites. The increase of n increases various quantum scales. In particular, the length of valence bond increases and the wave functions for valence electrons are de-localized in a larger volume.

Therefore the matrix elements of ΔU receive contributions from a volume, where ΔU is large. For flux tubes connecting neighboring unit cells it could be even larger than this.

Also the value of U as expectation value of Coulombic energy for single site is affected. When the value of the competing parameter U becomes large enough, band gap becomes so large that conductivity is lost and one has Mott insulator.

D.11.3 Mott insulators in TGD framework

In TGD framework the new view about valence bonds and anti-ferromagnetism provides new insights about Mott insulators.

1. The valence bonds for oxides such as NiO should have high values of n and for certain critical parameter values (quantum criticality) n might become even higher than for ordinary valence bonds. This would increase the quantum coherence length measured by the flux tubes connecting neighboring molecules: the naïve guess is that it is proportional to n (for the atomic orbitals it is proportional to n^2). This makes makes possible quantum coherence in longer scales than usually possibly leading to a formation of Cooper pairs implying superconductivity at least in short scales at low enough temperatures.
2. Transition metal property is essential for being a Mott insulator. The table of Wikipedia article gives an overall view about transition metals (see <http://tinyurl.com/ydyqum4>).

There are 4 groups corresponding to the values $r = 4, 5, 6, 7$ labelling the rows of the Periodic Table.

Ni atoms appearing in Mott insulator NiO and Cu atoms appearing in copper oxide high T_c superconductors belong to the group 4 of transition metals, which means that they belong to the fourth row of the Periodic Table (principal quantum number of highest valence electrons equals to 4). Ni and Cu are at the right end of the portion of 4th row containing transition metals. The value of n for copper oxides is predicted by TGD based model of valence bond to be highest in group 4 and second highest for Ni [L36] (see <http://tinyurl.com/ycg94xpl>). Copper oxides are therefore ideal candidates for high T_c superconductors in TGD Universe!

For the groups 5, 6, and 7 the oxides of the elements towards the ends of these rows, in particular those of the rightmost elements in the group are Ag, Au, and Hs are good candidates for high T_c superconductors if the TGD based interpretation makes sense. One can also ask whether T_c could be higher for the transition metals of higher groups.

Remark: ORMES are precious metals belonging to 5th and 6th groups of transition metals and claimed to be superconducting at room temperatures. Their claimed healthy effects could be due to the large metabolic energy content of the valence bonds involved liberated when utilized.

3. Anti-ferromagnetism is also essential for Mott insulator property besides the property called “mottism” summarized above. Also copper oxides are anti-ferromagnetic (AFM) and the TGD based model relies on the existence of parallel flux tubes carrying magnetic fluxes with same magnitudes but opposite directions [K33, K34]. The members of Cooper pairs are at different flux tubes and form spin singlets.
4. An intriguing property of Mott insulators is the existence of bosonic excitations with charge $2e$. They must consist of 2 electrons (see <http://tinyurl.com/ydyqunm4>) and are therefore natural candidates for the precursors of Cooper pairs in unconventional superconductivity.

Transition to non-conventional superconductivity

What could happen in the transition to non-conventional superconductivity?

1. Anti-ferromagnetism is a necessary ingredient. It requires the presence of flattened square shaped flux tube loops with opposite directions of magnetic flux for the opposite sides of the flattened square. Also the flux tubes defining the valence bonds and assignable to the magnetic bodies of electrons are present. The temporary reconnection of the valence flux loops would give rise to ohmic conductivity.

Could the valence flux tubes temporarily reconnect with AFM flux tubes inducing the transfer of electrons to them so that supra current would flow along the resulting flux tube pairs and one would have high T_c superconductivity.

There is however an objection against this idea. Valence electrons are responsible for ferromagnetism: can one really distinguish between the AFM flux loops and valence flux loops. Many-sheeted space-time suggests that this is possible. AFM loops would correspond to a higher level in the hierarchy of space-time sheets than valence loops do. Cooper pairs reside at these flux tubes whereas Ohmic current carriers reside at the valence loops.

2. How exactly are the Cooper pairs formed? Are they formed as Cooper pairs with members assignable to neighboring lattice sites and are these pairs transferred to AFM flux tube pairs by temporary reconnections? If so, the basic mechanism giving rise to supra current would be purely topological.

As already mentioned, Mott insulators are characterized by the existence of bosonic excitations with charge $2e$, which must consist of 2 electrons (see <http://tinyurl.com/ydyqunm4>). This would suggest that they are precursors for the Cooper pairs of high T_c superconductors appearing below the upper critical temperature T_{c1} but not yet giving rise to superconductivity in long length scales? The transition to superconductivity for Mott insulators would be analogous to the transition to superconductivity for high T_c superconductors.

3. According to TGD based model of high T_c superconductors [K8, K9, K33, K34] the transition to superconductivity would take place at two steps. At higher critical temperature T_{c1} a phase transition to a state containing Cooper pairs takes place but there is no super-conductivity in long scales yet. Supra currents would be associated with AFM flux loops having the shape of a flattened rectangle such that magnetic fluxes have opposite directions at the opposites sides of the rectangle. At lower temperature T_c a phase transition to a genuine super-conductivity takes place: sequences of the flux loops would reconnect to much longer flux loops making possible macroscopic supra currents.

D.11.4 TGD description for the super-conductivity of graphene

The above general model for high T_c super-conductivity and Mott insulators can be applied also to graphene bi-layer.

1. Graphene sheets are hexagonal lattices formed from aromatic rings of 6 C-atoms. Delocalization occurs for valence electrons inside 6-rings and a further delocalization occurs as the hexagonal lattice is formed and gives rise to conductivity. The current flow would be along routes associated with the flux tube network formed from the hexagons. As already explained, in the TGD based model for valence bonds the value of $h_{eff}/h = n$ is higher for valence bonds than for atoms.
2. For the generic twist angle θ the graphene sheets behave like independent conductors with a weak interaction. For critical twist angles the system behaves as a single coherent unit and becomes Mott insulator. The increase of h_{eff} increases the energy of the valence bond increasing band gap so that it becomes difficult to kick electrons to valence band by thermal energy. Conductivity is lost. The increase of quantum coherence length can however lead to a formation of Cooper pairs (as in Mott insulators quite generally) and an applied electric field can kick the electrons to a new conduction band allowing super-conductivity.
3. The critical twist angle can be understood in terms of a generation of lattice like structure with an increased size of the lattice cell. At the nodes of this super-lattice the carbon atoms of two sheets would be directly above each other. The formation of this super-lattice is known as Moire effect (see <http://tinyurl.com/qchunes>).

Cooper pairs would have periodic wave functions in the superlattice. Wave length would be equal to the lattice constant of the superlattice in the simplest situation. $h_{eff}/h = n$ view about dark matter would suggest that the members of Cooper pair are dark ($n = n_s$) and that the ratio of the lattice cells sizes for super-lattice (l_s) and the original lattice (l) equals to the ratio of corresponding values of n : $l_s/l_1 = n_s/n$.

4. Precursors of the Cooper pairs should be associated with the combination of flux tube networks defined by the two graphene lattices and would be transferred to AFM flux loops having longer length and reconnecting to long flux flux tube pairs.

Since superconductivity occurs only for a critical twist angle, a pairing of flux tubes connecting the nodes of the super-lattice should take place. The members of Cooper pair should be associated with members of these flux tube pairs. The distance between Cooper pairs would have upper bound give by l_s .

D.12 Rydberg polarons as a support for TGD view about space-time

I learned about very weird looking phenomenon (see popular article at <http://tinyurl.com/y96p48u5>) involving Bose-Einstein condensate (BEC) of strontium atoms at ultralow temperature corresponding to $T = 1.5 \times 10^{-7}$ K and thus thermal energy of order 10^{-11} eV. Experimenters create Rydberg atoms by applying a laser beam to BEC of strontium atoms: second valence electron of Sr is kicked to at an orbital with very large classical radius characterized by the principal quantum number n . This leads to a formation of “molecules” of BEC atoms inside the orbit of Rydberg

electron - Rydberg polarons as they are called. The term polaron comes from charge separation in the scale of polaron.

It seems strange that a tiny electron would be able to confine BEC molecules inside its orbit. The Rydberg polaron has several counter intuitive properties distinguishing it from ordinary polarons. Skeptic can also ask whether the formation of Rydberg atoms only makes the detection of BEC molecules possible when the atom to become Rydberg atom belongs to an already existing BEC molecule.

