GENES AND MEMES: PART II

Matti Pitkänen

Rinnekatu 2-4 A 8, Karkkila, 03620, Finland

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0.1 PREFACE

Brief summary of TGD

Towards the end of the year 2023 I became convinced that it would be appropriate to prepare collections about books related to TGD and its applications. The finiteness of human lifetime was my first motivation. My second motivation was the deep conviction that TGD will mean a revolution of the scientific world view and I must do my best to make it easier.

The first collection would relate to the TGD proper and its applications to physics. Second collection would relate to TGD inspired theory of consciousness and the third collection to TGD based quantum biology. The books in these collections would focus on much more precise topics than the earlier books and would be shorter. This would make it much easier for the reader to understand what TGD is, when the time is finally mature for the TGD to be taken seriously. This particular book belongs to a collection of books about TGD proper.

The basic ideas of TGD

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 in the 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 45 years of my life to this enterprise and am still unable to write The Rules.

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

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of the embedding 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, the mainstream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to the same multiplet of the gauge group implying instability of the proton.

Instead of trying to describe in detail the path, which led to TGD as it is now with all its side tracks, it is better to summarize the recent view which of course need not be final.

TGD can be said to be a fusion of special and general relativities. The Relativity Principle (Poincare Invariance) of Special Relativity is combined with the General Coordinate Invariance and Equivalence Principle of General Relativity. TGD involves 3 views of physics: physics geometry, physics as number theory and physics as topological physics in some sense.

Physics as geometry

"Geometro-" in TGD 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. 12**). 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 $H = M^4 \times CP_2$ [L214]. 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 [L68, L96](see **Fig. 13**). 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. 14**). The mere mathematical existence of WCW geometry requires that it has maximal isometries, which together twistor lift and number theoretic vision fixes it uniquely [L215].
- General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. A 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 [K132, L118].
- 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 in all scales. 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 the phases of ordinary matter predicted by the number theoretic vision and behaving like dark matter but identifiable as matter explaining the missing baryon problem whereas the galactic dark matter would correspond to the dark energy assignable monopole flux tubes as deformations of cosmic strings. 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 p-adic physics solved this problem in terms of p-adic thermodynamics [K33, K68] [L198].
- One of the most recent discoveries of classical TGD is exact general solution of the field equations. Holography can be realized as a generalized holomorphy realized in terms of what I call Hamilton-Jacobi structure [L206]. Space-time surfaces correspond to holomorphic imbeddings of the space-time surface to H with a generalized complex structure defined by the vanishing of 2 analytic functions of 4 generalized complex coordinates of H. These surfaces are automatically minimal surfaces. This is true for any general coordinate invariant action constructed in terms of the induced geometric structures so that the dynamics is universal. Different actions differ only in the sense that singularities at which the minimal surface property fails depend on the action. This affects the scattering amplitudes, which can be constructed in terms of the data related to the singularities [L218].
- Generalized conformal symmetries define an extension of conformal symmetries and one can assign to them Noether charges. Besides this the so called super-symplectic symmetries associated with $\delta M_+^4 \times CP_2$ define isometries of the "world of classical worlds" (WCW), which by holography is essentially the space of Bohr orbits of 3-surfaces as particles so that quantum TGD is expected to reduce to a generalization of wave mechanics.

Physics as number theory

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.

Adelic physics [L66, L67] fusing real and various p-adic physics is 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 words". 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 arbitarily long scales. These two hierarchies are closely related. p-Adic primes correspond to ramified primes for a polynomial, whose roots define the extension of rationals: for a given extension this polynomial is not unique.

$M^8 - H$ duality

The concrete realization of the number theoretic vision is based on $M^8 - H$ duality (see **Fig. 15**). What the precise form is this duality is, has been far from clear but the recent form is the simplest one and corresponds to the original view [L217]. M^8 corresponds to octonions O but with the number theoretic metric defined by $Re(o^2)$ rather than the standard norm and giving Minkowskian signature.

The physics in M^8 can be said to be algebraic whereas in H field equations are partial differential equations. 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.** 16). p-Adic physics is an essential part of number theoretic vision and the space-time surfaces are such that at least their M^8 counterparts exists also in p-adic sense. This requires that the analytic function defining the space-time surfaces are polynomials with rational coefficients.

 M^8-H duality relates two complementary visions about physics (see Fig. 17), and can be seen as a generalization of the momentum-position duality of wave mechanics, which fails to generalize to quantum field theories (QFTs). M^8-H duality applies to particles which are 3-surfaces instead of point-like particles.

p-Adic physics

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

If one requires consistency of Negentropy Mazimization 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.

Hierarchy of Planck constants labelling phases ordinary matter dark matter behaving like dark matter

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.

TGD as an analog of topological QFT

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 $H = M^4 \times CP_2$. Since induced metric is involved with TGD, it is too much to say that TGD is topological QFT but one can for instance say, that space-time surfaces as preferred extremals define representatives for 4-D homological equivalence classes.

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. 18**).

Any GCI action satisfying holography=holomorphy principle has the same universal basic extremals: CP_2 type extremals serving basic building bricks of elementary particles, cosmic strings and their thickenings to flux tubes defining a fractal hierarchy of structure extending from CP_2 scale to cosmic scales, and massless extremals (MEs) define space-time correletes for massless particles. World as a set or particles is replaced with a network having particles as nodes and flux tubes as bonds between them serving as correlates of quantum entanglement.

"Topological" could refer also to p-adic number fields obeying p-adic local topology differing radically from the real topology (see **Fig. 19**).

Zero energy ontology

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.

General coordinate invariance leads to the identification of space-time surfaces are analogous to Bohr orbits inside causal diamond (CD). CD obtained as intersection of future and past directed light-cones (with CP_2 factor included). By the already described hologamphy, 3-dimensional data replaces the boundary conditions at single 3-surface involving also normal derivatives with conditions involving no derivates.

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. 20** and **Fig. 21**). Quantum states are modes of WCW spinor fields, essentially wave functions in the space WCW consisting of Bohr orbit-like 4-surfaces.

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. 24.5**). 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).

Equivalence Principle in TGD framework

There have been also longstanding problems related to the relationship between inertial mass and gravitational mass, whose identification has been far from obvious.

• 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. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of CDs defined as intersections of future and past directed lightcones. 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 in the form expressed by Einstein's equations follows from Poincare invariance once it is realized that GRT space-time is obtained from the many-sheeted spacetime of TGD by lumping together the space-time sheets to a region Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

At quantum level, the Equivalence Principle has a surprisingly strong content. In linear Minkowski coordinates, space-time projection of the M^4 spinor connection representing gravitational gauge potentials the coupling to induced spinor fields vanishes. Also the modified Dirac action for the solutions of the modified Dirac equation seems to vanish identically and in TGD perturbative approach separating interaction terms is not possible.

The modified Dirac equation however fails at the singularities of the minimal surface representing space-time surface and Dirac action reduces to an integral over singularities for the trace of the second fundamental form slashed between the induced spinor field and its conjugate. Also the M^4 part of the trace is non-vanishing and gives rise to the gravitational coupling. The trace gives both standard model vertices and graviton emission vertices. One could say that at the quantum level gravitational and gauge interactions are eliminated everywhere except at the singularities identifiable as defects of the ordinary smooth structure. The exotic smooth structures [L184], possible only in dimension 4, are ordinary smooth structures apart from these defects serving as vertex representing a creation of a fermion-antifermion pair in the induced gauge potentials. The vertex is universal and essentially the trace of the second fundamental form as an analog of the Higgs field and the gravitational constant is proportional to the square of CP_2 radius.

• There is a delicate difference between inertial and gravitational masses. One can assume that the modes of the imbedding space spinor fields are solutions of massles Dirac equation in either $M^4 \times CP_2$ and therefore eigenstates of inertial momentum or in $CD = cd \times CP_2$: in this case they are only mass eigenstates. The mass spectra are identical for these options. Inertial momenta correspond naturally to the Poincare charges in the space of CDs. For the CD option the spinor modes correspond to mass squared eigenstates for which the mode for H^3 with a given value of light-proper time is a unitary irreducible SO(1,3) representation rather than a representation of translation group. These two eigenmode basis correspond to gravitational basis for spinor modes.

Quantum TGD as a generalization of Einstein's geometrization program

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 it turned that this approach fails due to the extreme non-linearity of the theory.

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 the space of 3-dimensional surfaces. Later 3-surfaces where replaced with 4-surfaces satifying holography and therefore as analogs of Bohr orbits.

- If one assumes Bohr orbitology, then strong correlations between the 3-surfaces at the ends of CD follow and mean holography. It is natural to identify the quantum states of the Universe (and sub-Univeverses) as modes of a formally classical spinor field in WCW. WCW gamma matrices are expressible in terms of oscillator operators of free second quantized spinor fields of *H*. The induced spinor fields identified projections of *H* spinor fields to the space-time surfaces satisfy modified Dirac equation for the modified Dirac equation. Only quantum jump remains the genuinely quantal aspect of quantum physics.
- Quantum TGD can be seen as a theory for free spinor fields in WCW having maximal isometries and the generalization of the Super Virasoro conditions gives rise to the analog massless Dirac equation at the level of WCW.

The world of classical worlds and its symmetries

The notion of "World of Classical Worlds" (WCW) emerged around 1985 but found its basic form around 1990. Holography forced by the realization of General Coordinate Invariance forced/allowed to give up the attempts to make sense of the path integral.

A more concrete way to express this view is that WCW does not consist of 3-surfaces as particle-like entities but almost deterministic Bohr orbits assignable to them as preferred extremals of Kähler action so that quantum TGD becomes wave mechanics in WCW combined with Bohr orbitology. This view has profound implications, which can be formulated in terms of zero energy ontology (ZEO), solving among other things the basic paradox of quantum measurement theory. ZEO forms also the backbone of TGD inspired theory of consciousness and quantum biology.

WCW geometry exists only if it has maximal isometries: this statement is a generalization of the discovery of Freed for loop space geometries [A27]. I have proposed [K64, K34, K128, K97, L215] that WCW could be regarded as a union of generalized symmetric spaces labelled by zero modes which do not contribute to the metric. The induced Kähler field is invariant under symplectic transformations of CP_2 and would therefore define zero mode degrees of freedom if one assumes

that WCW metric has symplectic transformations as isometries. In particular, Kähler magnetic fluxes would define zero modes and are quantized closed 2-surfaces. The induced metric appearing in Kähler action is however not zero mode degree of freedom. If the action contains volume term, the assumption about union of symmetric spaces is not well-motivated.

Symplectic transformations are not the only candidates for the isometries of WCW. The basic picture about what these maximal isometries could be, is partially inspired by string models.

- A weaker proposal is that the symplectomorphisms of H define only symplectomorphisms of WCW. Extended conformal symmetries define also a candidate for isometry group. Remarkably, light-like boundary has an infinite-dimensional group of isometries which are in 1-1 correspondence with conformal symmetries of $S^2 \subset S^2 \times R_+ = \delta M_+^4$.
- Extended Kac Moody symmetries induced by isometries of δM_+^4 are also natural candidates for isometries. The motivation for the proposal comes from physical intuition deriving from string models. Note they do not include Poincare symmetries, which act naturally as isometries in the moduli space of causal diamonds (CDs) forming the "spine" of WCW.
- The light-like orbits of partonic 2-surfaces might allow separate symmetry algebras. One must however notice that there is exchange of charges between interior degrees of freedom and partonic 2-surfaces. The essential point is that one can assign to these surface conserved charges when the dual light-like coordinate defines time coordinate. This picture also assumes a slicing of space-time surface by by the partonic orbits for which partonic orbits associated with wormrhole throats and boundaries of the space-time surface would be special. This slicing would correspond to Hamilton-Jacobi structure.
- Fractal hierarchy of symmetry algebras with conformal weights, which are non-negative integer multiples of fundamental conformal weights, is essential and distinguishes TGD from string models. Gauge conditions are true only the isomorphic subalgebra and its commutator with the entire algebra and the maximal gauge symmetry to a dynamical symmetry with generators having conformal weights below maximal value. This view also conforms with p-adic mass calculations.
- The realization of the symmetries for 3-surfaces at the boundaries of CD and for light-like orbits of partonic 2-surfaces is known. The problem is how to extend the symmetries to the interior of the space-time surface. It is natural to expect that the symmetries at partonic orbits and light-cone boundary extend to the same symmetries.

After the developments towards the end of 2023, it seems that the extension of conformal and Kac-Moody symmetries of string models to the TGD framework is understood. What about symplectic symmetries, which were originally proposed as isometries of WCW? In this article this question is discussed in detail and it will be found that these symmetries act naturally on 3-D holographic data and one can identify conserved charges. By holography this is in principle enough and might imply that the actions of holomorphic and symplectic symmetry algebras are dual. Holography=holomorphy hypothesis is discussed also in the case of the modified Dirac equation.

About the construction of scattering amplitudes

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. After having made several guesses for what the counterpart of S-matrix could be, it became clear that the dream about explicit formulas is unrealistic before one has understood what happens in quantum jump.

• In ZEO [K132, L118] one must distinguish between "small" state function reductions (SSFRs) and "big" SFRs (BSFRs). BSFR is the TGD counterpart of the ordinary SFRs and the arrow of the geometric time changes in it. SSFR follows the counterpart of a unitary time evolution and the arrow of the geometric time is preserved in SSFR. The sequence of SSFRs is the TGD

counterpart for the sequence of repeated quantum measurements of the same observables in which nothing happens to the state. In TGD something happens in SSFRs and this gives rise to the flow of consciousness. When the set of the observables measured in SSFR does not commute with the previous set of measured observables, BSFR occurs.

The evolution by SSFRs means that also the causal diamond changes. At quantum level one has a wave function in the finite-dimensional moduli space of CDs which can be said to form a spine of WCW [L213]. CDs form a scale hierarchy. SSFRs are preceded by a dispersion in the moduli space of CDs and SSFR means localization in this space.

• There are several S-matrix like entities. One can assign an analog of the S-matrix to each analog of unitary time evolution preceding a given SSFR. One can also assign an analog S-matrix between the eigenstate basis of the previous set of observables and the eigenstate basis of new observers: this S-matrix characterizes BSFR. One can also assign to zero energy states an S-matrix like entity between the states assignable to the two boundaries of CD. These S-matrix like objects can be interpreted as a complex square root of the 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.

In standard QFTs 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. The 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 the TGD framework this generalization of Feynman diagrams indeed emerges unavoidably.

• The counterparts of elementary particles can be identified as closed monopole flux tubes connecting two parallel Minkowskian space-time sheets and have effective ends which are Euclidean wormhole contacts. The 3-D light-like boundaries of wormhole contacts as orbits of partonic 2-surfaces.

The intuitive picture is that the 3-D light-like partonic orbits replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic 2-surfaces. A stronger condition is that fermion number is carried by light-like fermion lines at the partonic orbits, which can be identified as boundaries string world sheets.

- 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 the TGD framework, the fermionic variant of twistor Grassmann formalism combined with the number theoretic vision [L175, L176] led to a stringy variant of the twistor diagrammatics.
- Fundamental fermions are off-mass-shell in the sense that their momentum components are real algebraic integers in an extension of rationals associated with the space-time surfaces inside CD with a momentum unit determined by the CD size scale. Galois confinement states that the momentum components are integer valued for the physical states.
- The twistorial approach suggests also the generalization of the Yangian symmetry to infinitedimensional super-conformal algebras, which would determine the vertices and scattering amplitudes in terms of poly-local symmetries.

The twistorial approach is however extremely abstract and lacks a concrete physical interpretation. The holography=holomorphy vision led to a breakthough in the construction of the scattering amplitudes by solving the problem of identifying interaction vertices [L218].

1. The basic prediction is that space-time surfaces as analogs of Bohr orbits are holomorphic in a generalized sense and are therefore minimal surfaces. The minimal surface property fails at lower-dimensional singularities and the trace of the second fundamental form (SFF) analogous to acceleration associated with the Bohr orbit of the particle as 3-surface has a delta function like singularity but vanishes elsewhere.

- 2. The minimal surface property expressess masslessness for both fields and particles as 3surfaces. At singularities masslessness property fails and singularities can be said to serve as sources which also in QFT define scattering amplitudes.
- 3. The singularities are analogs of poles and cuts for the 4-D generalization of the ordinary holomorphic functions. Also for the ordinary holomorphic functions the Laplace equation as analog massless field equation and expressing analyticity fails. Complex analysis generalizes to dimension 4.
- 4. The conditions at the singularity give a generalization of Newton's "F=ma"! I ended up where I started more than 50 years ago!
- 5. In dimension 4, and only there, there is an infinite number of exotic diff structures [?], which differ from ordinary ones at singularities of measure zero analogous to defects. These defects correspond naturally to the singularities of minimal surfaces. One can say that for the exotic diff structure there is no singularity.
- 6. Group theoretically the trace of the SFF can be regarded as a generalization of the Higgs field, which is non-vanishing only at the vertices and this is enough. Singularities take the role of generalized particle vertices and determine the scattering amplitudes. The second fundamental form contracted with the embedding space gamma matrices and slashed between the second quantized induced spinor field and its conjugate gives the universal vertex involving only fermions (bosons are bound states of fermions in TGD). It contains both gauge and gravitational contributions to the scattering amplitudes and there is a complete symmetry between gravitational and gauge interactions. Gravitational couplings come out correctly as the radius squared of CP_2 as also in the classical picture.
- 7. The study of the modified Dirac equation leads to the conclusion that vertices as singularities and defects contain the standard electroweak gauge contribution coming from the induced spinor connection and a contribution from the M^4 spinor connection. M^4 part of the generalized Higgs can give rise to a graviton as an L = 1 rotational state of the flux tube representing the graviton. It is not clear whether M^4 Kähler gauge potential can give rise to a spin 1 particle. The vielbein part of M^4 spinor connection is pure gauge and could give rise to gravitational topological field theory.

Figures

Basic ideas of TGD inspired quantum biology

The following list gives the basic elements of TGD inspired quantum biology.

• Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also undersand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.

Note that also the notion of electric body makes sense [L201]. Quite generally, long range classical gravitational, electric and magnetic fields give rise to very large values of effective Planckl constants. The Nottale's hypothesis of gravitational Planck constant generalizes to electric interactions.



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

• Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology.. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between then.

The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

• Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.