D.12.1 Experimental findings

From the research article [D28] (see <http://tinyurl.com/ybqb7bmrv>) one learns that the experimenters use in a very clever manner the information about low energy scattering of Rydberg atoms in s and p partial waves to deduce so called Born-Oppenheimer potential (BOP). BOP is analogous to that used in molecular physics to deduce electronic states assuming molecular positions fixed. Now however Rydberg state for electron is fixed and one solves the states of BEC in this potential! The idea is that BEC behaves as a single particle. The objection to this is that the states are reported to be more like molecules of some BEC molecules containing also the Rydberg atom.

BOP is a combination of $|\Psi_R|^2$ and $|\nabla\Psi_R|^2$ with coefficients proportional to s- and p-wave scattering lengths A_s and A_p (which is momentum dependent) deduced from the low energy scattering of Rydberg atoms from BEC. The explicit expression for the BOP is given as

$$V(r) = \frac{2\pi\hbar^2}{m_e} [A_s|\Psi_R|^2 + 3A_p|\nabla\Psi_R|^2] . \quad (\text{D.12.1})$$

Here $\Psi(r)$ is the wave function of Rydberg electron. By using rather advanced methods (functional determinant approach (FDA) and mean field theory) the experimenters estimate the bound state energies of BEC atoms in BOP numerically. The bound states would be localized states associated with the minima of the BOP having oscillatory behavior.

The claim is that the experimental findings provide support the existence of these bound states. Usually polarons involve positive energy excitations of the surrounding medium - "cloud" - but now it would be negative energy excitations - bound states - that would be excited. The excitation means that energy is drawn from BEC by dropping some particle to negative energy state: this would be an analog of metabolism.

One can test this proposal experimentally by using two laser beams with frequencies 689 nm and 319 nm. The first beam generates intermediate excitations $5s^2 \rightarrow 5s5p^3P_1$ and latter beam the Rydberg excitations $5s5p^3P_1 \rightarrow 5snp^3S_1$. The frequency of 319 nm beam must be varied to cover the excitations corresponding to various values of n . Since the dependence of the bound states energy is of form $1/n^2$, a rather slight variation is enough to cover a wide range of values of n . One obtains peaks corresponding to various values of n .

The peaks labelled by n have however sub-structure. One can vary the beam frequency slightly downwards from the frequency $\nu_R(n)$, which generates free Rydberg atom. For given n one finds spectral peaks at lower frequencies $\nu = \nu_R(n) - \Delta\nu$. The data is expressed in terms of function $A(\nu)$ telling the intensity of the absorption of laser photons at given frequency ν , and one can estimate binding energies from the values of $\Delta E = h\Delta\nu$. For $n = 38$ $\Delta\nu$ is in the range [1, 40] MHz so that the binding energies ΔE are in the range $[1, 40] \times .4 \times 10^{-8}$ eV. The peak gets narrower for larger values n scaling like $1/n^3$ suggesting that the values of $\Delta\nu$ scales like $1/n^3$.

Remark: This is true for the ordinary value of Planck constant. For non-standard value $\hbar_{eff}/\hbar = n$ of Planck constant the estimate for the binding energies $\Delta E = \hbar_{eff}\Delta\nu$ would be scaled up. This would mean that also the beam energy is scaled up and this looks unrealistic. Since the temperature is extremely low, large $\hbar_{eff}/\hbar = n$ is not needed for macroscopic quantum coherence. Indeed, the thermal wavelength $\sqrt{1/2m_eT}$ of electron giving an idea about the scale of spatial quantum coherence is at the temperature considered of order 100 μm .

Fig. 2 of the article (see <http://tinyurl.com/ybqb7bmrv>) shows for $n = 38$ clearly the peaks at multiples of -5 MHz corresponding to $\Delta E = -2.1 \times 10^{-8}$ eV for the corresponding energy interpreted as binding energy rather than positive excitation energy in the initial state. The appearance of integer multiples suggests that harmonic oscillator excitations involving one or several oscillators are in question. What looks strange that the spectrum of excitations has negative

rather than positive energies. The finding is interpreted as a direct evidence for the existence of BEC molecules - Rydberg polarons predicted by the model based on scattering length data. For a small number of BEC atoms one can even study the molecules.

Remark: The analogy with harmonic oscillator spectrum leads to ask whether a genuine harmonic oscillator spectrum with positive excitation energies could be in question - say cyclotron energy spectrum for electrons in an external magnetic field B_R assignable to the pair of s-wave electrons of Rydberg atom and having therefore positive excitation energies. The interpretation would be in terms of the analog of metabolism analogy also now. The excited Rydberg atom would drop some BEC atoms to lower energy state and in this manner extract energy from BEC.

Authors report several features distinguishing the Rydberg polaron from ordinary polaron. Ordinary polaron corresponds to a ground state of a many-particle system but now one has multiple excitations from the ground state. Also the importance of bound states would distinguish Rydberg polaron from ordinary polarons. A universal behavior of the spectral line shape decreasing like $1/n^3$ as a function of principal quantum number characterizing the Rydberg electron suggests that quantum criticality. Also the narrowing of the spectral features with n is reported.

In the model of experimenters the binding energy spectrum depends on the value of the principal quantum number n since the positions of zeros of $V(r)$ depend on n . Since $V(r)$ is product of exponent function and polynomial of order $2n$, $dV(r)/dr$ has at most $2n - 1$ real zeros and at most n minima. One expects that harmonic oscillator strength has different values for these zeros, which also depends on n . One obtains in harmonic oscillator approximation integer multiples of the basic energy depending on the minimum of $V(r)$.

On basis of the article, I am not able to tell whether the authors have any concrete model for what the assumed (effectively contact -) interaction between the Rydberg atoms and BEC atom is. What this interaction is and how it leads to a generation of bound states (not necessarily!) in the case of BEC atoms but not in the case of ordinary atoms, remains a mystery to me. The question whether TGD might provide some ideas about in this respect, served as the basic motivation for the following considerations. This led to a considerably more detailed understanding about how TGD differs from Maxwellian electrodynamics.

D.12.2 Could TGD say something interesting about Rydberg polarons?

The obvious question in TGD framework is whether this mysterious interaction giving rise to the BEC molecules (or whatever they are) could be understood using the notions of many-sheeted space-time, magnetic flux quanta, and possibly also the identification of dark matter as phases of ordinary matter with non-standard value of $h_{eff}/h = n$.

Some applications of TGD view about space-time

I have applied this general rule in various scales with inspiration coming from the fractality of TGD Universe.

1. Elementary particles correspond in TGD pairs of wormhole contacts connected by flux tubes at both space-time sheets involved. Hadrons involve color flux tube structures carrying most of the energy of the hadron [K24, K27, K28].
2. Atomic nuclei and their dark variants explaining "cold fusion" are nuclear strings [L16, L30]. Dark nuclear strings are also in central role in TGD inspired quantum biology [L44] and their states are in correspondence with DNA, RNA, tRNA, and amino-acids [L23].
3. In TGD based view about chemistry valence bonds correspond to flux tubes with non-standard value of $h_{eff}/h = n$ [L36]. In biology valence bonds are carriers of metabolic energy with n measuring the amount of metabolic energy and increasing along the row of the Periodic Table. The model conforms with empirical facts and explains why the molecules towards the right end of the rows of the Periodic Table are carriers of metabolic energy.
4. Superconductivity and superfluidity are natural applications [K70, K85]. Flux tubes would serve as correlates for the correlation of the members of Cooper pair. In high T_c superconductivity supra currents flow along the flux tubes [K33, K34].

5. In neuroscience and biology the quantum entangled networks of neurons and cells define the correlates of mental images at the level of brain and body and also the part of magnetic body outside biological body is in central role [L29, L45]. Gravitational and other interactions are mediated along flux tubes and here the notion of gravitational (electromagnetic, etc) Planck constant is very useful [K88, K84, K85]. The notion of gravitational Planck constant $\hbar_{eff} = \hbar_{gr}$ is assignable to the flux tubes mediating gravitational interaction and having very large value is involved also with TGD inspired quantum biology and neuroscience [K51, K52].
6. At the second end of the scale hierarchy there is a model for the formation of galaxies as knots of long flux tubes carrying dark energy and dark matter and having stars as sub-knots of these knots. Second example is nuclear physics and its dark variants.

What guidelines to follow?

The listed successful applications encourage to ask whether the TGD could provide a model for Rydberg polaron. There are several guidelines to follow.

1. The key question concerns the role of Rydberg atom. Does its formation lead to the generation of Rydberg molecules or are they already present in BEC. The mechanism for the formation of the Rydberg molecules depends crucially on the answer to this question. If Rydberg atom is necessary, the magnetic field induced by the formation of Rydberg atom could be crucial for understanding what happens. This would also force the interpretation about the role of bound states unless the arrow of geometric time changes temporarily in the process. If Rydberg atom is not necessary, then alternative options can be considered.
2. The notion of cyclotron BEC as a condensate of cyclotron states of charged bosons or Cooper pairs playing important role in TGD inspired biology is of special interest since it could explain the appearance of excitation energies as basic energy identifiable as cyclotron energy. The BECs of electron Cooper pairs and of biologically important ions or their Cooper pairs are central in TGD based of quantum biology and neuroscience. What is encouraging that the energies identified as bound state energies have scale assignable to cyclotron states in magnetic field which is roughly $3.3 \times B_E$, where $B_E \simeq .5$ Gauss is the nominal value of the magnetic field B_E of Earth.

Remark: The strength of B_E varies in the range $[.25, .65]$ Gauss and one cannot exclude the possibility that $B_{end} = .2$ Gauss corresponds to minimum value of B_E achieved at equator. In dipole approximation the strength at poles is two times higher.

3. One can of course argue that the introduction of an external magnetic field is unrealistic. I do not know whether this is the case: dark magnetic fields would not be observable using the detection methods of standard physics. On the other hand, the origin of B_{end} has remained a mystery. Could its flux tubes connect charged particles of opposite spin so that B_R and B_{end} would accompany essentially same physical phenomenon?
4. The analogy with metabolism suggests the possible relevance of zero energy ontology (ZEO) leading to the proposal of what I call remote metabolism involving temporary reversal of the arrow of time at some level of the hierarchy of space-time sheets labelled by preferred p-adic primes and values of n and making possible for the system to extract energy from environment in apparent contradiction with the second law.

In the recent case the problem is that one would expect that the energy of laser photon is shared between the Rydberg atom and other BEC atoms. Just the opposite happens. One might argue that this is not a problem since temperature is so low but I am not certain about this. There is also a second problem: if B_R is responsible for the cyclotron states, then the only sensible interpretation is that the arrow of geometric time is temporarily changed since before its cyclotron BEC providing the “metabolic energy” is not present.

In ZEO “big” state function reduction behind TGD inspired theory of consciousness means temporary reversal of arrow of time for the entire system [L41]. Conscious entity as a generalized Zeno effect in turn would correspond to a sequence of ZEO analogs of weak measurements and dying when the big reduction takes place.

What looks for the observed with standard arrow of time like extraction of metabolic energy from BEC would correspond to sharing it with BEC if the arrow of time changes temporarily. This might relate to the finding that the entanglement between electrons of Sr^+ ions lasts surprisingly long time - 15 seconds. Could this time correspond to the duration of the time reversed state.

5. A further possible guideline comes from the general vision replacing many-particle states with tensor networks [L25] having particles as nodes connected by magnetic flux tubes carrying magnetic flux (possibly monopole flux). The general rule is that if there is quantum correlation/entanglement, it has flux tube as a space-time correlate. The model for valence bond based on $h_{eff}/h = n$ hierarchy could help here although the fact that valence bonds are between atoms with opposite electro-negativities suggests that this is not a correct guide line to follow. One can however ask whether Cooper pair as spin singlet bonded by flux tube might replace the valence bond.

One can imagine several options.

1. The energy scale of the excitations is very low suggesting that magnetic interaction energies are in question. Since Sr atoms have vanishing nuclear magnetic moment, the magnetic field generated by the two s-wave electrons of the Rydberg atom could serve as candidate for this external magnetic field. In Maxwellian framework this option fails but in flux tube picture for the magnetic field created by the electrons the situation changes as already briefly described in the introduction.
2. Could the formation of Rydberg molecules (or whatever they might be) be due to a formation of flux tube contacts between BEC atoms serving as analogs of valence bonds. An immediate objection is that in chemistry valence bond is between states of opposite electronegativity. Pairing might however occur by spin-spin interaction.

Now Maxwellian expression for the magnetic spin-spin interaction energy varies in a range involving 9 orders of magnitude and for the average distance of order $.1 \mu m$ it is several orders of magnitude too low. This means a loss of predictivity. One could imagine for instance a molecule of 3 BEC atoms ABC in which the distances between A and B and A and C would be different: this would give a non-trivial binding energy. Again Fermi statistics is a problem: it seem very difficult to avoid p-wave excitations of electrons.

Flux tubes distinguish TGD microscopically from Maxwell's theory. Could flux tubes be generated between the s-wave electrons of different BEC atoms. Also now the net interaction energy tends to cancel by statistics constraints in Maxwellian approach. TGD based model of superconductivity suggests a solution of the problem: the two s-electrons are condensed at different flux tubes and the spin-spin interaction between them gives rise to binding energy or at least binds them to Cooper pair (strontium-titanate is super-conductor!).

3. TGD inspired quantum biology suggests the most promising approach found hitherto. An external magnetic field would be present: either the Earth's magnetic field B_E with nominal value of .5 Gauss (experimental arrangement might eliminate B_E) or its "endogenous" dark variant with a nominal valued $B_{end} = 2/5 B_E = .2$ Gauss possibly characterized by $h_{eff}/h = n > 1$. Actually B_{end} has spectrum of strengths in TGD inspired quantum biology and explains bio-photons as ordinary photons resulting from dark photons in the transition $n > 1$.

The model of authors could be perhaps understood in terms of negative magnetic dipole interaction energy of electrons with this magnetic field. The two electrons in s^2 state would topologically condense at flux tubes with opposite magnetic fluxes and could have negative spin-spin interaction energy binding them to a Cooper pair. There is however a problem: the shape of the spectral peak depends on the principal quantum number n suggesting that the value of the magnetic field involved behaves like $B \propto 1/n^3$.

Skeptic of course argues that the introduction of external magnetic field is a desperate last attempt before giving up. The origin of B_{end} has however remained a mystery. Could it be that B_R and B_{end} are aspects of the same phenomenon? If so then also the $B \propto 1/n^3$ dependence could be understood.

4. An alternative model gives up the assumption that bound states are in question but allows temporarily time reversal. cyclotron excitations of the BEC condensate containing electrons of the BEC atoms still experiencing the Coulomb force would be in question. Magnetic field with strength $3.3 \times B_E \simeq 8B_{end}$ could explain the frequency spectrum quantitatively as cyclotron energy spectrum so that instead of bound states one would have positive energy states but the metabolic analogy would still apply.

Brief summary of TGD based model

TGD inspired model is based on a more detailed model for flux tubes.

1. The strength of the constant valued flux tube magnetic field B_R associated with the flux tube model of electron plays the role of the physical dipole as a region of constant magnetization associated with a real world dipole field. The flux tube carries a monopole flux made possible by CP_2 topology so that the Maxwellian counterpart does not exist for it. This view about dipole magnetic field is a signature of many-sheeted space-time.
2. One can model the quadrupole field B_R associated with two-sheeted closed flux tube connecting 5s and ns electrons of Rydberg atom. In Maxwellian theory B_R would vanish along the line between the dipoles but in TGD it has opposite directions at parallel (essentially same M^4 projection) space-time sheets so that it vanishes only at QFT limit. The members of BEC s^2 electron pairs topologically condense at separate flux tube sheets to minimize the magnetic interaction energy associated with their spins. This mechanism could also give rise to Cooper pairs. Negative energy spectrum could correspond to a generation of several electron pairs in energy minimum.
3. B_R gives rise to the analog harmonic oscillator potential with ground state energy defined by the interaction energy of spins with B_R . If B_R depends on the distance L between the s-wave electrons of the Rydberg atom in a universal manner $B_R \propto 1/L^{3/2}$, one can understand the universal $1/n^3$ dependence of the width of the observed peak.

The distances associated with the maxima of $|\Psi|^2$ give sub-peaks defining preferred Larmor frequencies so that the structure of the peak gives a map of $|\Psi(r)|^2$. If Rydberg atom moves with respect to BEC, one must add the p-wave contribution just like one does in the model of authors and find maxima for this. The basic difference with respect to the BOP approach of experimenters is that one has maxima rather than minima.