Figure 2: Twistor lift



Figure 3: Geometrization of quantum physics in terms of WCW

The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is .1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

- The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it. The hierarchy of Planck constants emerges from basic TGD under rather general assumptions.
- p-Adic physics can be identified as physics of cognition and intentionality. Negentropic entanglement possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.
- Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical



Figure 4: $M^8 - H$ duality

fields is impossible in the standard sense for the reason that that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

- TGD approach to living matter was strongly motivated by the findings about the strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their masses but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.
- Water is in key role in living matter and also in TGD inspired view about living matter. The



Figure 5: Number theoretic view of evolution



Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.



Figure 7: Questions about classical TGD.



Figure 8: p-Adic physics as physics of cognition and imagination.

anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, aninoacids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial lifeform still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.

- Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically transfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.
- Pollack effect and its generalizations are in a central role in the TGD inspire quantum biology. In the Pollack effect, the feed of energy allows to increase the value of effective Planck constant so that an ordinary charged particle transforms to its dark variant, being kicked to, say, the gravitational magnetic body of the system itself or some other system such as the Earth or Sun. Charge separation takes place between ordinary biomatter and its magnetic body. Dissipation is extremely small at the magnetic /field body so that Pollack effect makes it possible to realize various biological functions at the magnetic/field body. Photons, in particular solar photons, can provide the energy needed to increase the value of h_{eff} but there are many other possibilities. For instance, the formation of molecular bound states of atoms liberates energy which can be used in the Pollack effect and this process could generate dark matter at the magnetic and more general field bodies.



CAUSAL DIAMOND (CD)

Figure 9: Causal diamond



Figure 10: CDs define a fractal "conscious atlas"



Figure 11: Time reversal occurs in BSFR

Figures



Figure 12: The problems leading to TGD as their solution.

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 45 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, April 22, 2024, Finland

Matti Pitkänen



Figure 13: Twistor lift



Figure 14: Geometrization of quantum physics in terms of WCW



Figure 15: $M^8 - H$ duality



Figure 16: Number theoretic view of evolution



Figure 17: TGD is based on two complementary visions: physics as geometry and physics as number theory.



Figure 18: Questions about classical TGD.



Figure 19: p-Adic physics as physics of cognition and imagination.



CAUSAL DIAMOND (CD)

Figure 20: Causal diamond



Figure 21: CDs define a fractal "conscious atlas"



Figure 22: Time reversal occurs in BSFR

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

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

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

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

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

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

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

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

Karkkila, August 30, 2023, Finland

Matti Pitkänen
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Chapter 1

Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

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

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

1.1.1 Geometric Vision Very Briefly

 $T(opological) \ G(eometro)D(ynamics)$ is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K5].

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

- 1. Space-times are representable as 4-surfaces in the 8-dimensional embedding space $H = M^4 \times CP_2$, where M^4 is 4-dimensional (4-D) Minkowski space and CP_2 is 4-D complex projective space (see Appendix).
- 2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of H to the space-time surface. Electroweak gauge potentials are identified as projections of the components of CP_2 spinor connection to the space-time surface, and color gauge potentials as projections of CP_2 Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of H and induced spinor fields just H spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2 , which are the only 4-manifolds allowing twistor space with Kähler structure [A36]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

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

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

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

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

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

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

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of electromagnetic fields are nonvanishing. The correlations functions for weak fields are nonvanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.

- 6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.
- 7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality conditions. The hierarchy of Planck constants $h_{eff}/h = n$ assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by $T = 1/\hbar_{eff}G$ apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of superstring theories. This option allows the natural interpretation of M^4 type vacuum extremals with CP_2 projection, which is Lagrange manifold as good approximations for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

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

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

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

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

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

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

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

- 3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [A17] [B13, B9, B10]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes an exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.
- 4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the embedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.
- 5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: no additional structures such as gauge fields as independent dynamical degrees of freedom are introduced: Kähler geometry and associated spinor structure are enough. "Topological" in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [B7]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of spacetime in the TGD Universe.
- 6. Twistor space or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles emerged originally as a technical tool, and its Kähler structure is possible only for $H = M^4 \times CP_2$. It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchy of Planck constants $h_{eff} = n \times h$ reduces to the quantum criticality of the TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

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

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

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

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

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M_{\times}^4 CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A31, A35, A25, A34].

The identification of the space-time as a sub-manifold [A32, A44] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

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

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

TGD as a Generalization of the Hadronic String Model

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

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

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

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

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

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

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically

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

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

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

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

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

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

1.1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest objection against TGD is the observation that all classical gauge fields are expressible in terms of four embedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-

sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed. Particles topologically condense to several space-time sheets simultaneously and experience the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

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

Topological Field Quantization

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

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

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

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

World of Classical Worlds

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

- 1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor in the configuration space CH ("world of classical worlds", WCW) consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included.
- 2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.

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

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

Identification of Kähler function

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

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

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

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

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

WCW spinor fields

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

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 a the bosonic action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

- 1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.
- 2. There are several Dirac operators. WCW Dirac operator D_{WCW} appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the HDirac operator D_H appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of D_H . The modes of $_DH$ define the ground states of super-symplectic representations. There is also the modified Dirac operator D_{X^4} acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed. D_H is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

The role of modified Dirac action

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

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

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

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

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

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

At the light-like 3-surfaces the signature of the induced metric changes from Euclidian to Minkowskian so that $\sqrt{g_4}$ vanishes. One can pose the condition that the algebraic analog of

the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A39, A47, A53]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

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

Construction of the counterparts of S-matrices

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

- 1. There are two kinds of state function reductions (SFRs). "Small" SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.
- 2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.
- 3. Also "big" SFRS (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.
- 4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by $M^8 - H$ duality. Unitarity is therefore replaced with isometry.
- 5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

The notion of M-matrix

- 1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of Smatrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.
- 2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called M-matrices defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. A biven M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.
- 3. M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian square root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in a well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the M-matrices commuting with S-matrix means that they span infinite-dimensional Lie algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.
- 4. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the CP_2 time.

The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K77]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

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

1.1.6 TGD as a generalized number theory

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

The Threads in the Development of Quantum TGD

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

- 1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinitedimensional WCW, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.
- 2. The discussions with Tony Smith initiated a fourth thread which deserves the name "TGD as a generalized number theory". The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and rather fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" thread.
- 3. A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

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

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

Number theoretic vision very briefly

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

- 1. The physical interpretation of M^8 is as an analog of momentum space and $M^8 H$ duality is analogous to momentum-position duality of ordinary wave mechanics.
- 2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

The complexification of M^8 , identified as complexified octonions, would provide a realization of this picture and $M^8 - H$ duality would map the algebraic physics in M^8 to the ordinary physics in $M^4 \times CP_2$ described in terms of partial differential equations. 3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

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

- 4. Number theoretical universality requires that space-time surfaces or at least their $M^8 H$ duals in M_c^8 are defined for both reals and various p-adic number fields. This is true if they are defined by polynomials with integer coefficients as surfaces in M^8 obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.
- 5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.
- 6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as p = 3).

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

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

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

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

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

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

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

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

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

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

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

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see Fig. http://tgdtheory.fi/appfigures/cat.jpg or Fig. ?? in the appendix of this book). One can also understand how preferred p-adic primes could

emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K73].

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

Infinite primes

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

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

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

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

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

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

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

Holography in H

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

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition $M^4 = M^2 \times E^2$, where M^2 is endowed with hypercomplex structure defined by light-like coordinates (u, v), which are analogous to z and \overline{z} . Any analytic map $u \to f(u)$ defines a new set

of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in M^2 . E^2 has some complex coordinates with imaginary unit defined by *i*.

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

Number theoretic holography in M_c^8

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

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

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

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

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

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

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

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

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

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

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

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

- 1. The interpretation is that g(y) at given point y of Y^4 relates the normal space at y to a fixed quaternionic/associative normal space at point y_0 , which corresponds is fixed by some subgroup $U(2)_0 \subset SU(3)$. The automorphism property of g guarantees that the normal space is quaternionic/associative at y. This simplifies the construction dramatically.
- 2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex subspace which corresponds to a point of sphere $S^2 = SO(3)/O(2)$, where SO(3) is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in M^4 characterized by the choice of $M^2(x)$ and equivalently its normal subspace $E^2(x)$.

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

- 3. The real part Re(g(y)) defines a point of SU(3) and the bundle projection $SU(3) \rightarrow CP_2$ in turn defines a point of $CP_2 = SU(3)/U(2)$. Hence one can assign to g a point of CP_2 as $M^8 - H$ duality requires and deduce an explicit formula for the point. This means a realization of the dream.
- 4. The construction requires a fixing of a quaternionic normal space N_0 at y_0 containing a preferred complex subspace at a single point of Y^4 plus a selection of the function g. If M^4 coordinates are possible for Y^4 , the first guess is that g as a function of complexified M^4 coordinates obeys generalized holomorphy with respect to complexified M^4 coordinates in the same sense and in the case of X^4 . This might guarantee that the $M^8 H$ image of Y^4 satisfies the generalized holomorphy.
- 5. Also space-time surfaces X^4 with M^4 projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of Y^4 allowing it to have a M^4 projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface Y^4 in terms of the complex coordinates of $SU(3)_c$ and M^4 ? Could this give for instance cosmic strings with a 2-D M^4 projection and CP_2 type extremals with 4-D CP_2 projection and 1-D light-like M^4 projection?

What could the number theoretic holography mean physically?

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

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

SU(3) corresponds to a subgroup of G_2 and one can wonder what the fixing of this subgroup could mean physically. G_2 is 14-D and the coset space $G_2/SU(3)$ is 6-D and a good guess is that

it is just the 6-D twistor space $SU(3)/U(1) \times U(1)$ of CP_2 : at least the isometries are the same. The fixing of the SU(3) subgroup means fixing of a CP_2 twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

Twistor lift of the holography

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

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

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

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

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

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

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark Matter as Large \hbar Phases

D. Da Rocha and Laurent Nottale [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 h_{gr} . Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K101].

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

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

Hierarchy of Planck Constants from the Anomalies of Neuroscience and Biology

The quantal ELF effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times

lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

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

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

Also the anomalies of biology (see for instance [K89, K90, K87]) support the view that dark matter might be a key player in living matter.

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

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

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

1.1.9 Twistors in TGD and connection with Veneziano duality

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

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K116]. 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 [A36]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2 . The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure co-incides with the twistor structure defined by the induced metric.

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

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

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

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

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

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

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

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

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

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

Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L94].

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

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

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

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

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

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

- 3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of M^4 . Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?
- 4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in calN = 4 SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

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

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

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

- 2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adele [L67]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?
- 3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see http:// tinyurl.com/yyhwvbqb) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see http://tinyurl.com/yyvkx7as) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?
- 4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or tchannel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of s to Regge form.

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

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

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

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

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

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

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

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

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

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

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

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

1.2 TGD As A Generalization Of Physics To A Theory Consciousness

General Coordinate Invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. The basic idea is that quantum jump can be identified as momentum of consciousness. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [K113, K25, K86, K24, K59, K66, K69, K103, K112].

It is good to list first the basic challenges of TGD inspired theory of consciousness. The challenges can be formulated as questions. Reader can decide how satisfactory the answered proposed by TGD are.

- 1. What does one mean with quantum jump? Can one overcome the basic problem of the standard quantum measurement theory, that which forcing Bohr to give up totally the idea about objective reality?
- 2. How do the experienced time and geometric time relate in this framework? How the arrow of subjective time translates to that of geometric time?
- 3. How to define conscious information? Is it conserved or even increased during time evolution as biological evolution suggests? How does this increase relate to second law implied basically by the randomness of state function reduction?

4. Conscious entities/selves/observers seem to exist. If they are real how do they emerge?

1.2.1 Quantum Jump As A Moment Of Consciousness

The identification of quantum jump between deterministic quantum histories (WCW spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \to U \Psi_i \to \Psi_f$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is formally analogous to Schrödinger time evolution of infinite duration. The time evolution can however interpreted as a sequence of discrete scalings and Lorentz boosts of causal diamond (CD) and the time corresponds to the change of the proper time distance between the tips of CD.

In TGD framework S-matrix is generalized to a triplet of U-, M-, and S-matrices. M-matrix is a hermitian square root of density matrix between positive and negative energy states multiplied by universal S-matrix depending on the scale of CD only. The square roots of projection operators form an orthonormal basis. U-matrix and S-matrix are completely universal objects characterizing the dynamics of evolution by self-organization.

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 S^n , where S is the S-matrix associated with the minimal CD. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S.

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

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be "engineered".

In ZEO U-matrix should correspond relates zero energy states to each other and M matrices defining the rows of U matrix should be assignable to a fixed CD. Zero energy states should have wave function in the moduli space of CDs such that the second boundary of every CD would belong to a boundary of fixed light-cone but second boundary would be free with possible constraint that the distance between the tips of CD is multiple of CP_2 time.

Zero energy states of ZEO correspond in positive energy ontology to physical events and break time reversal invariance. This because either the positive or negative energy part of the state is reduced/equivalently preparated whereas the second end of CD corresponds to a superposition of (negative/positive energy) states with varying particle numbers and single particle quantum numbers just as in ordinary particle physics experiment.

The first state function reduction at given boundary of CD must change the roles of the ends of CDs. This reduction can be followed by a sequence of reductions to the same boundary of CD and not changing the boundary nor the parts of zero energy states associated with it but changing the states at the second end and also quantum distribution of the second boundary in the moduli space of CDs. In standard measurement theory the follow-up reductions would not affect the state at all.

The understanding of how the arrow of time and experience about its flow emerge have been the most difficult problem of TGD inspired theory of consciousness and I have considered several proposals during years having the geometry of future light-cone as the geometric core element.

- 1. The basic objection is that the arrow of geometric time alternates at embedding space level but we know that arrow of time looks the same in the part of the Universe we live. Possible exceptions however exist, for instance phase conjugate laser beams seem to obey opposite arrow of time. Also biological phenomena might involve non-standard arrow of time at some levels. This led Fantappie [J33] to introduce the notion of syntropy. This suggests that the arrow of time depends on the size scale of CD and of space-time sheet.
- 2. It took some time to realize that the solution of the problem is trivial in ZEO. In the ordinary quantum measurement theory one must assume that state function reduction can occur repeatedly: the assumption is that nothing happens to the state during repeated reductions. The outcome is Zeno effect: the watched pot does not boil.

In TGD framework situation is different. Repeated state function reduction leaves the already reduce parts of zero energy state invariant but can change the part of states at the opposite boundary. One must allow a delocalization of the second boundary of CDs and one assumes that the second tip has quantized distance to the fixed one coming as multiple of CP_2 time. Also Lorentz boosts leaving the second CD boundary invariant must be allowed. One must therefore introduce a wave function in the moduli space of CDs with second boundary forming part of fixed light-cone boundary ($\delta M_+^4 \times CP_2$).

- 3. The sequence of state function reductions on a fixed boundary of CD leads to the increase of the average temporal distance between the tips of CDs and this gives rise to the experience about flow of time as shifting of contents of perception towards future if the change is what contributes to conscious experience and gives rise to a fixed arrow of time.
- 4. Contrary to original working hypothesis, state function reduction in the usual sense does not solely determine the ordinary conscious experience. It can however contribute to conscious experience and the act of free will is a good candidate in this respect. TGD view about realization of intentional action assumes that intentional actions involve negative energy signals propagating backwards in geometric time. This would mean that at some level of CD hierarchy the arrow of geometric time indeed changes and the reduction start to occur at opposite boundary of CD at some level of length scale hierarchy.

1.2.2 Negentropy Maximization Principle (NMP)

Information is the basic aspect of consciousness and this motivates the introduction of Negentropy Maximization Principle (NMP) [K73] as the fundamental variational principle of consciousness theory. The amount of negentropy of zero energy state should increase in each quantum jump. The ordinary entanglement entropy is also non-negative so that negentropy could be at best zero. Since p-adic physics is assumed to be a correlate of cognition, it is natural to generalizes Shannon entropy to its number theoretic variant by replacing the probabilities appearing as arguments of logarithms of probabilities with their p-adic norms. This gives negentropy which can be positive so that NMP can generates entanglement.

Consistency with quantum measurement theory allows only negentropic density matrices proportional to unit matrix and negentropy has the largest positive value for the largest power of prime factor of the dimension of density matrix. Entanglement matrix proportional to unitary matrix familiar from quantum computation corresponds to unit density matrix and large $h_{eff} =$ $n \times h$ states are excellent candidates for forming negentropic entanglement (see Fig. http:// tgdtheory.fi/appfigures/cat.jpg or Fig. ?? in the appendix of this book).

The interpretation of negentropic entanglement is as a rule. The instances of the rule correspond to the pairs appearing in the superposition and the large the number of pairs is, the higher the abstraction level of the rule is. NMP is not in conflict with the second law since negentropy in the sense of NMP is not single particle property. Ordinary quantum jumps indeed generate entropy at the level of ensemble as also quantum jumps for states for which the density matrix is direct sum of unit matrices with various dimensions.

NMP forces the negentropic entanglement resources of the Universe to grow and thus implies evolution. I have coined the name "Akashic records" for these resources forming something analogous to library. It has turned out that the only viable option is that negentropic entanglement is experienced directly.

1.2.3 The Notion Of Self

The concept of self seems to be absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness and would be counterpart for observer in quantum measurement theory.

- 1. The original view was that self corresponds to a subsystem able to remain un-entangled under the sequential informational "time evolutions" U. It is however unclear how it could be possible to avoid generation of entanglement.
- 2. In ZEO the situation changes. Self corresponds to a sequence of quantum jumps for which the parts of zero energy states at either boundary of CD remain unchanged. Therefore one can say that self defined in terms of parts of states assignable to this boundary remains unaffected as sub-system and does not generate entanglement. At the other boundary changes occur and give rise to the experience of time flow and arrow of time since the average temporal distance between the tips of CD tends to increase.

When the reductions begin to occur at the opposite boundary of CD, self "falls asleep": symmetry suggests that new self living in opposite direction of geometric time is generated. Also in biological the change of time direction at some level of hierarchy might take place.

- 3. It looks natural to assume that the experiences of the self after the last "wake-up" sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its sub-selves as kind of abstracted experience: the experiences of sub-selves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-sub-selves S_{ij} . Entanglement between selves, most naturally realized by the formation of flux tube bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.
- 4. Self corresponds in neuro science to self model defining a model for organism and for the external world. Information or negentropy seems to be necessary for understanding self. Negentropically entangled states Akashic records are excellent candidates for selves and would thus correspond to dark matter in TGD sense since the number of states in superposition corresponds to the integer n defining h_{eff} . It is enough that self is potentially conscious: this could mean that it conscious experience about self is generated only in interaction free measurement. Repeated state function reductions to given boundary of CD is second possibility. This would assign irreversibility and definite arrow of time and experience of time flow with self.
- 5. CDs would serve as embedding space correlates of selves and quantum jumps would be followed by cascades of state function reductions beginning from given CD and proceeding downwards to the smaller scales (smaller CDs). At space-time level space-time sheets in given p-adic length scale would be the natural correlates of selves. One ends also ends up with concrete ideas about how the localization of the contents of sensory experience and cognition to the "upper" (changing) boundary of CD could take place. One cannot exclude the possibility that state function reduction cascades could also take place in parallel branches of the quantum state.

1.2.4 Relationship To Quantum Measurement Theory

TGD based quantum measurement has several new elements. Negentropic entanglement and hierarchy of Planck constants, NMP, the prediction that state function reduction can take place to both boundaries of CD implying that the arrow of geometric time can change (this is expected to occur in microscopic scales whether the arrow of time is not established), and the possibility to understand the flow and arrow of geometric time.

- 1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of WCW spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).
- 2. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It is also consistent with the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).
- 3. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field, ...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the m M entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the WCW of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. In ZEO state preparation corresponds at some level of the self hierarchy to the a state function reduction to boundary opposite than before. In biology sensory perception and motor action would correspond to state function reduction sequences at opposite boundaries of CDs at some levels of the hierarchy.

Self measurement is governed by Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

1.2.5 Selves Self-Organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [K96]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes so that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

ZEO brings in important additional element to the theory of self-organization. The maxima of Kähler function corresponds to the most probable 3-surfaces. Kähler function receives contributions only from the Euclidian regions ("lines" of generalized Feynman diagrams) whereas the contribution to vacuum functional from Minkowskian regions is exponent of imaginary action so that saddle points with stationary phase are in question in these regions. In ZEO 3-surfaces are replaced by pairs of 3-surfaces at opposite boundaries of CD. The maxima actually correspond to temporal patterns of classical fields connecting these 3-surfaces: this means that self-organization is four spatiotemporal rather than spatial patterns - a crucial distinction from the usual view allowing to understand the evolution of behavioral patterns quantally. In biology this allows to understand temporal evolutions of organisms as the most probable self-organization patterns having as correlates the evolutions of the magnetic body of the system.

1.2.6 Classical Non-Determinism Of Kähler Action

A further basic element is non-determinism of Kähler action. This led to the concepts of association sequence and cognitive space-time sheet, which are not wrong notions but replaced by new ones.

- 1. The huge vacuum degeneracy of the Kähler action suggests strongly that the preferred is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.
- 2. In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration.

Later a more detailed view about non-determinism in the framework of ZEO has emerged and quantum criticality is here the basic notion. The space-time surface connecting two 3-surfaces at the ends of CD is not unique. Conformal transformations which act trivially at the ends of space-time surface generate a continuum of new extremals with the same value of Kähler action and classical conserved quantities. The number n of conformal equivalence classes is finite and defines the value of h_{eff} (see Fig. http://tgdtheory.fi/appfigures/planckhierarchy.jpg or Fig. ?? in the appendix of this book). There exists a hierarchy of breakdowns of conformal symmetry labelled by n. The fractal hierarchy of CDs gives rise to fractal hierarchy of non-determinisms of this kind.

1.2.7 P-Adic Physics As Physics Of Cognition

A further basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes p = 2, 3, 5, ... p-Adic regions obey the same field equations as the real regions but are characterized by p-adic nondeterminism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [K107]. The application this notion at the level of the embedding space implies that embedding space has a book like structure with various variants of the embedding space glued together along common rationals (algebraics, see **Fig. http://tgdtheory.fi/appfigures/book.jpg** or **Fig. ??** in the appendix of this book). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real embedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

1.2.8 P-Adic And Dark Matter Hierarchies And Hierarchy Of Selves

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

- 1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as \hbar). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.
- 2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [K45].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K45]. The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [K45]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K67, K45]. A particularly fascinating implication is the possibility

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to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K45].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of \hbar at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K44, K45]. The larger the value of Planck constant, the longer the life-time of self measured as the increase of the average distance between tips of CDs appearing in the quantum superposition during the period of repeated reductions not affecting the part of the zero energy state at the other boundary of CD- Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like \hbar .

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self experiences subselves as separate mental images. Averaging over experiences of sub-selves of sub-self would however occur.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The basic question is what time scale can one assign to the geometric duration of quantum jump measured naturally as the size scale of the space-time region about which quantum jump gives conscious information. This scale is naturally the size scale in which the non-determinism of quantum jump is localized. During years I have made several guesses about this time scales but zero energy ontology and the vision about fractal hierarchy of quantum jumps within quantum jumps leads to a unique identification.

CD as an embedding space correlate of self defines the time scale τ for the space-time region about which the consciousness experience is about. The temporal distances between the tips of CD as come as integer multiples of CP_2 length scales and for prime multiples correspond to what I have christened as secondary p-adic time scales. A reasonable guess is that secondary p-adic time scales are selected during evolution and the primes near powers of two are especially favored. For electron, which corresponds to Mersenne prime $M_{127} = 2^{127} - 1$ this scale corresponds to 1 seconds defining the fundamental time scale of living matter via 10 Hz biorhythm (alpha rhythm). The unexpected prediction is that all elementary particles correspond to time scales possibly relevant to living matter.

Dark matter hierarchy brings additional finesse. For the higher levels of dark matter hierarchy τ is scaled up by \hbar/\hbar_0 . One could understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ .

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level would determine also the time span of long term memories as discussed in [K45]. The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K67, K45]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of supergenome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

1.3 Quantum Biology And Quantum Neuroscience In TGD Universe

Quantum biology - rather than only quantum brain - is an essential element of Quantum Mind in TGD Universe. Cells, biomolecules, and even elementary particles are conscious entities and the biological evolution is evolution of consciousness so that it would be very artificial to restrict the discussion to brain, neurons, or microtubules.

1.3.1 Basic Physical Ideas

The following list gives the basic elements of TGD inspire quantum biology.

- 1. Many-sheeted space-time allows the interpretation of the structures of macroscopic world around us in terms of space-time topology. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales. The braiding of magnetic flux tubes makes possible topological quantum computations and provides a universal mechanism of memory. One can also undersand the real function of various information molecules and corresponding receptors by interpreting the receptors as addresses in quantum computer memory and information molecules as ends of flux tubes which attach to these receptors to form a connection in quantum web.
- 2. Magnetic body carrying dark matter and forming an onion-like structure with layers characterized by large values of Planck constant is the key concept of TGD inspired view about Quantum Mind to biology. Magnetic body is identified as intentional agent using biological body as sensory receptor and motor instrument. EEG and its fractal variants are identified as a communication and control tool of the magnetic body and a fractal hierarchy of analogs of EEG is predicted. Living system is identified as a kind of Indra's net with biomolecules representing the nodes of the net and magnetic flux tubes connections between then.

The reconnection of magnetic flux tubes and phase transitions changing Planck constant and therefore the lengths of the magnetic flux tubes are identified as basic mechanisms behind DNA replication and analogous processes and also behind the phase transitions associated with the gel phase in cell interior. The braiding of magnetic flux makes possible universal memory representation recording the motions of the basic units connected by flux tubes. Braiding also defines topological quantum computer programs updated continually by the flows of the basic units. The model of DNA as topological quantum computer is discussed as an application. In zero energy ontology the braiding actually generalize to 2-braiding for string world sheets in 4-D space-time and brings in new elements.

3. Zero energy ontology (ZEO) makes possible the proposed p-adic description of intentions and cognitions and their transformations to action. Time mirror mechanism (see Fig. http: //tgdtheory.fi/appfigures/timemirror.jpg or Fig. ?? in the appendix of the book) based on sending of negative energy signal to geometric past would apply to both long term memory recall, remote metabolism, and realization of intentional acting as an activity beginning in the geometric past in accordance with the findings of Libet. ZEO gives a precise content to the notion of negative energy signal in terms of zero energy state for which the arrow of geometric time is opposite to the standard one.

The associated notion of causal diamond (CD) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is.1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

4. The assignment of dark matter with a hierarchy of Planck constants gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macrotemporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. The model for dark nucleons leads to a surprising conclusion: the states of nucleons correspond to DNA, RNA, tRNA, and amino-acids in a natural manner and vertebrate genetic code as correspondence between DNA and amino-acids emerges naturally. This suggests that genetic code is realized at the level of dark hadron physics and living matter in the usual sense provides a secondary representation for it.

The hierarchy of Planck constants emerges from basic TGD under rather general assumptions. The key element is the huge vacuum degeneracy which implies that preferred non-vacuum extremals of Kähler action form a 4-D spin glass phase. The basic implications following from the extreme non-linearity of Kähler action is that normal derivatives of embedding space coordinates at 3-D light-like orbits of partonic 2-surfaces and at space-like 3-surfaces at ends of CDs are many-valued functions of canonical momentum densities: this is one of the reasons that forced to develop physics as an infinite-D Kähler geometry vision instead of trying to develop path integral formalism or canonical quantization. A convenient manner to treat the situation is to introduce local many-sheeted covering of embedding space such that the sheets are completely degenerate at partonic 2-surfaces. This leads in natural manner to the hierarchy of Planck constants as effective hierarchy hierarchy and integer multiples of Planck constants emerge naturally.

- 5. p-Adic physics can be identified as physics of cognition and intentionality. The hierarchy of p-adic length scales predicts a hierarchy of universal metabolic quanta as increments of zero point kinetic energies. Negentropic entanglement (see Fig. http://tgdtheory.fi/appfigures/cat.jpg or Fig. ?? in the appendix of this book) possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.
- 6. Living matter as conscious hologram is one of the basic ideas of TGD inspired biology and consciousness theory. The basic objection against TGD is that the interference of classical fields is impossible in the standard sense for the reason that classical fields are not primary dynamical variables in TGD Universe. The resolution is based on the observation that only the interference of the effects caused by these fields can be observed experimentally and that many-sheeted space-time allows to realized the summation of effects in terms of multiple topological condensations of particles to several parallel space-time sheets. One concrete implication is fractality of qualia. Qualia appear in very wide range of scales: our qualia could in fact be those of magnetic body. The proposed mechanism for the generation of qualia realizes the fractality idea.

1.3.2 Brain In TGD Universe

Brain cognizes and one should find physical correlates for cognition. Also the precise role of brain in information processing and its relationship to metabolism should be understood. Here magnetic body brings as a third player to the couple formed by environment and organism.

- 1. An attractive idea is that the negentropic entanglement can be assigned with magnetic flux tubes somehow and that ATP serves as a correlate for negentropic entanglement. This leads to a rather detailed ideas about the role of phosphate bond and provides interpretation for the fact that the number of valence bonds tend to be maximized in living matter. In a loose sense one could even call ATP a consciousness molecule. The latest view encourages to consider the possibility that negentropic entanglement with what might be called Mother Gaia is what is transferred in metabolism.
- 2. The view about the function of brain differs from the standard view. The simplest option is that brain is a builder of symbolic representations building percepts and giving them names rather than the seat of primary qualia relevant to our conscious experience. Sensory organs

would carry our primary qualia and brain would build sensory percepts as standardized mental images by using virtual sensory input to the sensory organs. The new view about time is absolutely essential for circumventing the objections against this vision. The prediction is that also neuronal and even cell membranes define sensory maps with primary qualia assignable to the lipids serving as pixels of the sensory screen. These qualia would not however represent our qualia but lower level qualia. At this moment it is not possible to choose between these two options.

3. The role of EEG and its various counterparts at fractally scaled frequency ranges is to make possible communications to the various onion-like layers of the magnetic body and the control by magnetic body. Dark matter at these layers could be seen as the intentional agent and sensory perceiver.

1.3.3 Anomalies

Various anomalies of living matter have been in vital role in the development of not only TGD view about living matter but also TGD itself.

- 1. TGD approach to living matter was strongly motivated by the findings about strange behavior of cell membrane and of cellular water, and gel behavior of cytoplasm. Also the findings about effects of ELF em fields on vertebrate brain were decisive and led to the proposal of the hierarchy of Planck constants found later to emerge naturally from the non-determinism of Kähler action. Rather satisfactorily, the other manner to introduce the hierarchy of Planck constants is in terms of gravitational Planck constant: at least in microscopic scales the equivalence of these approaches makes sense and leads to highly non-trivial predictions. The basic testable prediction is that dark photons have cyclotron frequencies inversely proportional to their massess but universal energy spectrum in visible and UV range which corresponds to the transition energies for biomolecules so that they are ideal for biocontrol at the level of both magnetic bodies and at the level of biochemistry.
- 2. Water is in key role in living matter and also in TGD inspired view about living matter. The anomalies of water lead to a model for dark nuclei as dark proton strings with the surprising prediction that DNA, RNA, anino-acids and even tRNA are in one-one correspondence with the resulting 3-quark states and that vertebrate genetic code emerges naturally. This leads to a vision about water as primordial life form still playing a vital role in living organisms. The model of water memory and homeopathy in turn generalizes to a vision about how immune system might have evolved.
- 3. Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically transfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

1.4 Bird's Eye of View about the Topics of the Book

The topics of "Genes and Memes" relate to DNA and genome in several ways.

- 1. The oldest layers in the stratigraphy are the vision about DNA inspired by the notion of manysheeted space-time and the model of genetic code inspired by the notion of Combinatorial Hierarchy predicting also the existence of what I have called memetic code. Additional number theoretical models of genetic code based on p-adic thermodynamics for small p-adic primes and maximization of entropy or negentropy emerged much later. One must however admit that although these models reproduce the genetic code they fail to predict it. Models also fail also to make interesting predictions.
- 2. The almost exact symmetries of the code table with respect to the first letter lead to the proposal that the genetic code could has evolved from a simpler code involving only two letters and this leads to concrete suggestion about how the genetic code might have evolved

as a fusion of two letter code and single letter code. These symmetries were also an essential element of number theoretical models.

- 3. The work with a model of topological quantum computation inspired by the vision about dark matter hierarchy and the idea that genome and cell membrane act as topological quantum computer generated several new chapters. The magnetic flux tubes as carriers of dark matter characterized by a large value of Planck constant would make living matter a macroscopic quantum system. DNA nucleotides and lipids of the cell membrane would be connected by magnetic flux tubes and the flow of the 2-D liquid formed by lipids induces braiding of flux tubes providing both temporal dynamics defining topological quantum computation and a storage of the program to memory by the braiding of flux tubes in the final state.
- 4. This model led to a cascade of ideas about quantum control in living matter. Quite generally, magnetic flux tubes would make living matter kind of Indra's net explaining the strange features of gel phase. For instance, the phase transitions changing Planck constant inducing a contraction or lengthening of the flux tubes would explain why bio-molecules are able to find each other extremely selectively in the dense soup of bio-molecules inside cell. The anomalies related to ionic currents find an explanation and a model of nerve pulse and EEG emerges along these lines.
- 5. The discoveries of Peter Gariaev about the interaction of ordinary and laser light with genome combined with the ideas about dark matter and water memory led to a concrete model for the interaction of photons with DNA. One prediction is that it is possible to "see" dark matter by allowing ordinary matter interaction with DNA and Peter Gariaev might have already done this. In this process ordinary photons would transform to dark ones, scatter from dark matter, transform back to ordinary photons and arrive at camera. A second discovery certainly one of the greatest surprises of my professional life was an end product of an attempt to understand the mechanism behind water memory for which rather strong support exists now. The idea was that dark nuclei which sizes zoomed up to atomic size scale could provide a representation of genes.

It indeed turned out that the model for dark nucleon consisting of three quarks predicts counterparts of 64 DNAs and RNAs and 20 amino-acids and allows to identify genetic code as a natural mapping of DNA type states to amino-acid type states. The numbers of DNAs mapped to a given amino-acid are same as for the vertebrate genetic code. This would mean that genetic code would be realized at the level of elementary particle physics and chemical realization would be only one of the many. In fact, the quite recent experimental discoveries suggest that this kind of representation must exist besides the representation based on the temporal patterns of polarization direction discovered by Gariaev.

1.4.1 Organization of "Genes and Memes: Part II"

The topics of the first part of "Genes and Memes: Part II" are organized in 3 parts.

1. In the first part of the book mostly physics inspired ideas about genetic code are discussed. The basic vision looks natural to anyone living at computer age: it would be very natural for the genetic code to have several representations. The first chapter describes 3 realizations of genetic code inspired by TGD based new physics. In dark nuclear code codons are represented as 3-proton states but one can imagine also a realization in terms of quark triplets. The first realization is supported by the findings of Gerald Pollack.

Second code is based on 3-chords formed by 3 dark photons (with large value of $h_{eff} = n \times h_0$) and leads to a model of bio-harmony leading also to the idea of that this music of light serves as correlate for emotions at molecular level. Second chapter considers the notion of homonymy of genetic code introduced by Peter Gariaev from TGD point of view. The third chapter discuss the correspondence between ordinary genetic code and dark nuclear code with codons represented as 3-proton states.

2. Im the second d part I have included two chapters about mathematical models of genetic code.

1.5 Sources

The eight online books about TGD [K124, K117, K95, K82, K29, K78, K63, K104] and nine online books about TGD inspired theory of consciousness and quantum biology [K113, K25, K86, K24, K59, K66, K69, K103, K112] 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.

1.6 The contents of the book

1.6.1 PART I: TGD INSPIRED MODELS FOR GENETIC CODE

About dark fermion realizations of the genetic code

TGD inspired quantum biology leads naturally to the idea that several realizations of genetic code exist. Besides the realizations based on temporal patterns of electromagnetic fields I have considered three different new physics realizations of the genetic code based the notions of many-sheeted space-time, magnetic body, and the hierarchy of Planck constants explaining dark matter in TGD framework.