4. ZEO allows also to consider the possibility that the arrow of time is temporarily changed in the state function reduction creating the Rydberg atom: this interpretation would allow the excitation of cyclotron states with reversed arrow of time. For an observer living in standard direction of time the process would look like dropping cyclotron electrons to lower energy states to get surplus energy so that the laser photon energy need be so high. This would give harmonic oscillator spectrum for each electron pair behaving like Cooper pair. It should be easy to experimentally test for the correctness of the two proposals.

D.12.3 Maxwellian and TGD pictures for the magnetic interaction energy

TGD suggests that the proper way to model the spin-spin interaction is to use the flux tube picture. Maxwellian approach provides a second approach and one might hope that it could give a reasonable approximation.

Maxwellian approach

QFT limit of TGD with flux tubes replaced with Maxwellian magnetic fields is expected to give a good approximation of electromagnetic interactions. Therefore it is realistic to start from a Maxwellian picture for the electromagnetic fields. If Maxwellian picture gives reasonable order of magnitude estimates one can hope that also the TGD view based on the notion of magnetic body (MB) does so.

1. The obvious idea is that the magnetic field in atom is created by the total electron current of electrons. In particular, valence electrons give to this kind of current via Maxwell's equations: $\nabla \times B = j_e/4\pi$. This would give connection between electron current and B analogous to that appearing in BOP where modulus squared for electron's Schrödinger amplitude and its gradient appear.

This picture applies also Coulomb interaction: now the charge density of electrons would serve as the source of electric field via $\nabla \cdot E = \rho$.

2. The two electrons of Sr Rydberg atom create a magnetic field, call it B_R . Same applies to the valence electrons of s^2 state of BEC atom. In the first approximation the magnetic moment of the unexcited electron determines the magnetic field at large distances. Since the electron's wave functions depend on the radial coordinate only in s-wave, the current $\vec{j}_e$ due to the gradient of Ψ is radial for both electrons. One can reduce the equation $\nabla \times \vec{B} = \vec{j}_e/4\pi$ to a Laplace equation by using $\vec{B} = \nabla \times \vec{A}$ and Coulomb gauge $\nabla \cdot \vec{A} = 0$. This gives $\nabla^2 \vec{A} = \vec{j}_e \equiv j\vec{r}/4\pi$.

Besides this there is a contribution due to the spin of the electron and in the direction of spin projection for spin eigenstates. In the lowest order approximation the $n = 5$ electron looks like point-like magnetic dipole and generates dipole field. Same in principle applies also in the case of s^2 state of two electrons and also in case of electrons inside [Kr] shell (the electronic configuration of Sr is [Kr] s^2).

I do not know whether the above approach has been proposed earlier. In any case, it could be motivated by the following argument.

1. Also the electrons of BEC atom have spin-spin interaction and the first thing that comes into mind is to estimate its contribution to the energy by taking expectation value in the two fermion state defined by s-wave valence electrons. If the pair of s^2 electrons transforms a Cooper pair, one must be able to estimate the change in energy, in particular spin-spin interaction energy.
2. If found no mention about spin-spin interaction in web but found a popular article telling that the measurement of the spin-spin interaction energy is extremely difficult but was carried for a pair of Sr^+ ions (!) at distance of order $2 \mu\text{m}$ (see <http://tinyurl.com/yasjvufz>): this would partially explain why it has not been calculated. It was also found that the coherence time for entangled electron pair was unexpectedly long: 15 seconds.

In the popular article the calculation of the effect was mentioned to be very difficult. The repulsive interaction between fermions gives a competing contribution which - being expectation of $1/|r_1 - r_2|$ - is finite. As a matter of fact, I realized that the integral defining the expectation value of $1/|r_1 - r_2|^3$ appearing in the expectation value of spin-spin interaction energy in s-wave state in two fermion state diverges logarithmically!

The pragmatic way out of the difficulty would be straightforward: do not try to calculate anything giving an ill-defined answer! To gain more respectability for this view one could formulate the state of affairs as a general rule. One is allowed to estimate only the effects of external fields - say that of nucleus when calculating spin-orbit interaction energy or interactions between atoms - by using this approach. The external field depends in this case on the electron configuration involved so that one cannot regard spin-spin interaction as being due to an external magnetic field.

Atomistic skeptic can however argue that in Born-Oppenheimer approach assumes the configuration of atoms to be given and calculates electron states associated with this and then solves Schrödinger equation for the atoms. Also in the calculation of color-magnetic spin-spin splitting of mesons and baryons this approach is used. Therefore the problem is real and one must solve it.

The proposed approach could however allow to get rid of the divergence associated with spin-spin interaction since the magnetic field determined by the total current defined by electrons gives smoothed out magnetic field free of singularity associated with point-like magnetic dipole.

How flux tubes as mediators of magnetic spin-spin interaction would relate to the Maxwellian picture?

In TGD based approach flux tubes would mediate the magnetic interaction. For two different atoms electrons would be connected by flux tubes and the electrons at its end or possibly moving freely in the interior would interact with essentially 1-D magnetic flux. This picture could apply also to electrons inside single atom. Also Coulomb interaction energy could be estimated in the same manner between electrons of single atom. In the case of separate atoms one can argue that repulsive Coulomb interaction can be neglected in excellent approximation.

Remark: Strong form of holography (SH) implies that at least in the sense of information theory electrons at space-time level can be thought of as being localized at 2-D string world sheets - that is electron states are fixed by 2-D data. In this picture flux tubes are accompanied by fermionic strings with fermions at their ends assignable to the light-like orbits of partonic 2-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. At the level of imbedding space $M^4 \times CP_2$ the spinors characterizing ground states of super-conformal representations are however 8-D and it is these spinors that correspond to those of standard model.

One must have rules for how to replace Maxwellian field with flux tubes.

1. Flux tubes carry a conserved magnetic flux. Therefore the magnetic field is essentially constant inside flux tube and the situation is effectively 1-dimensional. One can consider also the possibility that the magnetic flux is quantized. In TGD framework it is also possible to have closed flux tubes carrying monopole flux looking locally like pair of flux tubes with opposite fluxes: they could appear in super-conductors and in cosmology. No currents are needed to create these magnetic fields made possible by the topology of CP_2 . The cross section of this kind of flux tube is closed 2-surface rather than a disk with holes. For these flux tube pairs Maxwellian limit does not exist.
2. Flux conservation implies that the spin-spin magnetic interaction energy for given flux tube does not depend on distance.
3. There is a distribution of magnetic flux tubes, which should correspond to the Maxwellian field. The intuitive picture is that the density dn/dS of flux tubes normal to given 2-surface having normal direction $\bar{n}$ multiplied by possibly quantized magnetic flux corresponds to the value of Maxwellian magnetic field:

$$\bar{B} \leftrightarrow \frac{dn}{dS} \Phi \bar{n} . \quad (D.12.2)$$

dn/dS would be determined by the wave function for 3-surfaces in the “world of classical worlds” (WCW). This picture would hold true at larger distances from the source - say dipole.

4. Flux tubes field could mimic Maxwellian field with a better accuracy if the flux tubes can branch at larger distances. This would look natural for dipole fields. The outcome be a kind of fractal tree like structure growing in the radial direction. This would involve reduction of the field strength and possible also the net flux which could be large in the vicinity of dipole but reduce later.

This picture generalizes to electric flux tubes/quanta carrying constant electric flux. By effective one-dimensionality the electric potential is proportional to distance along flux tube.

Interesting questions relate to the possibility of space-time sheets parallel in $M^4 \times CP_2$ and having same M^4 projection: at QFT limit they are replaced region of M^4 with deformed metric.

1. One can imagine that both valence electrons with opposite spins are accompanied magnetic flux tubes such that they correspond 4-surfaces on top of each other and extremely near to each other in $M^4 \times CP_2$ such that the magnetic fluxes are in opposite directions but of the same magnitude. At QFT limit the total magnetic field would vanish on test particle if it touches all parallel sheets and experiences the fields from all of them.

2. Consider a situation involving two magnetic flux tubes as different sheets associated with spins in opposite directions so that magnetic fluxes are opposite at them. One can imagine a deformation implying that space-time sheets are not at top of each other. Now the magnetic spin-spin interaction would be non-trivial in these regions and favor the formation of bound state spin singlet identifiable as Cooper pairs. Could energy minimization favor the formation of pairs of this kind of single-sheeted regions? For instance, the formation of groups of BEC atoms connected by flux tubes could involve this mechanism. In the situation when the flux tubes project to same region of M^4 , bound states would not be possible.