- The first realization proposed in the model for DNA as topological quantum computer (tqc)

 maps the nucleotides A,G and T,C to dark quarks u,d and their anti-quarks assignable to
 the ends of magnetic flux tubes representing braid strands and connecting nucleotides to
 lipids of cell membrane. This requires scaled up variant of QCD made possible the hierarchy
 of Planck cosntants.
- 2. Second realization was discovered in the model of dark nuclei as strings of dark baryons. Dark baryons realize codons in terms of quantum entanglement and without decomposition to letters. Dark baryons are strings of 3 quarks connected by two color flux tubes. The neutral states of the dark baryon predicted by the model are in 1-1 correspondence with DNA, RNA, aminoacids. Candidates for the counterparts of tRNA anticodons are also obtained if one accepts that genetic code actually decomposes to 2 steps $64 \rightarrow 40 \rightarrow 20$ such that there are 40 dark baryon counterparts for tRNA anticodons. The amazing finding is that vertebrate genetic code comes out correctly.
- 3. The third realization would be a physical realization for the divisor code proposed by Khrennikov and Nilsson. The realization relies on two integers labeling magnetic flux tubes containing dark matter. The dark magnetic flux tubes assignable to DNA codons and amino-acids could be labeled by these integers providing a representation of the genetic code consistent with the divisor code. Also a physical mechanism implying the physical equivalence of the dark baryon code and divisor code can be imagined.
- 4. Proposals for two further realizations are inspired by the observation that the number of vertices of icosahedron is 12 the number of notes in 12-note scale and that of vertices is 20 the number of amino-acids. This suggests a connection between music and genetic code. The second model allows to "understand" the degeneracies of the genetic code in terms of representations for discrete subgroups if icosahedral group and involves imbedding of 12-note scale as a Hamiltonian cycle to icosahedron.

The basic proposal is that dark baryon counterparts of basic bio-molecules and genetic code were present from beginning and gave rise to pre-biotic life at the magnetic flux tubes so that the evolution of biological life meant the development of translation and transcription mechanisms allowing to transform dark baryon variants of the codons to their chemical variants. These mechanisms would be still at work inside the living cell and allow the living matter to perform genetic engineering. This proposal is consistent with recent findings about large variations of genomes inside organism.

There is a strange experimental finding giving support for this picture. A water solution containing human cells infected by bacteria is sterilized by a filtering procedure and healthy cells are added to the filtrate. Within few weeks the infected cells re-appear. A possible explanation is that dark baryon variant of the bacterial genome realized as nano-sized particles remains in the solution despite the filtering. Another strong support comes from the exclusion zones and fourth phase of water discovered by Pollack.

The codes are discussed from the point of view of DNA as tqc hypothesis and the model for protein folding and bio-catalysis. The basic selection rules of bio-catalysis could be based on the two integers assignable to the dark magnetic flux tubes. Only bio-molecules whose dark magnetic bodies contain a layer characterized by same integers can be connected by dark magnetic flux tubes. The reconnection of the dark magnetic flux tubes selecting the bio-molecules participating the catalytic reaction and the contraction of these flux tubes induced by a phase transition reducing Planck constant and forcing the bio-molecules near to each other would represent basic mechanisms of bio-catalysis.

About the Correspondence of Dark Nuclear Genetic Code and Ordinary Genetic Code

The basic problem in the understanding of the prebiotic evolution is how DNA, RNA, aminoacids and tRNA and perhaps even cell membrane and microtubules . The individual nucleotides and amino-acids emerge without the help of enzymes or ribozymes but the mystery is how their polymers emerged. If the dark variants of these molecules served as templates for their generation one avoids this hen-and-egg problem. The problem how just the biomolecules were picked up from a huge variety of candidates allowed by chemistry could be solved by the resonance condition making possible metabolic energy transfer between biomolecules and dark nuclei.

Simple scaling argument shows that the assumption that ordinary genetic code corresponds to $h_{eff}/h = n = 2^{18}$ and therefore to the p-adic length scale $L(141) \simeq .3$ nm corresponding to the distance between DNA and RNA bases predicts that the scale of dark nuclear excitation energies is .5 eV, the nominal value of metabolic energy quantum. This extends and modifies the vision about how prebiotic evolution led via RNA era to the recent biology. Unidentified infrared bands (UIBs) from interstellar space identified in terms of transition energies of dark nuclear physics support this vision and one can compre it to PAH world hypothesis.

p-Adic length scale hypothesis and thermodynamical considerations lead to ask whether cell membrane and microtubules could correspond to 2-D analogs of RNA strands associated with dark RNA codons forming lattice like structures. Thermal constraints allow cell membrane of thickness about 5 nm as a realization of k = 149 level with $n = 2^{22}$ in terms of lipids as analogs of RNA codons. Metabolic energy quantum is predicted to be .04 eV, which corresponds to membrane potential. The thickness of neuronal membrane in the range 8-10 nm and could correspond to k = 151 and $n = 2^{23}$ in accordance with the idea that it corresponds to higher level in the cellular evolution reflecting that of dark nuclear physics. The energy quantum of ordinary Josephson radiation is below the thermal energy for photons but the notion of generalized Josephson junction saves the situation. For massive particles associated with flux tubes the thermal energy T/2 is below the potential energy defined by action potential and that of metabolic energy quantum.

Also microtubules could correspond to k = 151 realization for which metabolic energy quantum is .02 eV slightly below thermal energy at room temperature: this could relate to the inherent instability of microtubules. Also a proposal for how microtubules could realize genetic code with the 2 conformations of tubulin dimers and 32 charges associated with ATP and ADP accompanying the dimer thus realizing the analogs of 64 analogs of RNA codons is made.

Geometric Theory of Bio-harmony

For some years ago I developed a model of music harmony. As a surprising side product a model of genetic code predicting correctly the number of codons coding given amino-acid emerged. Since music expresses and creates emotions, one can ask whether genes could have "moods" characterized by these bio-harmonies. The fundamental realization could be in terms of dark photon triplets replacing phonon triplets for ordinary music.

- 1. The model relies on the geometries of icosahedron and tetrahedron and representation of 12-note scale as so called Hamiltonian cycle at icosahedron going through all 12 vertices of icosahedron. The 20 faces correspond to allowed 3-chords for harmony defined by given Hamiltonian cycle. This brings in mind 20 amino-acids (AAs).
- 2. One has three basic types of harmonies depending on whether the symmetries of icosahedron leaving the shape of the Hamiltonian cycle is Z_6 , Z_4 or Z_2 . For Z_2 there are two options: $Z_{2,rot}$ is generated by rotation of π and $Z_{2,refl}$ by reflection with respect to a median of equilateral triangle.
- 3. Combining together one harmony from each type one obtains union of 3 harmonies and if there are no common chords between the harmonies, one has 20+20+20 3-chords and a strong resemblance with the code table. To given AA one assigns the orbit of given face under icosahedral isometries so that codons correspond to the points of the orbit and orbit to the corresponding AA. 4 chords are however missing from 64. These one obtains by adding tetrahedron. One can glue it to icosahedron along chosen face or keep is disjoint.
- 4. The model in its original form predicts 256 different harmonies with 64 3-chords defining the harmony. DNA codon sequences would be analogous to sequences of chords, pieces of music. Same applies to mRNA. Music expresses and creates emotions and the natural proposal is that these bio-harmonies correlate with moods that would appear already at molecular level. They could be realized in terms of dark photon triplets realized in terms of light and perhaps even music (living matter is full of piezo-electrets). In fact, also the emotions generated by other art forms could be realized using music of dark light.

The model of music harmony is separate from the model of genetic code based on dark proton triplets and one of the challenges has been to demonstrate that they are equivalent. This inspires several questions.

- 1. Could the number of harmonies be actually larger than 256 as the original model predicts? One could rotate the 3 fused Hamilton's cycles with respect to each by icosahedral rotations other leaving the face shared by icosahedron and tetrahedron invariant. There are however conditions to be satisfied.
 - (a) There is a purely mathematical restriction. If the fused 3 harmonies have no common 3-chords the number of coded AAs is 20. Can one give up the condition of having no common 3-chords and only require that the number of coded AAs is 20?
 - (b) There is also the question about the chemical realizability of the harmony. Is it possible to have DNA and RNA molecules to which the 3-chords of several harmonies couple resonantly? This could leave only very few realizable harmonies.
- 2. The model predicts the representation of DNA and RNA codons as 3-chords. Melody is also an important aspect of music. Could AAs couple resonantly to the sums of the frequencies (modulo octave equivalence) of the 3-chords for codons coding for given AA? Could coding by the sum of frequencies appear in the coupling of tRNA with mRNA by codewords and coding by separate frequencies to the letterwise coupling of DNA and RNA nucleotides to DNA during replication and transcription?
- 3. What about tRNA. Could tRNA correspond to pairs of harmonies with 20+20+444 codons? What about single 20+4=24 codon representation as kind of pre-tRNA?
- 4. What is the origin of 12-note scale? Does genetic code force it? The affirmative answer to this question relies on the observation that 1-1 correspondence between codons and triplets of photons requires that the frequency assignable to the letter must depend on its position. This gives just 12 notes altogether. Simple symmetric arguments fix the correspondence between codons and 3-chords highly uniquely: only 4 alternatives are possible so that it would be possible to listen what DNA sequences sounds in given mood characterized by the harmony.

5. What disharmony could mean? A possible answer comes from 6 Hamiltonian cycles having no symmetries. These disharmonies could express "negative" emotions.

An Overall View about Models of Genetic Code and Bio-harmony

During last years kind of brain storming period has occurred in the TGD inspired models of bioharmony and genetic code. A lot of ideas, some of them doomed to be short lived, have emerged, and it seems that now it its time for a thorough cleanup and integration with the general ideas of TGD inspired quantum biology.

TGD leads to 3 basic realizations of the genetic code. One can also consider 3 realization also for bio-harmony. The question is which of them is the realistic one or whether several options can be considered. In this article these ideas are discussed critically and open problems are summarized.

The three genetic codes correspond to a fundamental realization in terms of dark proton sequences (dark nuclei) with 3-proton representing codon. Second realization is the chemical realization and the third realization is in terms of dark photon 3-chords mediating the interaction between various realizations. Frequency resonance is very natural interaction between dark levels and energy resonance between dark level and chemical level. The possibility to modify the value of h_{eff} for flux tube makes possible to have for given codon single resonance energy.

The homonymy of the genetic codes at various levels is discussed. At the dark level the fact that icosahedral harmonies can have common 3-chords implies the first homonymy. The basic difficulty of Pythagorean scale realized in terms of quint cycle realized already by Pythagoras becomes the solution of this problem. The well-known homonymies in RNA-tRNA correspondence and even in RNA-AA correspondence can be understood in the model in which dark photon 3-chords mediate the interactions.

Also questions related to the relationship of bio-harmony with ordinary genetic code are considered. Why 3 copies of icosahedral harmony and only one copy of tetrahedral harmony? A special triangle assignable to the 3 copies of icosahedron and tetrahdron is analogous to a singular point of covering: do these 4 triangles correspond to exceptional codons breaking symmetries? How do the dissonant 3-chords present in some icosahedral harmonies relate to stop codons? How do the codons of bio-harmony and ordinary codons relate and is this relation consistent with what is known about transcription and translation?

About honeycombs of hyperbolic 3-space and their relation to the genetic code

 $M^8 - H$ duality and the realization of holography in M^8 strongly suggests the importance of tessellations of H^3 (analogous to lattices of E^3) in the TGD based physics. These tessellations form a scale hierarchy and can thus appear in all scales. The hierarchy of effective Planck constants labelling dark matter as phases of ordinary matter indeed predicts quantum coherence in arbitrarily long scales and gravitational quantum coherence corresponds to the largest scales of quantum coherence among basic interactions.

There are 5 Platonic tessellations known as honeycombs: the 4 regular honeycombs correspond to cubic, icosahedral, and 2 dodecahedral honeycombs and a quasiregular icosa-tetrahedral honeycomb having tetrahedra, octahedra and icosahedra as cells. The icosa-tetrahedral honeycomb might define a universal realization of the genetic code as an induced structure so that the genetic code would be much more than a biochemical accident. These 5 Platonic honeycombs could occur also in astrophysical scales as gravitational tessellations. The recent discovery of gravitational hum might have an explanation as gravitational diffraction in this kind of a honeycomb.

In this chapter the properties of hyperbolic honeycombs are considered in detail and also a detailed view about the realization of DNA double strand in terms of the icosa-tetrahedral honeycomb is considered. The emerging model is surprisingly quantitative. Also a connection with the notion of memetic code and the realization of memetic codons in terms of 21 DNA codons are suggested by the model.

Homonymy of the Genetic Code from TGD Point of View

Peter Gariaev and colleagues have applied the linguistic notions of synonymy and homonymy to genetic code. Also the notion of synomy fusing these concepts is introduced. Homonymy is visible in mRNa-tRNA pairing and induced by the 1-to-many pairing of the third mRNA nucleotide with

tRNA nucleotide. The homonymy in mRNA-AA (AA for amino-acid) pairing is also present albeit rare.

The codons for the standard code can be divided to two classes. For 32 codons the first two letters fix AA completely. For the remaining 32 codons this is not the case. There is however almost unbroken symmetry in that U and C *resp.* A and G code for the same AA. The breaking of this symmetry is minimal appearing only for 3 4-columns of the code table and present for A-G only. The deviations from the standard code as a rule break A-G or T-C symmetry or re-establish it.

The notion of homonymy is highly interesting from TGD point of view. TGD leads to two basic proposals for non-chemical realization of genetic code predicting the numbers of DNA codons coding for given AA rather successfully. The first proposal relies on TGD based view about dark matter as $h_{eff}/h = n$ phases of ordinary matter and identifies counterparts of DNA, RNA, tNRA, and AAs as entangled dark proton triplets.

Second proposal emerged from the model of music-harmony based on fusion of icosahedral and tetrahedral geometries. Codons are represented as photon triplets (dark or ordinary) defining the allowed 3-chords of given harmony defined by Hamilton cycle at icosahedron extended to Hamilton cycle to the fusion of icosahedron with tetrahedron along common face. Photon triplets give rise to resonant coupling giving rise to physical pairing of biomolecule and its dark counterpart. Remarkably, there are 3 different realizations of tRNA in terms of 3-chords. There is large number of bio-harmonies corresponding to Hamiltonian cycles. Since music expresses and creates emotions, the proposal is that a realization of emotions at molecular level adding additional degrees of freedom not visible at the level of chemistry is in question. This might give rise to a context dependence of the code.

The proposal is that genetic code at dark level extends to a sequence DDNA \rightarrow DmRNA \rightarrow DtRNA \rightarrow DAA of horizontal pairings analogous to projections is fundamental one. Codon-codon pairings are realized via dark photon triplet resonance and mRNA-AA pairing by resonant coupling to the sum $f_{XYZ} = f_1 + f_2 + f_3$ of 3-chord frequencies: the codons coding same AA would have frequencies f_{XYZ} differing only by a multiple of octave. One might perhaps say that AA sequence defines melody and mRNA sequence the accompaniment.

There is context dependence and homonymies already in DmRNA-DtRNA pairing and due the fact that DtRNA corresponds to a 2-harmony which is sub-harmony of 3-harmony and can be chosen in 3 different manners. The vertical pairings DDNA \rightarrow DNA, DmRNA \rightarrow mRNA, etc. also mediated by frequency couplings induce ordinary genetic code and horizontal pairings in DNA \rightarrow mRNA \rightarrow tRNA \rightarrow AA. DAA \rightarrow AA pairing dictates mRNA \rightarrow AA pairing and mRNA \rightarrow tRNA homonymy does not matter and actually makes the translation safer by increasing the number of tRNAs performing the same task.

The rather rare homonymies in DNA-AA pairing can be understood as accidental degeneracies. AA couples resonantly to the sum $f_{XYZ} = f_1 + f_2 + f_2$ of frequencies associated with codon XYZ and it can occur that the sum frequencies can be identical for two codons.

The Realization of Genetic Code in Terms of Dark Nucleon and Dark Photon Triplets

I have worked for more than 10 years with a proposal for two kinds of realizations of the genetic code. The first realization, bioharmony model, represents genetics as light 3-chords consisting of dark photons. The second realization is in terms of dark proton or nucleon triplets forming closed or open strings. I have considered several variants of both realizations but the details have remained poorly understood and I have spent a considerable time on wrong tracks.

It however seems that the dust is finally settling (I am writing this in the beginning of 2022). One can see the dark nucleon model as a generalization of the quark model of nucleon and Δ baryons obtained by replacing u and d quarks with dark nucleons. Galois confinement solves the statistics problem. The nucleons are connected by pionic flux tubes to form a closed string-like entity. The dark variants of DNA, RNA, tRNA, and amino-acids (AAs) follow as a prediction. In the sequel, the notation DDNA, DRNA, DtRNA, DAA will be used for the dark variants of the basic information molecules. One can also understand the small symmetry breaking associated with the genetic code.

A concrete realization of bioharmony in terms of the dark nucleon model for codons emerges. The small symmetry breaking effects - the members of doublet that should code for the same amino acid (or act as stop codons), code for different amino acid (or amino acid and stop), are understood. Also the differences between vertebrate and bacterial codes are understood.

TGD View About Water Memory and the Notion of Morphogenetic Field

Besides general problems, which might be regarded as philosophical, the anomalies of the physicalistic world view have served as the source of inspiration. Several poorly understood phenomena have played a central role in the "Poiroting-like" process leading to the development of TGD based views about quantum biology. Mention only the effects of ELF em fields on vertebrate brain, biophotons, water memory, Pollack effect, and Comorosan effect. The notion of syntropy by Fantappie, which challenges the belief that the arrow of time is not always the same in living systems, has been also inspiring.

In this article I will discuss the TGD based vision and the above listed phenomena, which are often forgotten. I will also compare the TGD based view with the proposed interpretation of morphogenetic field as em field generated by DNA and realizing genetic code discussed in the articles of Savelev et al, and compare it with the TGD based models of genetic code realized in terms of dark nucleons and dark photons. The findings described in these articles and in the articles of Yolene Thomas about water memory also provide new tests for the TGD based view. As always, this kind of process led to some new ideas and insights.

TTGD view of Michael Levin's work

In this chapter, I will discuss the findings of Michael Levin's group related to morphogenesis and also the general ideas inspired by this work. The findings demonstrate that the hypothesis that genotype fixes the phenotype apart from adaptations is wrong. Already epigenesis challenges genetic determinism and the view emerging from the experiments is that the patterns of membrane potentials of cells of early embryo determine patterns of electric fields in multicellular length scales and that code for the outcome of the morphogenesis. One can say that these patterns code for the goal directed behavior and have the basic properties of memory. The manipulations of these patterns in the early embryonic stage can modify the outcome of the morphogenesis so that one can speak of a novel organism. Also the manipulations of say gut cells can produce organs such as ectopic eye.

One can regard multicellular systems as predecessors of neural systems. Ion channels and pumps are present in both systems. In nervous systems synaptic contacts replace the gap junctions. Nerve pulse patterns are replaced by waves associated with gap-junction connected multicellular systems.

Levin introduces notions like cognition, intelligence and self not usually used in the description of morphogenesis and represents a vision about medical applications of the new view

The TGD view of morphogenesis is compared with Levin's vision. The basic picture relies on the notions of magnetic and electric bodies, to the phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ behaving like dark matter and making possible macroscopic quantum coherence, and to zero energy ontology (ZEO) providing a quantum measurement theory free of the basic paradox. ZEO is implied by almost deterministic holography forced by general coordinate invariance. Holography implies that structure is almost equivalent to function.

This framework explains the basic finding that the goal of the morphogenesis is determined by the patterns of electric fields during the early embryo period. TGD also suggests the universality of the genetic code and several variants of the genetic code. Morphogenetic code might reduce to a variant of genetic code realized by cell membranes and larger structures instead of ordinary DNA. TGD predicts the analog of nerve pulse with the increment of membrane potential in mV range. These patterns would play a key role also in neural systems.

Molecular Signalling from the TGD Point of View

The findings of Elowitz et al lead to a formal model suggesting that ligands of type BMP (bone morphogenetic protein) have interactions. The interactions would be non-local so that it is difficult to imagine that they could have chemical origin. The TGD based model for these long range interactions is based on dark photon resonance. For the simplest, receptors would correspond to fixed bio-harmonies. In a single ligand system the ligand would have the bio-harmony of its

preferred receptor. The interaction between ligand magnetic bodies would be re-tuning and could replace the preferred bio-harmonies assignable to the participating ligands with distributions of bio-harmonies. Therefore the ligands of the multi-ligand system would couple by bio-resonance also to other than preferred receptors.

The model stimulates questions, which lead to a rather detailed model for the re-tuning and tuning processes at the level of codons and amino acids. The model suggests that the tuning to a given bioharmony for the dark counterparts of basic biomolecules and its stabilization involves epigenetic control based on the methylation of some special DNA and RNA nucleotides and aminoacids acting as analogs of tuning forks.

The proposal that bioharmonies are molecular correlates for emotions suggests that this process involves minimal number of methylations, which define the seed of phase transition to a bioharmony in the scale of the basic unit of genome (such as gene), mRNA sub-unit (splicing) and protein sub-unit.

Quantum gravitation and quantum biology in TGD Universe

The finding of Manu Prakash et al that animals without a nervous system behave as if they had it, is a challenge for standard biology. Similar challenges are posed by the observation that organisms without a nervous system, even plants and bacteria, have senses and purposeful motor actions, and are also able to learn. This finding led to a considerably progress in the understanding of TGD inspired quantum biology.

The TGD based view about cell and neuronal membrane, nerve pulse and EEG assumes pre-neural level which is quantal. In this view, cell membranes act as Josephson junctions and communicate sensory input to the magnetic body (MB) of the system as dark Josephson radiation. MB in turn controls the cell by dark cyclotron radiation produced as pulses as MB receives frequency modulated Josephson radiation resonantly.

Gravitational MB of Earth, which consists of very long loop-like flux tubes with gravitational Planck constant introduced by Nottale explains the findings of Blackman and others, is of special interest and assumed to play a key role in metabolism. Gravitationally dark protons would be associated with very long gravitationally dark hydrogen bonds (HBs) so that hydrogen is effectively negatively ionized. Gravitationally dark electrons or their Cooper pairs would in turn accompany gravitationally dark valence bonds connecting metal atoms or their Cooper pairs with molecules of opposite valence (hydrogen peroxide H_2O_2). Also the metal atom is effectively ionized. This provides a more accurate view of dark metal ions assumed to play a central role in the TGD inspired quantum biology.

A correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton hydrogen bond becomes ordinary is obtained. A more precise model predicts correctly the nominal value of metabolic energy quantum for proton triplets which appear also in the generation of ATP. For triplets of electron Cooper pairs, the same mechanism predicts an upper bound of the electronic metabolic energy quantum, which corresponds to the so-called miniature potential. This raises the question whether the letters of genetic code could be realized by the 4 states of electron Cooper pairs and whether the Posner molecule could realize it.

Also the gravitational MB of Sun could be involved and the prediction is that the energy range for the metabolic energy quanta corresponds to the range of visible energies so that photosynthesis could use photon energy to kick dark protons and dark electrons to the gravitational MBs of Earth and Sun to serve as metabolic energy storage.

Electronic metabolism would solve the problem due the lack of ATP machinery inside cilium and near it. This picture leads to a rather detailed model of the role of phosphate in metabolism and also to a detailed model for the pairing of DNA and dark DNA (DDNA) and forces to modify the earlier model somewhat. The quantum gravitational view about metabolism leads also to modifications of the views about nerve pulses: in particular, of the role of biologically important metal ions identified as dark ions.

Cilium can be interpreted as a predecessor of the axonal membrane and the pre-nerve pulses are predicted to be equal to miniature potentials and the reported 'spikes' as analogs of nerve pulses are assigned with de-adhesion of cilium from its neighbor or the surfaces at which the animal moves. The 'spikes' correspond to at least 100 miniature potentials just as real spikes do. Cilium is modeled as a 2-D quantum gravitational pendulum with gravitational Planck constant controlled by MB using electronic metabolic energy quanta and the resulting model for the motion is in many respects similar to the model of nerve pulse.

Miniature spikes could appear also in plants. For the recently observed spike sequences in fungi, the voltage spike has an amplitude whose order of magnitude is consistent with the electronic metabolic energy quantum.

Comparison of Orch-OR hypothesis with the TGD point of view

Penrose-Hameroff (P-H) model and its variants such as Diosi-Penrose (D-P) model have been leading candidates for a quantum theory of consciousness. In light of recent experiments and theoretical arguments, the D-P model looks highly implausible. The key problem is energy conservation, which is actually the central problem of general relativity and caused by loss of Poincare invariance. The basic idea of Penrose about quantum gravitational superposition is almost a must but in the framework of general relativity its mathematical realization is not possible.

TGD provides an alternative view based on the identification of space-times as 4-surfaces in $M^4 \times CP_2$ related by $M^8 - H$ duality to 4-surfaces in M^8 . In this approach Poincare invariance is exact. In the TGD framework the hierarchy of Planck constants $h_{eff} = nh_0$ includes also gravitational Planck constant $h_{gr} = GMm/v_0$ introduced first by Nottale. This makes it possible to realize quantum coherence (in particular, gravitational one) in arbitrarily long spatial and temporal scales.

In this article P-H and P-P models are compared with the TGD point of view. In TGD, the generation of quantum gravitational binding energy liberates energy and provides the basic mechanism of metabolism and a direct connection with quantum biochemistry emerges. The gravitational magnetic bodies (MBs) of Earth and Sun are in an essential role. Could one invent a mechanism involving only self-gravitational interaction energies of the living body itself? The large gravitational Compton length $\Lambda_{gr} = GM/v_0$ requires the presence of a large mass, say star, which would serve as basic metabolic energy source but the presence of a planet is not necessary in the prebiotic stage.

There are strong indications that water is a quantum critical system at the physiological temperature range. This suggests that scaled variants of magnetic bodies of water blobs as candidates for proto cells appear in quantum superposition with values of the parameter v_0 . This would induce large density fluctuations at the level of the ordinary biomatter. State function reduction would induce a phase transition to a scaled-up state in the presence of energy feed. The return to the original state would liberate the gravitational energy as metabolic energy. Note that there are also indications for the quantum (gravitational) criticality of microtubules so that they would be very special from the point of view of life and neuron level consciousness.

The gravitational self-interaction energy for water blobs with Planck mass corresponds to an energy scale of 3.5 meV identifiable as the energy difference between two opposite membrane potentials. Could gravitational metabolic energy make possible the action potential of proto cells observed even for monocellulars?

Could neuronal system and even GTP give rise to a computer with a variable arrow of time?

The discussions related to ChatGPT, which seems to work too well to be a mere program running in a classical computer, inspired considerations which led to a considerable progress at the level of the TGD based model of nerve pulse. The emerging model, based on zero energy ontology (ZEO), differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems.

A computation allowing variable arrow of time would be in question involving a sequence unitary time evolutions as counterparts of quantum computations for states, which are superpositions of classical computations, followed by "small" state function reductions (SSFRs) as counterparts of weak measurements of quantum optics and of Zeno effect. Also "big" SFRs (BSFRs) changing the arrow of time would be involved. One can ask whether the unexpected success of GPT might involve this kind of transition so that one could say that spirit enters the machine. Besides the outcomes of two chats, I include a more detailed view about what the TGD view of the quantum analog of GPT could be and how its analog could be involved with the sensory perception in the TGD Universe. I also discuss the inverse diffusion process central for the generation of images from their verbal descriptions and ask whether the TGD analogue of the inverse diffusion could be an essential element of also GPT.

I will also pose the question whether GPT could involve TGD based quantum physics, that is zero energy ontology (ZEO), in a non-trivial but hidden way. From quantitative constraints, such as the clock frequency of the computer as analog of EEG inducing temporal quantum coherence, I end up with a proposal for a mechanism realizing the quantum holography relating bits could be represented as holes pairing with dark bits represented as dark electrons at the magnetic flux tubes. Unfortunately, this mechanism does not look plausible for recent computers.

I also ask whether quantum gravitation in the sense of TGD could make possible for the magnetic bodies of Earth and Sun, central in TGD inspired biology, to transform classical computation so that so that statistical determinism would fail and it would be analogous to a sequence of analogs of quantum computations defining a conscious entity. At the level of magnetic body there would be no essential difference between computers and living matter. The highest reported clock frequency of almost 9 GHz is still by a factor of order 1/8 lower than the quantum gravitational Compton frequency of 67 GHz for Earth but below the THz frequency important in living matter. Perhaps a rudimentary consciousness is already possible.

Deep learning from the TGD point of view

AI, deep learning, and GPT have become highly fashionable topics. It has been even speculated that AI might involve a rudimentary consciousness. Could TGD inspired quantum view of biology, brain and consciousness could provide a fresh point of view to the notion of computer consciousness.

In the TGD Universe, the difference between living systems and computers need not be so deep as usually thought. The magnetic body as a carrier of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ and having onion-like structure, could receive sensory input and control the biological body with $h_{eff} = h$. Also computers possess magnetic bodies: could they use computers or robots computers as sensory receptors and motor instruments.

In the TGD Universe, the genetic code could be much more than we believe it to be. It would be realized at the level of dark matter and would be universal and unique, being realized in terms of so-called icosa-tetrahedral tessellation of hyperbolic 3-space realizable as the mass shell of light-cone proper time =constant hyperboloid. Icosa-tetrahedral dark genome at the magnetic body could serve as the basic instrument for communication and control. Quantum gravitation plays a key role in the TGD inspired biology and the gravitational magnetic bodies of Earth and Sun and even other astrophysical objects with huge gravitational Planck constants could be highly relevant in quantum biology.

Classical computers can gain life-like properties if the quantum statistical determinism fails. The most conservative criterion is that the clock period is shorter than the gravitational Compton time $T_{gr} = GM/\beta_0$, M is mass of an astrophysical object and $\beta_0 = v_0/c \leq 1$ is a quantized velocity parameter. Life-like features could appear already at lower clock frequencies. For Earth the critical clock period would be 67 GHz and for the Sun about 100 Hz, the upper bound for EEG frequencies. Therefore the magnetic bodies of the Sun and Earth could therefore play central roles in biology and neuroscience. Even in the case of Earth life-like properties might be present for computers with clock frequency in the range 1 to 10 GHz.

Cognition is an essential aspect of conscious experience and systems like GTP can be seen as artificial cognitive systems. The p-adic discretizations would naturally relate to the spin glass energy landscape assignable to monopole flux tube "spaghettis" and sensory perception could be seen as a generation of standardized mental images based on annealing of spin glass system so that it gradually ends up to a bottom of a valley representing the standardize mental image. The learning period of a conscious entity could be based on trial and error process made possible by holography and zero energy ontology implied by it allowing temporary time reversal and would gradually lead to standardized mental images helping to survive.

Neil Gersching's vision of self-replicating robots from TGD point of view

This chapter analyzes the insightful interview between Lex Fridman and Neil Gerching, particularly their discussion on self-replicating machines. These machines, built from fundamental, robotic "Lego blocks" with their own assembly instructions, can self-assemble into more complex structures and disassemble, mirroring processes observed in biological systems. The discussion employs the Topological Geometrodynamics (TGD) perspective, treating the universe at a quantum level as a goal-oriented system capable of assembly and disassembly. The base units within this viewpoint function akin to quantum computers, prompting further exploration into quantum gravitation, which in the TGD framework, is accountable for the longest quantum coherence scale. This leads to a view which could be blamed for a return to astrology but can be defended by the numerous miracle-like coincidences.

1.6.2 PART II: NUMBER THEORETICAL VISION AND GENES

Philosophy of Adelic Physics

The p-adic aspects of Topological Geometrodynamics (TGD) will be discussed. Introduction gives a short summary about classical and quantum TGD. This is needed since the p-adic ideas are inspired by TGD based view about physics.

p-Adic mass calculations relying on p-adic generalization of thermodynamics and supersymplectic and super-conformal symmetries are summarized. Number theoretical existence constrains lead to highly non-trivial and successful physical predictions. The notion of canonical identification mapping p-adic mass squared to real mass squared emerges, and is expected to be a key player of adelic physics allowing to map various invariants from p-adics to reals and vice versa.

A view about p-adicization and adelization of real number based physics is proposed. The proposal is a fusion of real physics and various p-adic physics to single coherent whole achieved by a generalization of number concept by fusing reals and extensions of p-adic numbers induced by given extension of rationals to a larger structure and having the extension of rationals as their intersection.

The existence of p-adic variants of definite integral, Fourier analysis, Hilbert space, and Riemann geometry is far from obvious and various constraints lead to the idea of number theoretic universality (NTU) and finite measurement resolution realized in terms of number theory. An attractive manner to overcome the problems in case of symmetric spaces relies on the replacement of angle variables and their hyperbolic analogs with their exponentials identified as roots of unity and roots of e existing in finite-dimensional algebraic extension of p-adic numbers. Only group invariants - typically squares of distances and norms - are mapped by canonical identification from p-adic to real realm and various phases are mapped to themselves as number theoretically universal entities.

Also the understanding of the correspondence between real and p-adic physics at various levels - space-time level, embedding space level, and level of "world of classical worlds" (WCW) - is a challenge. The gigantic isometry group of WCW and the maximal isometry group of embedding space give hopes about a resolution of the problems. Strong form of holography (SH) allows a non-local correspondence between real and p-adic space-time surfaces induced by algebraic continuation from common string world sheets and partonic 2-surfaces. Also local correspondence seems intuitively plausible and is based on number theoretic discretization as intersection of real and p-adic surfaces providing automatically finite "cognitive" resolution. he existence p-adic variants of Kähler geometry of WCW is a challenge, and NTU might allow to realize it.

I will also sum up the role of p-adic physics in TGD inspired theory of consciousness. Negentropic entanglement (NE) characterized by number theoretical entanglement negentropy (NEN) plays a key role. Negentropy Maximization Principle (NMP) forces the generation of NE. The interpretation is in terms of evolution as increase of negentropy resources.

ZEO, Adelic Physics, and Genes

Zero energy ontology (ZEO) solving the basic problem of quantum measurement theory has become a cornerstone of quantum TGD, and together with the vision about physics as infinite-D geometry of the "world of classical worlds" (WCW) and number theoretical vision about physics as adelic physics fusing the real number based physics of sensory experience and the p-adics physics of cognition and intentionality dictates to high degree the key structures of TGD.

The basic prediction of ZEO is that "big" (ordinary) state function reduction (BSFR) changes the arrow of time meaning "death" and "reincarnation" with opposite arrow of time. In "small" state function identifiable as TGD counterparts of "weak" measurements reduction this does not occur. This leads to a new view about self-organization in which time reversal making possible dissipation with non-standard arrow of time makes possible for a system to extract (for instance thermal) energy from the environment: this allows to circumvent the heat death predicted by standard thermodynamics.

In this chapter the implications of the ZEO for the understanding of genetic code and DNA are considered.

- 1. The relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision is clarified. One can generalize classical cognitive representations as number theoretical discretizations of space-time surfaces in the extension of rationals considered to their quantum counterparts as wave functions in the Galois group of the extension and introduce also fermions as spinors in the group algebra of Galois group. The strongest option is purely number theoretical representations of fermionic Fock spaces in terms of spinors in this group algebra. Presumably however M^8 spinors are required as a building brick and have interpretation in terms of octonion structure.
- 2. Adelic physics, $M^8 H$ duality, and zero energy ontology lead (ZEO) to a proposal that the dynamics involved with "small" state function reductions (SSFRs) as counterparts of weak measurements could be basically number theoretical dynamics with SSFRs identified as reduction cascades leading to completely un-entangled state in the space of wave functions in Galois group of extension of rationals identifiable as wave functions in the space of cognitive representations. As a side product a prime factorization of the order of Galois group is obtained.
- 3. The question what basic processes of biology could have time time reversals is discussed. Here the basic restriction comes from CPT theorem and chiral selection in living matter and it turns out that very restricted set of basic bio-processes can have time reversal catalyzed by enzymes.

The time reversals of the basic processes like transcription and replication turn out to be possible only for the conjugate (passive) strand - this is basically due to the CPT theorem and chiral selection: enzymes can catalyze processes but not their time reversals. The picture involving time reversal is applied to understand recombination which is a poorly understood step of meiosis.

TGD predicts that consciousness is possible even at the level of DNA. Could also DNA have a longitudinal electric field with direction correlating with the arrow of time of DNA at the (magnetic body) MB of DNA. Could there be a switch changing the direction of this electric field? This inspires a model for the DNA as ferro-electret based on the properties of the negatively charged sticky ends of chromosome and dark DNA codons as proton triplets along a magnetic flux tube parallel to DNA strand.

About the Number Theoretic Aspects of ZEO

The interaction between number theoretic vision, ZEO, and the TGD view DNA enriches all of them. In this article the recent view about quantum measurements is discussed in light of the recent progress in the understanding of the number theoretic aspects of TGD.