What could happen when the Maxwellian approach fails?

To understand the flux tube picture and connect with the Rydberg polaron, it helps to ponder what happens when the Maxwellian approach fails. For the magnetic dipole field the region near the locus of the dipole represents a situation, where Maxwellian description might indeed fail. One can take the TGD inspired model of electron itself as a starting point.

1. Electron (actually any elementary particle) would be a pair of wormhole contacts (I and II with throats I1,I2 and II1,II2) connecting two space-time sheets with electron at the throat I1 of contact I and left-handed neutrino ν_L at throat II1 and right-handed neutrino $\bar{\nu}_R$ at throat II2 of contact II. The flux tubes would carry monopole magnetic flux flowing also through the contacts and stabilizing it: otherwise the space-time sheets would only touch for some time.

In scales shorter than the length L of the flux tubes electron would have also weak isospin. At longer scales electron would effectively have only em charge just as standard model predicts.

2. The flux tubes at given space-time sheet would be a correlate for the dipole assigned with dipole magnetic field and carry a constant flux. This corresponds to constant magnetization for a non-ideal dipole created by an inductance in circuit theory.

Now no current is needed to create the constant magnetic field since monopole flux is in question and the cross section of flux tube is a closed 2-surface. The absence of the current corresponds to the fact that electron's magnetic moment is due to spin and is not created by a current. Monopole flux tube would however give a space-time correlate for the dipole created by spin.

The strength of the magnetic field would be proportional to $1/S$, S the area of the flux tube projection in M^4 . Magnetic dipole would be effectively a pair of magnetic charges (TGD does not however allow isolated magnetic charges) made possible by the topology of CP_2 . For non-standard values of h_{eff} these dipoles could have even macroscopic sizes. Monopole fluxes could explain even the mysterious existence of long length scale magnetic fields in cosmological scales.

D.12.4 A model for Rydberg polaron

The proposed picture for spin dipoles allows to imagine a concrete model for the quadrupole type magnetic field created by a pair of s-wave electrons taken far apart as in the formation of Rydberg atom. This model applies also to Cooper pairs and perhaps even to s^2 pairs of electrons in atom.

1. What happens when one has two electrons identifiable as dipoles with opposite spins as in the case of Rydberg atom? Suppose that the spins are oriented along the connecting line. In the region between electrons the magnetic field vanishes in the Maxwellian world. In many-sheeted space-time it is enough that the magnetic fields have opposite direction but exist as induced magnetic fields at parallel space-time sheets. At QFT limit the field vanishes as sum of these fields.

One could imagine the following model for the resulting magnetic field. The monopole flux tube pairs associated with electrons would reconnect to a single flux tube pair so that the wormhole throats carrying ν_L and $\bar{\nu}_R$ disappear and $\nu_L\bar{\nu}_R$ pairs at throats opposite to electron carrying throats to take care about the vanishing of weak isospin at longer length scales correlating with the massivation causing the short range of weak forces. The magnetic

fields at the opposite throats of both wormhole contacts would have opposite values and at QFT limit the total magnetic field would vanish. This effect is not possible in Maxwellian electrodynamics.

2. The magnetic field would be constant at the flux tubes and equal to $eB = \Phi/S$, $\Phi = BS = n$. One can imagine a topological condensation of the BEC atoms at this flux tube pair. The s^2 electrons of BEC atom would condense at different flux tubes to minimize their magnetic interaction energies $E = -\mu_e \times B$, $\mu_e = e\hbar/2m_e$. Maybe this kind of process could produce the Rydberg polaron.
3. What would be the dependence of the surface area S of the flux tube on the distance L between the electrons? The naïve guess that B has dependence $B \propto 1/L^3$ classically would give $S \propto L^3$. This does not make sense as detailed checks demonstrated.

If I have interpreted correctly the findings about Rydberg atom, the spectral width as the width of absorption spectrum as function of frequency becomes narrower and scales down as $1/n^3$: the experimenters talk about universality. The $B \propto 1/n^3$ scaling of the magnetic interaction energies would explain this. If the magnetic interaction energies are responsible for the observed spectrum then the proportionality of the size scale of Rydberg atom to n^2 would require $S \propto L^{3/2} \propto n^3$. For $n = 38$ one has $\Delta f = -5$ MHz. This gives the rough estimate

$$\frac{\mu_B \Phi}{S(n=38)} = \frac{\mu_B \Phi}{\pi R^2(n=5)} \left(\frac{5}{38}\right)^3 = 2.1 \times 10^{-8} \text{ eV} .$$

This condition fixes the radius $R(n=5)$ of the flux tube at distance $L(n=5) \sim 6.3$ Angstrom to be $R \simeq 10^4 a_0 \simeq .5 \mu\text{m}$. More generally, the basic length scales of biology might be hidden to many-sheeted atomic physics.

4. One could hope that this dependence of S on the distance L between electrons of opposite spin with the line connecting the electrons serving as quantization axis is universal. Could this idea have some explanatory power?

In TGD inspired quantum biology one encounters the notion of endogenous magnetic field $B_{\text{end}} = 2/5 B_E$, which is roughly by factor $x = 1/7.5 \sim 2^{-3}$ weaker than $B(n=38)$. As a matter of fact, B_{end} must have spectrum reflected directly in the spectrum of bio-photons in visible and UV [K51, K52] and in the spectrum of audible frequencies [K35]. The origin of this magnetic field has remained a mystery. Could it correspond to a magnetic field associated with a flux tube connecting electron dipoles with opposite directions at distance L_{end} ?

The proposed model would give the factor

$$x = \frac{S(38)}{S} = \left(\frac{L(38)}{L_{\text{end}}}\right)^{3/2}$$

allowing to estimate corresponding distance L_{end} between electrons as

$$L_{\text{end}} = x^{-2/3} L(38) = 4 \times L(38) = \left(\frac{38}{5}\right)^2 L(5) \simeq 231 L(5) .$$

Assuming that Sr atom behaves for $n = 5$ state like hydrogen atom with effective nuclear charge $Z_{\text{eff}} = 2$ (screening would be due to [Kr] shell), one obtains a rough estimate for $L(5)$ would be $5^2 a_0 / 2 \simeq 6.3$ Angstrom. This would give $L_{\text{end}} \sim 1.5 \mu\text{m}$. It is encouraging that this corresponds to the p-adic length scale $L(169) \simeq 1.5 \mu\text{m}$ assignable to cell nucleus size. Note that the p-adic length scale $L(167) = 2.5 \mu\text{m}$ corresponds to Gaussian Mersenne $M_{G,n=167} = (1+i)^n - 1$.

The factor 2 would suggest that the B_{end} corresponds to Rydberg atom with $n = 2 \times 38 = 76$. This is only a rough estimate: the estimate for $L(5)$ assumes hydrogen-like atom and this assumes is only approximate since the s^2 electrons spend considerable time inside [Kr] shell which tends to reduce the radius $L(5)$. An interesting question concerns the identification of

Rydberg atom(s) possibly responsible for the generation of B_{end} . The spectrum for $B_{end}(n)$ would be of form $1/n^3$. For given n there would be a spectrum along the n :th row of Periodic Table.

Spin-spin interaction energy at temperature of 1.5×10^{-11} eV would correspond to an energy which is by a factor 10^{-3} lower than that associated with $L(n = 38)$. This corresponds to the scaling $n \rightarrow 10n$ and $L(38) \rightarrow 100L(38)$.

5. In the realistic situation the Rydberg electron has wave function Ψ . $|\Psi|^2$ has several maxima and minima which correspond to zeros for a polynomial closely related to the square of Laguerre polynomial and having degree $2n$ so that the number of real maxima would be at most $n - 1$. One would have a quantum superposition of also flux tube pairs with different lengths L .

The flux tube lengths L associated with the maxima would be visible as peaks in the absorption spectrum. One would have peaks at the corresponding Larmor frequencies (and possibly also cyclotron frequencies if temporary time reversal takes place). This picture includes only s wave scattering length and the reason would be that one indeed has pure s -wave electrons.