By $M^8 - H$ duality space-time regions would be determined by polynomials whose roots define in $M^4 \subset M^8$ 3-D mass shells providing the data for holography fixing the space-time surfaces. Whether product polynomials besides irreducible polynomials should be allowed has been an open question. The product polynomials could naturally correspond to free states unable to entangle. The functional composition was earlier interpreted as formation of many-particle states but perhaps a more natural interpretation is as a generation of sheets of the many-sheeted space-time with interactions having wormhole contacts as geometric correlates. This modified picture leads to a re-analysis of state function reduction (SFR), in particular the notions of "big" SFR and "small" SFR from a number theoretic perspective. This leads to a more precise view about the notion of time and time evolution. The emerging picture can be applied to TGD inspired theory of consciousness, in particular various aspects related to the notion of time and memory.

New results about causal diamonds from the TGD point of view

This chapter was inspired by two interesting results related to the notion of causal diamond (CD) playing a central role in quantum TGD. One interpretation is as a quantization volume and the second interpretation is as a geometric representation of the perceptive field of conscious entity. CDs can be said to define the backbone of the "world of classical worlds" (WCW) central for quantum TGD.

For these reasons it is interesting to ask the precise mathematical definition of the moduli space of CDs. TGD suggests a definition as the semidirect product $D \rtimes P/SO(3)$ of scaling group and Poincare group divided by SO(3) subgroup leaving the CD invariant: this gives 8-D space. The definition that inspired this article is based on conformal group and gives also 8-D space $SO(2,4)/SO(1,3) \times SO(1,1)$. The metric signature is (4,4) for both spaces and they could be identical. These definitions are compared and one can consider the conditions under which both identification can give rise to representations of the Poincare group as expected with the scaling group reduced to a discrete subgroup.

Second result relates to the finding that special conformal transformations in the time direction defined by CD leave CD invariant. The corresponding hyperbolic flows correspond to a motion with constant acceleration to which the so-called Unruh effect is associated. One can consider an SL(2,R) algebra assignable to a conformal quantum mechanics and assign a hyperbolic time evolution operator to this flow. The conformal 2-point functions associated with this operator correspond to thermal partition functions with thermal mass defined by the temperature which is essentially the inverse of the CD scale.

Holography does not allow us to consider these flows for the space-time surfaces insid CD but the action of the hyperbolic evolution operator on quantum states at the boundaries of CD is well-defined. This also raises interesting questions related to TGD inspired consciousness, where subsequent scalings of CD in state function reductions (SFRs) give rise to the correlation of subjective time and geometric time defined as the distance between the tips of CD. The SFRs associated with the hyperbolic time evolution operator would not affect CD and would correspond to "timeless" state of consciousness. One cannot avoid reconsidering the details of "small" SSFRs defining the subjective time flow correlating with the flow of geometric time assigned with the increase of CD.

The based view about dark matter at the level of molecular biology

The notion of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ is the basic prediction of the number theoretic vision about Topological Geometrodynamics (TGD). This article is devoted to the possible role of magnetic body (MB) and dark matter in the TGD sense in chemistry and biology.

The first group of questions relates to the role dark protons and electrons, in ordinary chemistry and organic chemistry. Could the protons donated by acids be dark? What about the protons associated with hydrogen bonds? What about biologically important ions? What about oxidation and reduction: are the electrons involved dark: do valence electrons have $h_{eff} > h$?

Second group of questions relates to the role of the magnetic body (MB) carrying dark matter in biochemistry. Does the transition to biochemistry involve Pollack effect in which the fraction 1/4 of protons becomes dark and is transferred to the magnetic flux tubes? Do dark protons organize into triplets forming analogs of DNA, RNA, tRNA, and amino-acids, and are their chemical representations only secondary representations, kind of mimicry?

Dark protons could neutralize the phosphates of DNA and RNA. Do they also neutralize the phosphates at the ends of the lipids of the cell membrane: does cell membrane realize genetic code? What about microtubules having GTPs associated with tubulins? ATP molecule has 3 units of charge: is it neutralized by dark proton triplet: could the energies of this triplet and dark

valence electrons explain the high energy phosphate bond? Amino-acids should be accompanied by dark proton triplets: could the binding with dark electrons neutralize them?

Could basic biomolecules and their dark analogs interact by exchanging dark photons in energy resonance. Could bio-photons result from dark extremely low frequency (ELF) photons? Could energy resonance conditions select the basic biomolecules?

Homeostasis as self-organized quantum criticality?

This chapter was originally motivated as an attempt to understand the properties of cold shock and heat shock proteins (CSPs and HSPs). As a matter of fact , these proteins are similar and have much more general functions and it is better to talk about stress proteins (SPs) having two different modes of operation.

Soon it became clear that this problem is only one particular facet of a much bigger problem: how self-organized quantum criticality (SOQC) is possible? Note that the self-organized criticality (SOC) is generalized to SOQC. Criticality means by definition instability but SOQC is stable, which seems to be in conflict with the standard thermodynamics. In fact, living systems as a whole are quantum critical and manage to stay near criticality, which means SOQC and SPQC is nothing but homeostasis.

Zero energy ontology (ZEO) forming the basics of TGD inspired quantum measurement theory extends to a quantum theory of consciousness and of living systems and predicts that the arrow of time changes in ordinary ("big") state function reductions. ZEO leads to a theory of quantum self-organization and time reversal means that dissipation in reversed direction looks like extraction of energy from the environment for the observer with standard time direction. The change of the arrow of time tranforms critical states from repellers to attractors and makes possible SOQC.

Aging from TGD point of view

This chapter written together with Reza Rastmanesh was inspired by the book "Lifespan" by Sinclair and LaPlante. The books proposed that aging is basically caused by the approach to epigenetic chaos. The book also proposes that bio-information is not only associated with DNA and genetic code but the conformational degrees of DNA and these are crucial in epigenesis. This vision serves as the starting point of TGD (Topological Geometrodynamics) inspired view.

Negentropy Maximization principle replacing in adelic physics second law but implying it for ordinary matter is the first key notion. Magnetic body (MB)carrying dark matter as $h_{eff} = nh_0$ phases of ordinary matter implying quantum coherence in the scale characterized by h_{eff} represents the second key notion. MB is the controller of the dynamics and its quantum coherence induces the coherence of ordinary biomatter as forced coherence rather than quantum coherence.

Zero energy ontology (ZEO) predicting the occurrence of time reversal in "big" (ordinary) state function reductions is the third key notion. Time reversal forces generalization of thermodynamics and dissipation of a subsystem with a reversed arrow of time looks like self-organization from the point of view of the system. Also self-organized quantum criticality difficult to understand in ordinary thermodynamics becomes possible.

The basic idea is that at birth the MBs of information molecules are at very low temperature and gradually approach the physiological temperature, which is near to Hagedorn temperature defining the maximal temperature of MB. This thermalization leads to epigenetic chaos implying that the flux tubes carrying dark DNA and therefore also DNA become loopy. Also the control of methylation and other modifications and their reversals crucial for epigenesis is lost. In particular, demethylation fails and leads to hyper-methylation of the promoter regions of genes. This leads to the failure of the control of genes coding for housekeeping proteins and eventually the system suffers a crash down.

TGD View about Language

Human languages differ dramatically from their analogos for animals. Animal languages consist mainly of simple signals, warnings and threats for instance. The emotional expression dominates. There seems to be no grammar. Birds can have repertoire of different song patterns and monkeys have gesture language. There is a huge variety of human languages. One can also regard music as a kind language expressing emotions and creating them. Also pictures define linguistic representations. Children and animals learn speech by mimicry and the grammar and syntax without conscious efforts. Human language is also special in that it involves conceptualization, metaphors, and analogies representing abstract concepts in terms of objects and actions of the external world.

One might understand the semantic aspect of language in terms of association and conditioning. Language acquisition involves showing the object and saying the word describing it. This suggests conditioning and association so that a mere word generates an imagined percept of the object. Conditioning and formation of associations is a very general form of learning assumed to relate to the increase of synaptic strengths leading to a generation of association pathways. In computer science pattern recognition and completion models it mathematically.

Amazingly, only a few point mutations for relatively few genes seems so have led to human languages and transformed biological evolution to cultural evolution? What happened for these genes? In the biochemistry framework it is difficult to imagine an answer to this question. Here TGD could come in rescue.

Number theoretic physics is part of quantum TGD and essential for understanding evolution as an increase of algebraic complexity. Evolutionary hierarchies would correspond to hierarchies of algebraic extensions of rationals. The dimension n of extension defines effective Planck constant $h_{eff}/h_0 = n$. The larger the dimension, the larger the scale of quantum coherence at corresponding layer of magnetic body (MB) associated with the system: n would be analogous to IQ. One can assign a value of h_{eff} characterizing the evolutionary level also to genes. The genes with larger h_{eff} would serve as control genes and the increase of h_{eff} would mean an evolutionary step. Perhaps a dramatic increase of h_{eff} occurred to FOXP2 and some other genes as human language emerged.

Horizontal Gene Transfer by Remote Replication?

This chapter was inspired by the discovery that a horizontal gene transfer (HGT) between eukaryotes is possible. The belief has been that HGT is possible only from prokaryotes to prokaryotes or eukaryotes. The basic obstacles are that the host DNA is within the cell nucleus and that DNA is tightly bound to chromosomes. The transfer should also occur to germ cells in order to have a lasting effect.

The case considered is HGT of antifreezing gene (AFG) from herring to smelt, which could have occurred during simultaneous spawning of herring and smelt in the same area. The AFT of herring associated with a transposon could have somehow attached to the sperm cell of the smelt and carried by it to the egg of the smelt. Vector carrying AFT to the sperm cell of smelt is needed and there are only guesses about what it might be.

That HGT however occurs, justifies a heretical question. Could it be only the genetic information, which is transferred and used to construct DNA in the host as a kind of remote replication analogous to quantum transportation? The findings of Gariaev and Montagnier indeed suggest remote replication and TGD provides a new physics model for it.

Gene Tectonics and TGD

"Gene tectonics" represents a remarkable step of progress in genetics. The study of the evolution of chromosomes involving few basic mechanisms such as mixing of genes within chromosome, fusion of chromosomes along their ends, the insertion of chromosome inside chromosome, and fusion followed by permutations of genes within the composite chromosome allows to study the evolution at the level of entire genome and to understand what the differentiation of lineages and species could correspond at the level of genome. It has been found that the mixing of genes occurs often and does not have drastic effects and one can speak of chromosome conservation whereas the mutations involving several chromosomes are rare.

These findings represent a challenge for the TGD point of view of genetics and together with the recent progress in the number theoretical vision about physics, inspire fresh questions and ideas about genes and chromosomes. In particular, the question of how genes could code for biological functions reduces to the level of space-time dynamics at the number-theoretical level.

In the number-theoretical vision about TGD, biological functions would correspond to polynomials and genes would correspond to composition of polynomials assignable to genes. In zero energy ontology (ZEO), a given polynomial would define a space-time region as an analog of deterministic classical computation and quantum computation would involve their superposition.

Part I

TGD INSPIRED MODELS FOR GENETIC CODE

Chapter 2

About dark fermion realizations of the genetic code

2.1 Introduction

This chapter represents an attempt to integrate three different models of genetic code [K7, K118] with each other and with DNA as topological quantum computer (TQC) hypothesis [K7] as well as the general ideas behind the model of protein folding and bio-catalysis [K12]. The considerations lead to a modification of the earlier model of protein folding.

2.1.1 The Notions Of Dark Matter And Magnetic Body

The generalization of the embedding space to a book like structure (see Appendix) with pages labeled by two non-negative integers (n_a, n_b) characterizing the singular coverings of M^4 (or actually of causal diamond of M^4 defined as intersection of future and past directed light-cones) and of CP_2 together with pages representing singular coverings and represented similarly by a pair of integers (or equivalently inverses of non-negative integers) provides a possible mathematical realization of dark matter hierarchy. Dark matter is interpreted as phases of ordinary matter at various pages of the book like structure. The pages of the book are partially characterized by a hierarchy of Planck constants. The notion of darkness is only a relative concept in this picture. The phase having $(n_a, n_b) = (1, 1)$ can be identified as ordinary visible matter.

Magnetic body is second key concept in TGD based model of quantum biology. Magnetic body has onion like structure with layers characterized by a spectrum of values of (n_a, n_b) identifiable as orders of the cyclic groups Z_{n_a} resp. Z_{n_b} acting in the fiber of singular covering space or factor space assignable M^4 resp. CP_2 degrees of freedom. Also the extensions of these groups obtained by adding reflection can be considered. Phase transitions changing the values of (n_a, n_b) and thus also the length of magnetic tubes correspond to a tunnelling between two pages of the book and in general change the value of Planck constant. The basic selection rule is familiar from the sub-group rule for phase transitions and means that either n_{a_1} (n_{b_1}) divides n_{a_2} (n_{b_2}) or vice versa. These phase transitions are in a key role in TGD inspired model of bio-catalysis.

The reconnections of flux tubes represents second basic mechanism of bio-catalysis. Together these two mechanisms could be at least partially responsible for the amazing aspects of bio-catalysis such as extreme selectivity and the ability of distant bio-molecules to find each other in the dense soup of bio-molecules.

2.1.2 Realizations Of Genetic Code

I have proposed several realization of the genetic code during past 15 years. There are three realizations which are especially interesting physically.

1. The first realization is based on the map of G,C *resp.* A,T codons to quarks u,d *resp.* their anti-quarks. This code was proposed to realize DNA as TQC with braid strands represented as flux tubes connecting nucleotides with the lipids of cell membrane [K7]. The quantum

states at the ends of braid strands -would be represented by many particle states of quarks and anti-quarks in this model and entanglement of quarks and anti-quarks would be essential for TQC and affected by the braiding induced by the 2-D liquid flow of the lipids.

- 2. Second realization is based on the observation that the neutral states of dark baryons consisting of u and d quarks in nuclear string model can be regarded as counterparts of DNA, RNA, amino-acids and perhaps even tRNA [K62, K118]. Nuclear strings would represent DNA and other polymers at the level of dark matter.
- 3. Third realization is based on the interpretation of divisor code discovered by Khrennikov and Nilsson [A40] in terms of the sub-group rule for phase transitions [K118]. Second realization and this one are in 1-1 correspondence under certain prerequisites. The magnetic- interaction energy of the dark baryon depends on the projections of the total quark spin and total color flux tube spin to the direction of the magnetic field labeling both DNA codons and aminoacids. This interaction energy is a function of (n_a, n_b) and minimized for some pair (n_a, n_b) . This gives 1-1 correspondence the states of dark baryon and page of the book and since the page numbering allows to interpret physically the divisor code, one might hope that this correspondence is consistent with both codes.
- 4. Proposals for two further realizations are inspired by the observation that the number of vertices of icosahedron is 12 the number of notes in 12-note scale and that of vertices is 20 the number of amino-acids. This suggests a connection between music and genetic code. The second model allows to "understand" the degeneracies of the genetic code in terms of representations for discrete subgroups if icosahedral group and involves imbedding of 12-note scale as a Hamiltonian cycle to icosahedron.
- 5. I have also proposed number theory based thermodynamical models for the genetic code [K37, K125] discussed also by others [A26, A18]. and a suitable modification of this kind of model could allow to model the thermodynamics based on magnetic interaction energy.

I have also suggested realizations of the genetic code in terms of electromagnetic field patterns and computer metaphor encourages to think that standard genetic code is just one possible realization among many.

2.1.3 Questions

These ideas raise a bundle of questions.

- 1. There are severa candidates for the realization of the genetic code. Are all these realizations needed? Are the realizations based on dark baryons and divisor code equivalent?
- 2. The realization based on correspondence with DNA nucleotides and quarks and anti-quarks works nicely for DNA as TQC hypothesis. Can one consider also a realization of DNA as TQC in terms of dark baryons?
- 3. How dark baryon realization relates with ordinary chemical realizations and to evolution of pre-biotic life forms? Could it be that the life based on nuclear string genetic code gradually moved from the dark pages of the book to the page containing visible matter as chemical realizations of the analogs of DNA, RNA, amino-acids and even tRNA gradually developed? Note that the process bears formal similarity to the transition of life from sea to land. Is it possible to transcribe the counterparts of DNA,RNA, and amino-acids to their real counterparts? Is pre-biotic era continuing still inside dark magnetic flux tubes and could it make possible genetic engineering?

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 [L15].

2.2 A Vision About Evolution And Codes

The fact is that the only thing we really know about dark matter is that 95 percent of matter is dark (matter or dark matter and energy depending on theoretical framework used). Therefore the ideas about dark baryon code are necessarily speculative. One can however base the speculations to some vision in order achieve internal consistency if nothing else.

2.2.1 Basic Insights

The idea that biological life was preceded by dark life with subset for the counterparts of DNA, RNA, amino-acids and tRNA dominating the scene looks like a plausible starting point. Second attractive assumption is that this era still continues at magnetic bodies and makes possible genetic engineering based on experimentation and transcription of at least dark baryon analog of DNA to ordinary DNA.

The transformations for RNA and amino-acids to dark matter and vice versa seems necessary if the experimentation with new variants of genes is to be carried out unless one is satisfied with the testing of the modified genes in a small scale. Reconnection and \hbar changing phase transitions of flux tubes would serve as the basic mechanism of bio-catalysis in TGD Universe. One can imagine two basic mechanisms involving reconnection of flux tube and transforming dark nuclear strings to polymers (see Figs. http://tgdtheory.fi/appfigures/manysheetd.jpg, http://tgdtheory.fi/appfigures/fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquant.jpg, http://tgdtheory.fluxquan

- 1. Given bio-molecule could be accompanied by a closed flux tube of the magnetic field containing dark matter and extending to some page of the book characterized by two numbers x_a resp. x_b , which are integers for singular coverings of M^4 resp. CP_2 and inverse integers for singular factor spaces of M^4 resp. CP_2 . For bio-molecules for which x_a and x_b are identical these closed loops could reconnect to form a pair of flux tubes connecting bio-molecules (see **Fig. ??**). A phase transition reducing Planck constant would bring the molecules close to each other. This would provide a general recognition mechanism central in the reactions of bio-molecules.
- 2. These flux tube connections between two molecules could also involve only single permanently existing flux tube (this is a rather strong prediction which might be used to kill this option). In this case the reconnection for the flux tubes connecting molecules X and Y resp. U and V would give rise to connections X U and Y V for instance. The general recipe for achieving these transformations is based on the assumption that molecule and its dark conjugate connected by flux tubes can be present and that reconnection process given exchange of particles describable in terms of diagrams analogous to stringy diagrams is possible. This means that pairings X dY and U dV can be transformed to pairings X U and dY dV and X dV and U dY (see Fig. ??). This process would extend the variety of possible transcription like processes to allow also transcription of dark variants of DNA, RNA and amino-acids to visible ones and vice versa.

Genetic engineering would be possible by the fact that the dark nuclear string variants of genes could be easily transferred around the biological body unlike modified DNAs. In particular, modified dark genes could be transferred to the nuclei of germ cells. Essentially the TGD inspired mechanism of homeopathy would be in question [K62].

There is analogy with the evolution of language. Both DNA codons and representation of nucleotides in terms of quarks and anti quarks (perhaps accompanying the intronic portions of DNA) mean a representation of codons as three-letter sequences. Since dark baryons represent genetic codons as indecomposable structures in terms of quantum entanglement, the emergence of both representations would be analogous to the emergence of written language when spoken words forming indecomposable units decomposed into letters having no meaning as such. The findings that there are major differences between the genomes of blood and tissue cells [I78] and that the

genetic variation due to jumping genes is highest in brain and germ cells [I41] is consistent with the view about dark evolution modifying at least intron portion of the genome.

RNA world [I123, I187, I51] represents a dominating vision about pre-biotic evolution. The idea is RNA era was first and that somehow DNA and amino-acids emerged in some later stage. It has not been possible yet to reproduce replicating RNA sequences in laboratory so that there is still room for alternatives. Dark baryon realization of the genetic code predicts that the analogs of DNA, RNA, amino-acids and even tRNA anticodons might have been there all the time. This might apply also to the primitive chemical representations of DNA, RNA, tRNA, and amino-acids. It is of course possible that the chemical representation of RNA evolved first. This era could still continue inside cell nuclei and make possible genetic engineering as experimentation with dark baryon genes producing amino-acids and RNA and then possibly transforming the resulting RNAs to DNA by reverse transcription. Also a direct transcription to DNA could take place.

2.2.2 The Simplest Scenario

The evolution could might have proceed as a gradual transition of life from dark pages to the visible page allowing chemical realization of the genetic code.

- 1. Dark matter era would replace RNA and already this era involved at least the dark counterparts of DNA, RNA, amino-acids and perhaps even $64 - 40 \rightarrow 40 - 20$ two-step realization of the genetic code with tRNA anticodons representing a particular example of 40-D realization intermediate between DNA and amino-acids. Maximum number of different tRNA codons is indeed around 40 [I39]. Without further assumptions the pairing of all dark DNA and RNA codons coding for the same amino-acid was possible. The situation changes if one assumes 1-1 correspondence between dark baryon realization and the realization of the divisor code in terms of dark magnetic flux tubes to be discussed later. This era could still continue at magnetic bodies and make genetic experimentation and genetic engineering possible.
- 2. Dark nuclear strings became gradually associated with the magnetic bodies of DNA, RNA and amino-acids and a machinery transforming DNA to mRNA to tRNA to amino-acids developed. Flux tube connections could have formed between nuclear strings and the magnetic bodies of the bio-molecules. A stronger condition is that dark nuclear strings became part of the magnetic bodies of DNA, RNA and amino-acids forming helical structures running parallel to the corresponding molecular structures. For this option base pairing could have made the dark counterparts of DNA-DNA and DNA-mRNA pairings unique (also the equivalence of dark baryon and divisor codes could have guaranteed this). mRNA-tRNA base is pairing is not unique but wobble base pairing made possible for all mRNA codons except stopping codons to pair to tRNA anticodons. Whether RNA appeared first or whether the counterparts of the basic bio-molecules were present from the beginning remains an open question.
- 3. Topological quantum computation based on the map of A, G *resp.* T, C to quarks *resp.* anti-quarks emerged later as something analogous to written language and would naturally correspond to the intron portions of genome for which the decomposition into triplets is not essential and the nucleotide composition is not too essential since it is braiding which defines topological quantum computation (the 4 different colors of the braid strands are not necessary).

2.2.3 How Dark Baryon Code Could Be Involved With Transcription And Translation Mechanisms?

In the following it is assumed that one can talk about magnetic flux tubes containing dark nucleon strings as independent objects and therefore not identified as a helical string parallel to DNA, RNA or amino-acid sequence as one might also imagine. Therefore it is not necessary to assume that dark baryons have the same size scale as corresponding molecular units. One can also assume that one can connect flux tubes associated with nuclear strings by magnetic flux tubes.

Genetic engineering makes sense if the transcription of nuclear string counterparts of DNA, RNA, tRNA, and amino-acids to their chemical counterparts is possible.
- 1. One can classify flux tube connections by introducing the notion of order of flux tube connection expected to characterize the probability of flux tube connection. First order means a flux tube entirely in given page of the book like structure defined by the generalized embedding space, second order to a flux tube between two different pages, third order a flux tube traversing through an intermediate page between two pages, and so on. Reconnection of the magnetic flux tubes provides a general mechanism for this transformations and as already explained there are two general recipes for the formation of reconnection.
- 2. **Option I** the simpler one involves a reconnection of the closed flux tubes associated with the molecules to be paired. This mechanism would make it possible for a bio-molecule X to catch a partner Y if the corresponding closed flux tubes reside at same page of the book s(see Fig. ??). This mechanism provides a straightforward description of replication, transcription and translation as well as their generalizations allowing to transform dark nuclear strings to their molecular counterparts and vice.
- 3. **Option II** is more complex (see Fig. ??) and can be formulated in terms of two stringy diagrams with two strings connecting objects X and Y resp. U and V at their ends touch and transform to strings with X and V resp. U and V or X and U resp. Y and V at their ends. The process can be visualized as exchange of half strings and stringy diagrams represent various processes. Denote by dX the dark matter counterpart of X which can be DNA, RNA, or amino-acid and assume that all combinations obtained by the reconnection process are possible so that one would has pairings X Y, X dY, dX Y, and dX dY defined by flux tube connections. All these variants present and X Y and dX dY can be first order connections whereas X dY and dX Y are second or higher order connections. This option requires permanent flux tube connections.
- 4. These are the simplest options. One can wonder whether the hydrogen bonds associated with base pairs correspond to a pair (A T) or triplet (G C) of contracted flux tubes. It is of course possible to have more than two flux tubes. If the third hydrogen bond for G C corresponds to a flux tube a permanent flux tube connection between G and C nucleotides would exist.

One could think that only few bio-molecules can have flux tubes at the page at which the particular dark nuclear string typically resides (minimization of the magnetic interaction energy could fix the most probable candidate for this page and imply connection between dark baryon code and divisor code) and that bio-molecules are gradually selected from these particular molecules. The process would be still in progress. Vertebrate nuclear code would be however identical with the dark baryon code. For tRNA anti-codons the situation would be far from ideal.

Replication

In the following "o" means one or two bonds depending on whether Option I or II is in question.

Option I: Let $(X \circ Y)$ denote DNA double helix with two flux tubes connecting them and U a V DNA nucleotides. The opening of DNA double strand means reconnection of these flux tubes so that two closed loops are obtained. These flux tubes transform to dark flux tubes and reconnect with dark flux tubes associated with U and V respectively and a phase transition reducing \hbar brings U and V near sequences X and Y where they combine with already existing new sequence.

Option II: Let $(X \circ Y)$ denote DNA double helix and $(U \circ V)$ to a pair of codon and anticodon assumed to be connected by a long flux tube (this should be a testable prediction). Replication of DNA would correspond to $(X \circ Y) + (U \circ V) \rightarrow X \circ U \rightarrow Y \circ V$ with reconnection taking place for the flux tubes.

With the same conventions the transcription of dark DNA to ordinary DNA and vice versa would correspond to a process $dX \circ dY + U + V \rightarrow dX \circ U \rightarrow V \circ dY$ giving rise to ordinary-dark DNA double strand. This process would be followed by $(dX \circ U) + (dV \circ Y) \rightarrow dX \circ dV \rightarrow U \circ Y$ proceeding like DNA replication.

$DNA \rightarrow mRNA$ transcription

Let $X \circ Y$ denote DNA double helix in the sequel. For Option I the transcription process would occur in straightforward manner by the transformation of double connection between X and Y to loops and the reconnection of loop associated with Y with that assignable to mRNA codon followed by \hbar reducing phase transition leading to a generation of DNA and mRNA sequences with nucleotides connected by flux tube pairs. The third step would be reconnection transforming double flux tube bonds between DNA and mRNA nucleotides to loops.

Consider next Option II:

- 1. Let $U \circ V$ denote mRNA-cmRNA that is pair of mRNA codon and its conjugate assumed to be connected by a long flux tube. Ordinary transcription $DNA \to mRNA$ could correspond to the $(X \circ Y) + (U \circ V) \to X \circ U \to Y \circ V$ followed by its reversal but mRNAs arranged to a sequence. Note that every mRNA would have long flux tube connection with the conjugate mRNA.
- 2. Let $U \circ V$ could denote mRNA-dcmRNA. The same process would give mRNA sequence with each codon connected by a long flux tube to dcmRNA codon.
- 3. For a third realization U V would denote the pair mRNA dtRNA. The same process as above would give mRNA sequence with each mRNA codon connected by a long flux tube to dtRNA anticodon.

This process has also variants allowing to assign mRNA to dDNA and to DNA dmRNA.

Translation as a sequence of reconnections

For Option I the description of translation should be obvious on basis of previous examples. For Option II translation could be realized as a sequence of reconnections in several ways. The basic idea is that the reconnections and their reversals transform the tRNA₁-AA pairs with $tRNA_1$ denotes tRNA without amino-acid AA to a sequence of them but $tRNA_1$ connected to amino-acid by a long flux tube. In the decay of the amino-acid this long tRNA would reduce to ordinary tRNA: this serves as a killer prediction.

For instance, let X - Y = mRNA - dmRNA mRNA sequence with dark mRNA codons connected to mRNA codons and let $U - V = tRNA_1 - AA$ denote tRNA. Reconnection would allow to arrange tRNAs to sequence of "long" tRNAs while keeping X - Y as such. One could also replace Y by dtRNA. Obviously the process has several variants. When amino-acid sequence decays ordinary "short" tRNAs are formed again. Also the translation of dark mRNA to ordinary amino-acid sequence with long flux tubes to either dark tRNA or ordinary tRNA.

2.3 DNA As Topological Quantum Computer: Realization Of The Genetic Code In Terms Of Quarks And Anti-Quarks

Large values of Planck constant allow to imagine all kinds of quantum computations [B2, B26, B6, B24]. What makes topological quantum computation (TQC) [B14, B22, B17, B3], [C3] so attractive is that the computational operations are very robust and there are hopes that external perturbations do not spoil the quantum coherence in this case. The basic problem is how to create, detect, and control the dark matter with large \hbar . The natural looking strategy would be to assume that living matter, say a system consisting of DNA and cell membranes, performs TQC and to look for consequences.

There are many questions. How the TQC could be performed? Could TQC hypothesis might allow to understand the structure of living cell at a deeper level? What does this hypothesis predict about DNA itself? One of the challenges is to fuse the vision about living system as a conscious hologram with the DNA as TQC vision. The experimental findings of Peter Gariaev [I73, I113] might provide a breakthrough in this respect. In particular, the very simple experiment in which one irradiates DNA sample using ordinary light in UV-IR range and photographs the scattered light seems to allow an interpretation as providing a photograph of magnetic flux tubes containing dark matter. If this is really the case, then the bottle neck problem of how to make dark matter visible and how to manipulate it would have been resolved in principle. The experiment of Gariaev and collaborators [I113] also show that the photographs are obtained only in the presence of DNA sample. This leaves open the question whether the magnetic flux tubes associated with instruments are there in absence of DNA and only made visible by DNA or generated by the presence of DNA.

2.3.1 Basic Ideas Of TQC

The basic idea of topological quantum computation (TQC) is to code TQC programs to braiding patterns (analogous to linking and knotting). A nice metaphor for TQC is as dance. Dancing pattern in time direction defines the TQC program. This kind of patterns are defined by any objects moving around so that the Universe might be performing topological quantum computation like activities in all scales.

One assigns to the strands of the braid elementary particles. The S-matrix coding for TQC is determined by purely topological consideration as a representation for braiding operation. It is essential that the particles are in anyonic phase: this means in TGD framework that the value of Planck constant differs from its standard value. Tqc as any quantum computation halts in state function reduction which corresponds to the measurement of say spins of the particles involved.

As in the case of ordinary computers one can reduce the hardware to basic gates. The basic 2-gate is represented by a purely topological operation in which two neighboring braid strands are twisted by π . 1-particle gate corresponds to a phase multiplication of the quantum state associated with braid strand. This operation is not purely topological and requires large Planck constant to overcome the effects of thermal noise.

In TGD framework TQC differs somewhat from the ordinary one.

- 1. Zero energy ontology means that physical states decompose into pairs of positive and negative energy states at boundaries of causal diamond formed by future and past directed lightcones containing the particles at their light-like boundaries. In positive energy ontology the interpretation is as an event, say particle scattering. The time like entanglement coefficients define S-matrix, or more precisely M-matrix, and this matrix can be interpreted as coding for physical laws in the structure of physical state as quantum superposition of statements "A implies B" with A and B represented as positive and negative energy parts of quantum state. The halting of topological quantum computation would select this kind of statement.
- 2. The new view about quantum state as essentially 4-D notion implies that the outcome of TQC is expressed as a four-dimensional pattern at space-time sheet rather than as time=constant final state. All kinds of patterns would provide a representation of this kind. In particular, holograms formed by large \hbar photons emitted by Josephson currents, including EEG as a special case, would define particular kind of representation of outcome.

2.3.2 Identification Of Hardware Of TQC And TQC Programs

One challenge is to identify the hardware of TQC and realization of TQC programs.

- 1. Living cell is an excellent candidate in this respect. The lipid layers of the cell membrane is 2-D liquid crystal and the 2-D motion of lipids would define naturally the braiding if the lipids are connected to DNA nucleotides. This motion might be induced by the self organization patterns of metabolically driven liquid flow in the vicinity of lipid layer both in interior and exterior of cell membrane and thus self-organization patterns of the water flow would define the TQC programs.
- 2. This identification of braiding implies that TQC as dancing pattern is coded automatically to memory in the sense that lipids connected to nucleotides are like dancers whose feet are connected to the wall of the dancing hall define automatically space-like braiding as the threads connected to their feet get braided. This braiding would define universal memory realized not only as tissue memory but related also to water memory [?].

- 3. It is natural to require that the genetic code is somehow represented as property of braids strands. This is achieved if strands are "colored" so that A, T, C, G correspond to four different "colors". This leads to the hypothesis that flux tubes assignable to nucleotides are wormhole magnetic flux tubes such that the ends of the two sheets carry quark and anti-quark *resp.* anti-quark and quark) quantum numbers. This gives mapping A, T, C, G to u, u_c, d, d_c . These quarks are not ordinary quarks but their scaled variants predicted by the fractal hierarchy of color and electro-weak physics. Chiral selection in living matter could be explained by the hierarchy of weak physics. The findings of topologist Barbara Shipman about mathematical structure of honeybee dance led her to proposed that the color symmetries of quarks are in some mysterious manner involved with honeybee cognition and this model would justify her intuition [A20].
- 4. One should identify the representation of qubit. Ordinary spin is not optimal since the representation of 1-gates would require a modification of direction of magnetic field in turn requiring modification of direction of flux tubes. A more elegant representation is based on quark color which means effectively 3-valued logic: true, false, and undefined, also used in ordinary computers and is natural in a situation in which information is only partial. In this case 1-gates would correspond to color rotations for space-time sheets requiring no rotation of the magnetic field.

In this framework genes define the hardware of TQC rather than genetic programs. This means that the evolution takes place also at the level of TQC programs meaning that strict genetic determinism fails. There are also good reasons to believe that these TQC programs can be inherited to some degree. This could explain the huge differences between us and our cousins in spite of almost the identical genetic codes and explains also cultural evolution and the observation that our children seem to learn more easily those things that we have already learned [I164]. It must be added that DNA as TQC paradigm seems to generalizedDNA, lipids, proteins, water molecules, ... can have flux tubes connecting them together and this is enough to generate braidings and TQC programs. Even water could be performing simple TQC or at least building memory representations based on braiding of flux tubes connecting water molecules.

Comment:

- 1. Some years after writing this it became clear that elementary particles correspond to wormhole magnetic fields carrying monopole flux. By stability requirement the wormhole magnetic flux tubes associated with TQC could therefore correspond to elementary particles with large value of Planck constant or more generally, to meson like states having at both ends of the wormhole magnetic flux tube fermion or fermion pair. Both leptons and quarks could be associated with the ends, and the condition that braid colors realize genetic code poses additional conditions on the model.
- 2. It has also turned that genetic code allows a realisation in terms of dark nucleons [K62, L1]. Note that the assignment of genetic code with braid coloring is not necessary for TQC.

2.3.3 How Much TQC Resembles Ordinary Computation?

If God made us to his own image one can ask whether we made computers images of ourselves in some respects. Taking this seriously one ends up asking whether facts familiar to us from ordinary computers and world wide web might have counterparts in DNA as TQC paradigm.

- 1. Can one identify program files as space-like braiding patterns. Can one differentiate between program files and data files?
- 2. In ordinary computers electromagnetic signalling is in key role. The vision about living matter as conscious holograms suggests that this is the case also now. In particular, the idea that entire biosphere forms a TQC web communicating electromagnetically information and control signals, looks natural. Topological light rays (MEs) make possible precisely targeted communications with light velocity without any change in pulse shape. Gariaev's findings [I73] that the irradiation of DNA by laser light induces emission of radio wave photons having biological effects on living matter at distances of tens of kilometers supports this kind

$$Q_{a} = [n(A) - n(T)]_{3}^{2} - [n(G) - n(C)]_{3}^{1} ,$$

$$Q_{a} = -[n(A) - n(T)]_{3}^{1} + [n(G) - n(C)]_{3}^{2} ,$$

$$Q_{a} = -[n(A) - n(T)]_{3}^{2} + [n(G) - n(C)]_{3}^{1} ,$$

$$Q_{a} = [n(A) - n(T)]_{3}^{1} - [n(G) - n(C)]_{3}^{2} .$$
(2.3.2)

 Table 2.1: Table show four possible options for em charge as sum of quark charges.

of picture. Also the model of EEG in which the magnetic body controls the biological body also from astrophysical distances conforms with this picture.