The BOP of authors includes also a term proportional to p -wave scattering length: one must add to Ψ a term proportional to the gradient of Ψ representing the change of the wave function due to the motion. When the Rydberg atom moves with respect to BEC, the wave function has also p -wave component and the scattering length A_p is indeed momentum dependent going to zero at the limit of vanishing momentum. If one can neglect the cross terms proportional to $p \cdot (\bar{\Psi} \nabla \Psi + c.c)$ one obtains the BOP. It therefore seems that TGD might be able to explain the basic properties of the Rydberg polaron.

To sum up, Rydberg polaron could provide a clearcut evidence for the notions of many-sheeted space-time, flux tube, and ZEO and also allow to assign “endogenous” magnetic fields to Rydberg atoms.

Acknowledgements

I am grateful for Hafedh Abdelmelek and his collaborators for sharing their experimental data about effective super-conductivity in sciatic nerves as for collaboration. I want to thank also Lian Sidorov for very fruitful discussions.

Appendix E

Quantum Hall effect and Hierarchy of Planck Constants

E.1 Introduction

Quantum Hall effect [D81, D87, D17] 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 coefficient 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 [D22] (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 manner in the Nobel lecture (see <http://tinyurl.com/y8mvdxpj>) of Horst L. Stormer [D58]. As a matter fact, I regret that I did not read it for years ago!

E.1.1 Abelian And Non-Abelian Anyons

The model explaining FQHE is based on pseudo particles known as anyons identifiable as magnetic vortices [A18] , [D81]. According to the general argument of [D96] 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 [A18] 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 $Q = \nu e$ [D33]. This finding favors non-Abelian models [D17].

Non-Abelian anyons [D81, D82] 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 [D83]. 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.

E.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 imbedding 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 $1 \rightarrow n_a$ correspondence and at the space-like ends of the space-time surface at light-like boundaries of causal diamond one has $1 \rightarrow n_b$ correspondence. This implies that at partonic 2-surfaces defined as the intersections of these two kinds of 3-surfaces one has $1 \rightarrow n_a \times n_b$ correspondence. This correspondence can be described by using a local singular n -fold covering of the imbedding 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 states 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>) [D82] 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 correspond to that of 4-fold covering space of imbedding 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 [K12, K45, K57] 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 multi-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> [L11].

E.2 Fractional Quantum Hall Effect

E.2.1 Basic Facts About FQHE

E.2.2 A Simple Model For Fractional Quantum Hall Effect

Recall first the basic facts. Quantum Hall effect (QHE) [D81, D3, D87] 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

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} , \\ \nu &= \frac{n}{m} . \end{aligned} \tag{E.2.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15, \dots, 2/3, 3/5, 4/7, 5/9, 6/11, 7/13, \dots, 5/3, 8/5, 11/7, 14/9, \dots, 4/3, 7/5, 10/7, 13/9, \dots, 1/5, 2/9, 3/13, \dots, 2/7, 3/11, \dots, 1/7, \dots$ with odd denominator have been observed [D3]. 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 is 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 function predicting fractional quantum Hall effect for filling fractions $\nu = 1/m$ [D87]. The model of Laughlin [D87] cannot explain all observed filling fractions.
2. The best existing model proposed originally by Jain [D68] is based on the notion of composite fermion. These would result as bound states of electron and even number of magnetic flux quanta [D68]. 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 Wilczek [D81]. 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 [K59, K58] , [B14], [C3] is one of the most fascinating applications of FQHE. It relies on the notion of braids with strands representing the orbits 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 [D17, D33].

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 Newton's 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

$$\sigma_{xy} = \frac{\rho}{B} = e^2 \frac{N}{\Phi} \quad , \quad \Phi = eBS = e \int B dS \quad .$$

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 conclude that N equals to integer multiple of $h\Phi$.

2. Consider next a quantum explanation. Choose the coordinates of the current carrying 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 $\sigma = j_y/E_x = n_e e v / v B = n_e e / B = Ne^2 / h e B S = Ne^2 / m h$, where 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

$$\Psi \propto \exp(iky) H_n(x + kl^2) \exp\left(-\frac{(x+kl^2)^2}{2l^2}\right) \quad , \quad l^2 = \frac{\hbar}{eB} \quad . \quad (\text{E.2.2})$$

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.

E.2.3 The Model Of FQHE Based On Composite Fermions

The model of FQHE based on composite 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/y8mvdxpj>) of Horst L. Stormer [D58].

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} [D68] with even number $2p$ flux quanta subtracted. B_{eff} is given by

$$B_{eff} = B - 2pB_1, \quad B_1 = \rho\Phi_0, \quad \Phi_0 = h/e. \quad (E.2.3)$$

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

$$\nu = \frac{\nu_{eff}}{1 + 2p\nu_{eff}} = \frac{n}{1 + 2pn}. \quad (E.2.4)$$

The formula is amazingly simple and consistent with all experimental findings hitherto. Note that at the limit $n \rightarrow \infty$ 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 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?

E.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.

E.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 [A18], [D81]. 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 $G \rightarrow H$ 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 [D81] 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 $G \rightarrow H$ defines a representation of the braid group. The construction of these representations is discussed in [D81] 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.

E.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

$$\frac{k}{4\pi} \text{Tr} \left(A \wedge (dA + \frac{2}{3} A \wedge A) \right)$$

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 [A5, A22] 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 $SU(2)_q$ 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 [K64].

Witten's article [A10] "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 [A24]. 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 [K64]. 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].

E.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 [D87]. 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 [A18] 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.

E.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 [D83]. 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 [B23]. 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 [B24]. 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.

E.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 [D81, D3, D87] 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 [D58]) - 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 imbedding 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.

E.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. A.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 [K58].

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 astrophysical 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.

E.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 $2/\pi i$ 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 $n \rightarrow \infty$ 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 [K45]. 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 imbedding 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 [K94].

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 $q = \exp(i2\pi/n)$ [K45].

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 composite 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 hierarchy of Planck constants? The proposal is that $h_{eff} = n \times h$ corresponds to a formation of effective n -sheeted covering of imbedding 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/ybml3d3hw>) [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.

E.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/ybk5rkf1>) [D38].

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 the 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 [K45]. 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 [K34] 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 $1/h$.

E.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 [D40] (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 [D94] (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 as second Chern number [D70]- 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.

E.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 [D40] (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 cylinders 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.

E.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 [L36].

The binding energy spectrum changes dramatically in other dimensions. In particular, in dimension $D = 4$ the dependence of binding energies on Planck constant is not a power law as it is in other dimensions [L24] (see <http://tinyurl.com/yam7rbk6>). The energies of the hydrogen atom depend on $\hbar_{eff} = n \times \hbar$ 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 $E_n \propto (\hbar_{eff}/\hbar)^m$, $m = 2 + 4/(D - 4)$. 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 [L26]. The temporary reduction of n makes possible biocatalysis 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 [L32] 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 [L41] (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 the 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 $X^4 \rightarrow CP_2$ 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 $CP_2 \rightarrow M^4$. 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 $M^4 \rightarrow CP_2$ can be however multiple-valued such that the branches co-index in S .

Consider first Minkowskian signature for the induced metric, that is maps representable as graphs $M^4 \rightarrow CP_2$ (note that locally also the representation as map $CP_2 \rightarrow M^4$ are possible at points where the instanton density is non-vanishing).

1. One must allow multiple-valued maps $M^4 \rightarrow CP_2$. 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 coincide.

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-vanishing 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 $M^4 \rightarrow CP_2$ or $CD \rightarrow CP_2$ with winding number n very probably do not exist [L22] (see <http://tinyurl.com/yboog5sr>).
3. At QFT limit one consider only Minkowskian 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 $CP_2 \rightarrow M^4$ 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 imbedding 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.

Appendix i

Appendix

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 regard as 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 imbedding space and related spaces are discussed and the relationship of CP_2 to standard model is summarized. 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. 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. Hierarchy of Planck constants can be now understood in terms of the non-determinism of Kähler action and the recent vision about connections to other key ideas is summarized.

A-1 Imbedding Space $M^4 \times CP_2$ And Related Notions

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 imbedding 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. Imbedding 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) 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 [A15] 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 Basic Facts About CP_2

CP_2 as a four-manifold is very special. The following arguments demonstrates that it codes for the symmetries of standard models via its isometries and holonomies.

A-2.1 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

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) . \quad (\text{A-2.1})$$

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 homeomorphic 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 [A11] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it , \\ \xi^2 &= x + iy . \end{aligned} \quad (\text{A-2.2})$$

These are related to the “spherical coordinates” via the equations

$$\begin{aligned} \xi^1 &= r \exp(i \frac{(\Psi + \Phi)}{2}) \cos(\frac{\Theta}{2}) , \\ \xi^2 &= r \exp(i \frac{(\Psi - \Phi)}{2}) \sin(\frac{\Theta}{2}) . \end{aligned} \quad (\text{A-2.3})$$

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 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. <http://tgdtheory.fi/appfigures/cp2.jpg>

A-2.2 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

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b, \quad (\text{A-2.4})$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K, \quad (\text{A-2.5})$$

where the function K , Kähler function, is defined as

$$\begin{aligned} K &= \log(F), \\ F &= 1 + r^2. \end{aligned} \quad (\text{A-2.6})$$

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

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2 \sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F}, \quad (\text{A-2.7})$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2 \sigma_1 &= \text{Im}(\xi^1 d\xi^2 - \xi^2 d\xi^1), \\ r^2 \sigma_2 &= -\text{Re}(\xi^1 d\xi^2 - \xi^2 d\xi^1), \\ r^2 \sigma_3 &= -\text{Im}(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2). \end{aligned} \quad (\text{A-2.8})$$

R denotes the radius of the geodesic circle of CP_2 . The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A, \quad (\text{A-2.9})$$

are given by

$$\begin{aligned} e^0 &= \frac{dr}{F}, & e^1 &= \frac{r\sigma_1}{\sqrt{F}}, \\ e^2 &= \frac{r\sigma_2}{\sqrt{F}}, & e^3 &= \frac{r\sigma_3}{F}. \end{aligned} \quad (\text{A-2.10})$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \frac{dr}{F}, & e^1 &= \frac{r(\sin\Theta \cos\Psi d\Phi + \sin\Psi d\Theta)}{2\sqrt{F}}, \\ e^2 &= \frac{r(\sin\Theta \sin\Psi d\Phi - \cos\Psi d\Theta)}{2\sqrt{F}}, & e^3 &= \frac{r(d\Psi + \cos\Theta d\Phi)}{2F}. \end{aligned} \quad (\text{A-2.11})$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + \cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + \sin^2\Theta d\Phi^2) . \quad (\text{A-2.12})$$

The vierbein connection satisfying the defining relation

$$de^A = -V_B^A \wedge e^B , \quad (\text{A-2.13})$$

is given by

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} , & V_{23} &= \frac{e^1}{r} , \\ V_{02} &= -\frac{e^2}{r} , & V_{31} &= \frac{e^2}{r} , \\ V_{03} &= (r - \frac{1}{r})e^3 , & V_{12} &= (2r + \frac{1}{r})e^3 . \end{aligned} \quad (\text{A-2.14})$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= e^0 \wedge e^1 - e^2 \wedge e^3 , & R_{23} &= e^0 \wedge e^1 - e^2 \wedge e^3 , \\ R_{02} &= e^0 \wedge e^2 - e^3 \wedge e^1 , & R_{31} &= -e^0 \wedge e^2 + e^3 \wedge e^1 , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 , & R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 . \end{aligned} \quad (\text{A-2.15})$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -ig_{a\bar{b}}d\xi^a d\bar{\xi}^b , \quad (\text{A-2.16})$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J_r^k J^{rl} = -s^{kl} . \quad (\text{A-2.17})$$

The form J is integer valued and by its covariant constancy satisfies free Maxwell equations. Hence it 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). Locally one has therefore

$$J = dB , \quad (\text{A-2.18})$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

It should be noticed that 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

$$\begin{aligned} B &= 2re^3 , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + \cos\Theta d\Phi) + \frac{r^2}{2F} \sin\Theta d\Theta d\Phi . \end{aligned} \quad (\text{A-2.19})$$

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 coordinates in which 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

$$\begin{aligned}
P_1 &= -\frac{1}{1+r^2} , \\
P_2 &= \frac{r^2 \cos \Theta}{2(1+r^2)} , \\
Q_1 &= \Psi , \\
Q_2 &= \Phi .
\end{aligned} \tag{A-2.21}$$

A-2.3 Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A6]. 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 : $e^A = R_B^A e^B$ 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 $R_B^A(v)$ 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 $\text{Spin}(4)$ (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 $\text{Spin}(4)$ 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 $B/2$.

A-2.4 Geodesic Sub-Manifolds Of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the imbedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h_α^k (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 [A21] 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

$$[X, [Y, Z]] \in t \text{ for } X, Y, Z \in t . \quad (\text{A-2.22})$$

$SU(3)$ 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

$$S_I^2 : \xi^1 = \bar{\xi}^2 \text{ or equivalently } (\Theta = \pi/2, \Psi = 0) ,$$

$$S_{II}^2 : \xi^1 = \xi^2 \text{ or equivalently } (\Theta = \pi/2, \Phi = 0) .$$

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_I^2 . S_{II}^2 is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-3 CP_2 Geometry And Standard Model Symmetries

A-3.1 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 [B21] 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

$$\begin{aligned} \Gamma \Psi &= e \Psi , \\ e &= \pm 1 , \end{aligned} \quad (\text{A-3.1})$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \times \gamma_5$, $1 \times \gamma_5$ and $\gamma_5 \times 1$ 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: $SO(4) = SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) . \quad (\text{A-3.2})$$

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

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} , & V_{23} &= \frac{e^1}{r} , \\ V_{02} &= -\frac{e^2}{r} , & V_{31} &= \frac{e^2}{r} , \\ V_{03} &= (r - \frac{1}{r})e^3 , & V_{12} &= (2r + \frac{1}{r})e^3 , \end{aligned} \quad (\text{A-3.3})$$

and

$$B = 2re^3 , \quad (\text{A-3.4})$$

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

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 , \quad (\text{A-3.5})$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} . \end{aligned} \quad (\text{A-3.6})$$

A_{ch} is clearly left handed so that one can perform the identification

$$W^{\pm} = \frac{2(e^1 \pm ie^2)}{r} , \quad (\text{A-3.7})$$

where $W^{\pm}$ denotes the charged intermediate vector boson.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$\begin{aligned} X &= re^3 , \\ Y &= \frac{e^3}{r} , \end{aligned} \quad (\text{A-3.8})$$

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

$$\begin{aligned} \bar{\gamma} &= aX + bY , \\ \bar{Z}^0 &= cX + dY , \end{aligned} \quad (\text{A-3.9})$$

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

$$\begin{aligned}
A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\
&+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 .
\end{aligned}
\tag{A-3.10}$$

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

$$c = -d . \tag{A-3.11}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0 (I_L^3 - \sin^2 \theta_W Q_{em}) . \tag{A-3.12}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{aligned}
Q_{em} &= \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} , \\
I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} .
\end{aligned}
\tag{A-3.13}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned}
\gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) , \\
Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) .
\end{aligned}
\tag{A-3.14}$$

The value of the Weinberg angle is given by

$$\sin^2 \theta_W = \frac{3b}{2(a+b)} , \tag{A-3.15}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of Weinberg angle is a dynamical problem. The angle is completely fixed once the YM action is fixed by requiring that action contains no cross term of type γZ^0 . Pure symmetry non-broken electro-weak YM action 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.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) , \tag{A-3.16}$$

where one has

$$\begin{aligned}
R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) , \\
R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) , \\
J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) ,
\end{aligned}
\tag{A-3.17}$$

in terms of the fields γ and Z^0 (photon and Z - boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - \sin^2\theta_W Q_{em}) . \quad (\text{A-3.18})$$

Evaluating the expressions above one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - \sin^2\theta_W R_{12} , \\ Z^0 &= 2R_{03} . \end{aligned} \quad (\text{A-3.19})$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + \sin^2\theta_W Z^0) . \quad (\text{A-3.20})$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} , \\ L_{sym} &= \frac{1}{4g^2} \text{Tr}(F^{\alpha\beta} F_{\alpha\beta}) , \end{aligned} \quad (\text{A-3.21})$$

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

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} , \\ K &= \text{Tr} [Q_{em}(I_L^3 - \sin^2\theta_W Q_{em})] , \end{aligned} \quad (\text{A-3.22})$$

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18 + 2n_i^2)\sin^2\theta_W}{9} \right] , \quad (\text{A-3.23})$$

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

$$\sin^2\theta_W = \frac{9 \sum_i 1}{(fg^2 + 2 \sum_i (18 + n_i^2))} . \quad (\text{A-3.24})$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$\sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} . \quad (\text{A-3.25})$$

The bare value of the Weinberg angle is $9/28$ in this scenario, which is quite close to the typical value $9/24$ of GUTs [B5] .

A-3.2 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

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi . \quad (\text{A-3.26})$$

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

$$\begin{aligned} m^k &\rightarrow T(M^k) , \\ \xi^k &\rightarrow \bar{\xi}^k , \\ \Psi &\rightarrow \gamma^1 \gamma^3 \otimes 1 \Psi . \end{aligned} \quad (\text{A-3.27})$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2 :

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k , \\ \Psi &\rightarrow \Psi^\dagger \gamma^2 \gamma^0 \otimes 1 . \end{aligned} \quad (\text{A-3.28})$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-4 The Relationship Of TGD To QFT And String Models

TGD could be seen as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

Fig. 5. TGD replaces point-like particles with 3-surfaces. <http://tgdtheory.fi/appfigures/particleetgd.jpg>

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 completely unique position as far as symmetries are considered.

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 TGD Universe and 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 situation in Minkowskian regions of space-time surface. <http://tgdtheory.fi/appfigures/fermistring.jpg>

TGD based view about elementary particles has two aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidian 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. Fermion number is carried by the modes of the induced spinor field. In Minkowskian space-time regions the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle corresponds 4-D generalization of world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidian 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 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 hadronic string as physical counterpart. Long strings should be distinguished from wormhole contacts which due to their superconformal 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 particle 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 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.

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 imbedding 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 of imbedding space at their image points. In the recent case the imbedding of space-time surface to imbedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the imbedding space to the space-time surface (see **Fig. ??**).

Induction procedure makes sense also for the spinor fields of imbedding 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 imbedding 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>

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

$$\gamma = \left(\frac{3}{4} - \frac{\sin^2(\theta_W)}{2}\right)Z^0 \simeq \frac{5Z^0}{8} \quad .$$

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-5.1 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 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 imbedding 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 them 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 than 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 imbedding 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 general 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-5.2 Imbedding 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 imbedding 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 imbedding 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 of 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 imbedding space spinor connection carries W gauge potentials one can say that the imbedding 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-5.3 Space-Time Surfaces With Vanishing Em, Z^0 , Or Kähler Fields

In the following the induced gauge fields are studied for general space-time surface without assuming the extremal property. In fact, extremal property reduces the study to the study of vacuum extremals and surfaces having geodesic sphere as a CP_2 projection and in this sense 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

$$\begin{aligned} J &= \frac{r}{F^2} dr \wedge (d\Psi + \cos(\Theta)d\Phi) + \frac{r^2}{2F} \sin(\Theta)d\Theta \wedge d\Phi , \\ F &= 1 + r^2 . \end{aligned} \quad (\text{A-5.1})$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3 + 2p) \frac{r}{F^2} dr \wedge (d\Psi + \cos(\Theta)d\Phi) + (3 + p) \frac{r^2}{2F} \sin(\Theta)d\Theta \wedge d\Phi , \\ p &= \sin^2(\Theta_W) , \end{aligned} \quad (\text{A-5.2})$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi , \\ (3 + 2p) \frac{1}{r^2 F} (d(r^2)/d\Theta)(k + \cos(\Theta)) + (3 + p) \sin(\Theta) &= 0 , \end{aligned} \quad (\text{A-5.3})$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} , \\ X &= D \left[\frac{(k+u)}{C} \right]^\epsilon , \\ u &\equiv \cos(\Theta) , \quad C = k + \cos(\Theta_0) , \quad D = \frac{r_0^2}{1+r_0^2} , \quad \epsilon = \frac{3+p}{3+2p} , \end{aligned} \quad (\text{A-5.4})$$

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

$$\text{sign}(u+k) \times \left[\frac{1+r_0^2}{r_0^2} \right]^{\frac{3+2p}{3+p}} \leq k+1 \quad ,$$

where $\text{sign}(x)$ denotes the sign of x .

The expressions for Kähler form and Z^0 field are given by

$$\begin{aligned} J &= -\frac{p}{3+2p} X du \wedge d\Phi \quad , \\ Z^0 &= -\frac{6}{p} J \quad . \end{aligned} \tag{A-5.5}$$

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:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2} (k+u) \frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \quad , \\ r &= \sqrt{\frac{X}{1-X}} \quad , \quad X = D|k+u| \quad , \\ \gamma &= -\frac{p}{2} Z^0 \quad . \end{aligned} \tag{A-5.6}$$

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

$$\begin{aligned} ds_{eff}^2 &= (s_{rr} (\frac{dr}{d\Theta})^2 + s_{\Theta\Theta}) d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi}) d\Phi^2 = \frac{R^2}{4} [s_{\Theta\Theta}^{eff} d\Theta^2 + s_{\Phi\Phi}^{eff} d\Phi^2] \quad , \\ s_{\Theta\Theta}^{eff} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X \right] \quad , \\ s_{\Phi\Phi}^{eff} &= X \times [(1-X)(k+u)^2 + 1 - u^2] \quad , \end{aligned} \tag{A-5.7}$$

and is useful in the construction of vacuum imbedding of, say Schwartzchild 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

$$\begin{aligned}\Psi &= \omega_2 m^0 + k_2 m^3 + n_2 \phi + \text{Fourier expansion} , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1 \phi + \text{Fourier expansion} .\end{aligned}\tag{A-5.8}$$

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 imbedding for, say a constant magnetic field. Although global imbedding 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

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 ,\tag{A-5.9}$$

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-6 P-Adic Numbers And TGD

A-6.1 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 [A4]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k \geq k_0} x(k) p^k, \quad x(k) = 0, \dots, p-1 .\tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| = p^{-k_0(x)} . \quad (\text{A-6.2})$$

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

$$x = p^{k_0} \varepsilon(x) , \quad (\text{A-6.3})$$

where $\varepsilon(x) = k + \dots$ 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:

$$d(x, z) \leq \max\{d(x, y), d(y, z)\} . \quad (\text{A-6.4})$$

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

$$d(x, y) \leq D . \quad (\text{A-6.5})$$

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.

A-6.2 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.

Basic form of canonical identification

There exists a natural continuous map $I : R_p \rightarrow R_+$ 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

$$\begin{aligned} y &= \sum_{k > N} y_k p^k \rightarrow x = \sum_{k < N} y_k p^{-k} , \\ y_k &\in \{0, 1, \dots, p-1\} . \end{aligned} \quad (\text{A-6.6})$$

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 ($1 = 0.999\dots$) for the real numbers x , which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^N x_k p^{-k} , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,\dots} p^{-k} . \end{aligned} \quad (\text{A-6.7})$$

The p-adic images associated with these expansions are different

$$\begin{aligned} y_1 &= \sum_{k=N_0}^N x_k p^k , \\ y_2 &= \sum_{k=N_0}^{N-1} x_k p^k + (x_N - 1)p^N + (p-1)p^{N+1} \sum_{k=0,\dots} p^k \\ &= y_1 + (x_N - 1)p^N - p^{N+1} , \end{aligned} \quad (\text{A-6.8})$$

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.

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-6.2**) 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:

$$\begin{aligned} (x+y)_R &\leq x_R + y_R, \\ |x|_p |y|_R \leq (xy)_R &\leq x_R y_R, \end{aligned} \quad (\text{A-6.9})$$

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).

$$\begin{aligned} (x+y)_R &\leq x_R + y_R, \\ |\lambda|_p |y|_R \leq (\lambda y)_R &\leq \lambda_R y_R, \end{aligned} \quad (\text{A-6.10})$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = \left(\sum_n x_n^2 \right)_R. \quad (\text{A-6.11})$$

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.

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

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \quad (\text{A-6.12})$$

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.

Generalization of number concept and notion of imbedding 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 imbedding 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 imbedding 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 $e^p \bmod p = 1$.

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 imbedding 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.

A-6.3 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 vreaks general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic imbedding space with chart maps to real imbedding space and assuming preferred coordinates made possible by isometries of imbedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-7 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 might be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierarchy 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-determinism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manifolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2 . For a given 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 imbedding 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 (Minkowskian 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 imbedding space. A stronger assumption would be that they are expressible 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 imbedding 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-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 from 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 communicate 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/reconnect2.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 $\hbar_{eff}$ 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 imbedding 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 thought, 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 possibility 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 intentional 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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