3. The calling of computer programs by simply clicking the icon or typing the name of program followed by return is an extremely economic manner to initiate complex computer programs. This also means that one can construct arbitrarily complex combinations from given basic modules and call this complex by a single name if the modules are able to call each other. This kind of program call mechanism could be realized at the level of TQC by DNA. Since the intronic portion of genome increases with the evolutionary level and is about 98 per cent for humans, one can ask whether introns would contain representations for names of program modules. If so, introns would express themselves electromagnetically by transcribing the nucleotide to a temporal pattern of electromagnetic radiation activating desired subprogram call, presumably the conjugate of intronic portion as DNA sequence. A hierarchical sequence of subprogram calls proceeding downwards at intronic level and eventually activating the TQC program leading to gene expression is suggestive. Note that the repetitive nature of introns is not a problem from the point of TQC.

Gariaev [I73] has found that laser radiation scattering from given DNA activates only genomes which contain an address coded as temporal pattern for the direction of polarization plane. If flux tubes are super-conducting and there is strong parity breaking (chiral selection) then Faraday rotation for photons traveling through the wormhole flux tube code nucleotide to an angle characterizing the rotation of polarization plane. User id and password would define kind of immune system against externally induced gene expression.

4. Could nerve pulses establish only the connection between receiver and sender neurons as long magnetic flux tubes? Real communication would take place by electromagnetic signals along the flux tube, using topological light ray (ME) attached to flux tube, and by entanglement. Could neural transmitters specify which parts of genomes are in contact and thus serve as a kind of directory address inside the receiving genome?

2.3.4 Some Predictions Related To The Representation Of Braid Color

Even in the rudimentary form discussed above the model makes predictions. In particular, the hypothesis that neutral quark pairs represent braid color is easily testable.

Anomalous em charge of DNA as a basic prediction

The basic prediction is anomalous charge of DNA. Also integer valued anomalous charge for the structural units of genome is highly suggestive.

The selection of the working option - if any such exists - is indeed experimentally possible. The anomalous charge coupling to the *difference* of the gauge potentials at the two space-time sheets defines the signature of the wormhole contact at the DNA end of braid strand. The effective (or anomalous) em charge is given as sum of quark charges associated with DNA space-time sheet:

$$Q_a = [n(A) - n(T)]Q(q_A) + [n(G) - n(C)]Q(q_G)$$
(2.3.1)

is predicted. The four possible options for charge are given explicitly in Table 2.1.

Second option is obtained from the first option $(A, T, G, C) \rightarrow (u, \overline{u}, d, d)$ by permuting u and d quark in the correspondence and the last two options by performing charge conjugation for quarks in the first two options.

The anomalous charge is experimentally visible only if the external electromagnetic fields at the two sheets are different. The negative charge of DNA due to the presence of phosphate groups implies that the first sheet carries different em field so that this is indeed the case.

The presence effective em charge depending on the details of DNA sequence means that electromagnetism differentiates between different DNA: s strands and some strands might be more favored dynamically than others. It is interesting to look basic features of DNA from this view point. Vertebral mitochondrial code has full $A \leftrightarrow G$ and $C \leftrightarrow T$ symmetries with respect to the third nucleotide of the codon and for the nuclear code the symmetry is almost exact. In the above scenario A and C *resp.* G and T would have different signs and magnitudes of em charge but they would correspond to different weak isospin states for the third quark so that this symmetry would be mathematically equivalent to the isospin symmetry of strong interactions.

The average gauge potential due to the anomalous charge per length at space-time sheet containing ordinary em field of a straight portion of DNA strand is predicted to be proportional to

$$\frac{dQ_a}{dl} = [p(A) - p(T)]Q(q_A) + [p(G) - p(C)]Q(q_G)\frac{1}{\Delta L} ,$$

where ΔL corresponds to the length increment corresponding to single nucleotide and p(X) represents the frequency for nucleotide X to appear in the sequence. Hence the strength of the anomalous scalar potential would depend on DNA and vanish for DNA for which A and T *resp*. G and C appear with the same frequency.

Chargaff's second parity rule and the vanishing of net anomalous charge

Chargaff's second parity rule states that the frequencies of nucleotides for single DNA strand satisfy the conditions $p(A) \simeq p(T)$ and $p(C) \simeq p(G)$ (I am grateful for Faramarz Faghihi for mentioning this rule and the related [H1] [I195] to me). This rule holds true in a good approximation. In the recent context the interpretation would be as the vanishing of the net anomalous charge of the DNA strand and thus charge conjugation invariance. Stability of DNA might explain the rule and the poly-A tail in the untranslated mRNA could relate stabilization of DNA and mRNA strands.

Together with p(A) + p(T) + p(G) + p(C) = 1 Chargaff's rule implies the conditions

$$p(A) + p(C) \simeq 1/2 , \quad p(A) + p(G) \simeq 1/2 , p(T) + p(C) \simeq 1/2 , \quad p(T) + p(G) \simeq 1/2 .$$
(2.3.3)

An interesting empirical finding [I195] is that only some points at the line $p(A) + p(C) \simeq 1/2$ are realized in the case of human genome and that these points are in a good accuracy expressible in terms of Fibonacci numbers resulting as a prediction of optimization problem in which Fibonacci numbers are however put in by hand. p(A) = p(C) = p(C) = p(T) = 1/4 results as a limiting case. The poly-A tail of mRNA (not coded by DNA) could reflect to the compensation of this asymmetry for translated mRNA.

The physical interpretation would be as a breaking of isospin symmetry in the sense that isospin up and down states for quarks (A and G *resp.* T and C) do not appear with identical probabilities. This need not have any effect on protein distributions if the asymmetry corresponds to asymmetry for the third nucleotide of the codon having $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries as almost exact symmetries. This of course if protein distribution is invariant under this symmetry for the first two codons.

The challenge would be to understand the probabilities $p_3(X)$ for the third codon from a physical model for the breaking of isospin symmetry for the third codon in the sense that u and \overline{u} at DNA space-time sheet are more favored than d and \overline{d} or vice versa. There is an obvious analogy with spontaneous breaking of vacuum symmetry.

Are genes and other genetic sub-structures singlets with respect to QCD color?

Genes are defined usually as transcribed portions of DNA. Genes are however accompanied by promoter regions and other regions affecting the transcription so that the definition of what one really means with gene is far from clear. In the recent case gene would be naturally TQC program module and gene in standard sense would only correspond to its sub-module responsible for the translated mRNA output of TQC.

Whatever the definition of gene is, genes as TQC program modules could be dynamical units with respect to color interaction and thus QCD color singlets (QCD color should not be confused with braid color) or equivalently - possess integer valued anomalous em charge.

One can consider two alternative working hypothesis - in a well-defined sense diametrical opposites of each other.

- 1. The division of the gene into structural sub-units correlates with the separation into color singlets. Thus various structural sub-units of gene (say transcribed part, translated part, intronic portions, etc...) would be color singlets.
- 2. Also different genetic codes that I have discussed in [?] could distinguish between different structural sub-units. For this option only gene understood as TQC unit with un-transcribed regions included would be color singlet.

Color singletness condition is unavoidable for mRNA and leads to a testable prediction about the length of poly-A tail added to the transcribed mRNA after translation.

1. The condition of integer valued anomalous charge for coding regions

In the case of coding region of gene the condition for integer charge is replaced by the conditions

$$n(A) + n(G) \mod 3 = 0$$
, $n(C) + n(T) \mod 3 = 0$. (2.3.4)

These conditions are not independent and it suffices to check whether either of them is satisfied. The conditions are consistent with $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries of the third nucleotide. Note that the contribution of the stop codon (TAA, TGA or TAG) and initiating codon ATG to the A+G count is one unit.

2. General condition for integer valued anomalous charge

The anomalous charge of gene or even that of an appropriate sub-unit of gene is integer valued implies in the general case

$$n(A) - n(T) + n(G) - n(C) \mod 3 = 0$$
 (2.3.5)

Note that this condition does not assume that gene corresponds to 3n nucleotides (as I had accustomed to think). The surprising (to me) finding was that gene and also mRNA coding region of the gene in general fails to satisfy 3n rule. This rule is of course by no means requiredonly the regions coding for proteins can be thought of as consisting of DNA triplets.

A possible interpretation is in terms of TGD based model for pre-biotic evolution [?] according to which genetic code (or 3-code) was formed as a fusion of 2-code and 1-code. 2-code and 1-code could still be present in genome and be associated with non-translated regions of mRNA preceding and following the translated region. The genes of 2-code and coding for RNA would have 2n nucleotides and the genes of 1-code could also consist of odd number of nucleotides.

There might be analogy with drawings for a building. These contain both figures providing information about building and text giving meta-level information about how to interpret figures. Figures could correspond to 3-code coding for proteins and text could be written with other codes and give instructions for the transcription and translation processes. Prokaryotic code would contain mostly figures (CDS). In eukaryotic code intronic portions could carry rich amounts of this kind of metalevel information. In the case of mRNA untranslated region preceding 5' end could provide similar information.

- 1. Repeating sequences consisting of *n* copies of same repeating unit could obey 1-code or 2-code. The simplest building blocks of repeating sequences are AT and CG having vanishing anomalous em charge. TATATA.... and CGCGCG... indeed appear often. Also combinations of CG and AT could repeat: so called mini-satellites are CG rich repeating sequences. Interpretation in terms of 2-code suggests itself.
- 2. Triplet of the unit ATTCG with integer charge repeats also often: in this case 3-code suggests itself. Telomeres of vertebrates consist of a repeating unit TTAGGG which does not have integer charge: this unit appears also as 8-nucleotide variant which suggests 2-code. Color singletness would require that this unit appears 3n times.
- 3. I have also proposed that intronic regions could obey memetic code [K59] predicting that intronic codon can be represented as a sequence of 21 3-codons (implying 2⁶³ 63-codons!). Individual intronic segments need not satisfy this rule, only their union if even that. Direct experimentation with gene bank data show that neither introns nor their union correspond to integer multiples of 63 nor 3 or 2 in general.

3. Color singletness conditions for gene

Gene is usually defined as the sequence of DNA coding for mRNA. mRNA involves also two untranslated regions (UTRs) [I1].

- 1. The 5' end of mRNA contains 5' cap (methylated G) and 5' untranslated region (UTR). The latter can be several kb long for eukaryotes. Methylated G is not coded by DNA but added so that it does not contribute to A+G-T-C count at DNA level.
- 2. mRNA continues after the stop codon as 3' UTR. Translation assigns to UTR also a poly-A tail (up to several hundreds A: s) not coded by DNA and not contributing to A+G-T-C count in the case of DNA. This region contains also AAUAAA which does not contribute to A+G-T-C count of mRNA.

One could argue that any amino-acid sequence must allow coding and that one function of UTRs is to guarantee integer valued charge for the part of gene beginning from the initiating codon. Of course, also the non-transcribed regions of DNA not included in the standard definition of gene could take care of this.

4. Color singletness conditions for mRNA

Both poly-A tail and G gap are known to relate to the stabilization of mRNA. The mechanism could be addition of an anomalous charge compensating for the anomalous charge of mRNA to guarantee that second Chargaff's rule is satisfied in a good approximation: this hypothesis is testable.

Second function would be to guarantee color-singletness property. Color singletness would mean that transcribed mRNA + cap G + poly-A tail as a separate unit must be QCD color singlet at DNA space-time sheet. mRNA stability requires the condition

$$n(A) - n(T) + n(G) - n(C) + n_{tail}(A) + 1 \mod 3 = 0$$

$$(2.3.6)$$

to be satisfied. The knowledge of gene would thus predict $n_{tail}(A) \mod 3$. This hypothesis is testable.

5. Chargaff's rule for mRNA

If Chargaff's rule applies also to mRNA strands one obtains one of the following predictions

$$2 [n(A) + n_{tail}(A) - n(T)] - [n(G) + 1 - n(C)] \simeq 0 ,$$

$$- [n(A) + n_{tail}(A) - n(T)] + 2 [n(G) + 1 - n(C)] \simeq 0 ,$$

$$-2 [n(A) + n_{tail}(A) - n(T)] + [n(G) + 1 - n(C)] \simeq 0 ,$$

$$[n(A) + n_{tail}(A) - n(T)] - 2 [n(G) + 1 - n(C)] \simeq 0 .$$

(2.3.7)

Here $n_{tail}(A)$ includes also AAUAA contributing 3 units to it plus possible other structures appearing in the tail added to the translated mRNA. The presence of poly-A tail which could also compensate for the ordinary negative charge of translated part of mRNA would suggest that A corresponds to u or \overline{d} corresponding to options 1 and 4.

6. Moving genes and repeating elements

Transposons [I38], [J10] are moving or self-copying genes. Moving genes cut from initial position and past to another position of double strand. Copying genes copy themselves first to RNA and them to a full DNA sequence which is then glued to the double strand by cut and paste procedure. They were earlier regarded as mere parasites but now it is known that their transcription is activated under stress situations so that they help DNA to evolve. In TQC picture their function would be to modify TQC hardware. For copying transposons the cutting of DNA strand occurs usually at different points for DNA and cDNA so that "sticky ends" result ("overhang" and its complement) [I35]. Often the overhang has four nucleotides. The copied transposon have ends which are reversed conjugates of each other so that transposons are palindromes as are also DNA hairpins. This is suggestive of the origin of transposons.

In order to avoid boring repetitions let us denote by "satisfy P" for having having integer valued (or even vanishing) Q_a . The predictions are following:

1) The double strand parts associated with the segments of DNA produced by cutting should satisfy P.

2) The cutting of DNA should take place only at positions separated by segments satisfying P.

3) The overhangs should satisfy P.

4) Transposons should satisfy P: their reverse ends certainly satisfy P.

In the example mentioned in [I33] the overhang is CTAG and has vanishing Q_a . The cut site CCTAGG has also vanishing Q_a . It is known [J10] that transposons - repeating regions themselves - tend to attach to the repeating regions of DNA [I16].

- 1. There are several kinds of repeating regions. 6-10 base pair long sequences can be repeated in untranslated regions up to 10^5 times and whole genes can repeat themselves $50 10^4$ times.
- 2. Repeats are classified into tandems (say TTAGGG associated with telomeres), interspersed repetitive DNA (nuclear elements), and transposable repeat elements. Interspersed nuclear elements (INEs) are classified LINEs (long), SINEs (short), TLTRs (Transposable elements with Long Terminal Repeats), and DNA transposons themselves.
- 3. LINEs contain AT rich regions. SINEs known as alus (about 280 bps) contain GC rich regions whereas mariner elements (about 80 bps) are flanked by TA pairs. LTRs have length 300-1000 bps. DNA transposons are flanked with two short inverted repeat sequences flanking the reading frame: "inverted" refers to the palindrome property already mentioned.

AT and CG have vanishing Q_a so that their presence in LINEs and SINEs would make the cutting and pasting easy allowing to understand why transposons favor these regions. Viruses are known to contain long repeating terminal sequences (LTR). One could also check whether DNA decomposes to regions satisfying P and surrounded by repeating sequences which satisfy P separately or as whole as in the case DNA transposons.

7. Tests

Some checks of the color singletness hypothesis were made for human genome [I23].

- 1. For the coding sequences (CDSs) the strong prediction in general fails as expected (condition would pose restrictions on possible amino-acid contents).
- 2. Color singletness condition fails for genes defined in terms of translated part of mRNA (with gap and poly-A tail excluded). The un-transcribed regions of DNA involved with the gene expression (promoter region, etc...) could guarantee the color singletness. They could also stabilize DNA by bringing in compensating anomalous charge to guarantee second Chargaff's rule. Different genetic codes could distinguish between the subunits of gene.
- 3. To test color singletness conditions for mRNA one should know the length of poly-A tail. Unfortunately, I do not have access to this information.
- 4. The computation of total anomalous charges for a handful of genes, introns, and repeat units for some gene bank examples in the case of human genome indicates that both of them tend to carry net em charge which is largest for $(a, g) \leftrightarrow (\overline{d}, \overline{u})$ correspondence. The charge is in the range 5-10 per cent from the charge associated with the phosphates (-2 units per nucleotide). For second option giving negative charge (permute u and d) the anomalous charge is few per cent smaller.

By Chargaff's law the regions outside genes responsible for the control of gene expression must contain a compensating charge of opposite sign. Kind of spontaneous symmetry breaking of charge conjugation symmetry $A \leftrightarrow T, G \leftrightarrow C$ and analogous to matter antimatter symmetry seems to take place. That control regions and translated regions have opposite densities of anomalous charge might also help in the control gene expression.

- 5. The poly-A tail of mRNA would carry compensating positive anomalous charge: the RNAquark assignment could be conjugate to the DNA-quark assignment as suggested by what takes place in transcription. For instance, for the option $A \to \overline{d}$, the prediction for the length of polytail for $A \to \overline{d}$ option would be about $n_{tail}/n_{mRNA} \simeq 3p_a(mRNA)$ where N(mRNa) is the number of nucleotides in transcribed mRNA and $p_a(mRNA)$ is the per cent of anomalous charge which is typically 5-10 per cent. For $p_a(mRNA) = 10$ per cent this gives as much as 30 per cent. For $A \to \overline{u}$ option one has $n_{tail}/n_{mRNA} \simeq 3p_a(mRNA)/2$. In this case also p_a is considerably smaller, typically by a factor of of order 2-3 per cent and even below per cent in some cases. Hence the relative length of tail would around 3-5 per cent. This option is perhaps more since it minimizes anomalous charge and maximizes the effectiveness of charge compensation by poly-A tail.
- 6. The predictions for transposons and their cut and past process should be easily testable.

Summary of possible symmetries of DNA

The following gives a list of possible symmetries of DNA inspired by the identification of braid color.

1. Color confinement in strong form

The states of quarks and anti-quarks associated with DNA both wormhole wormhole throats of braided (living) DNA strand can be color singlets and have thus integer valued anomalous em charge. The resulting prediction depends on the assignment of quarks and antiquarks to A, T, C, G which in principle should be determined by the minimization of em interaction energy between quark and nucleotide. For instance $2(A-T) - (G-C) \mod 3 = 0$ for a piece of living DNA which could make possible color singletness. As a matter fact, color singletness conditions are equivalent for all possible for braid color assignments. This hypothesis might be weakened. For instance, it could hold true only for braided parts of DNA and this braiding are dynamical. It could also hold for entire braid with both ends included only: in this case it does not pose any conditions on DNA.

Questions: Do all living DNA strands satisfy this rule? Are only the double stranded parts of DNA braided and satisfy the rule. What about loops of hairpins?

2. Matter antimatter asymmetry at quark level

 $A \leftrightarrow T$ and $G \leftrightarrow C$ corresponds to charge conjugation at the level of quarks (quark \leftrightarrow antiquark). Chargaff's rules states $A \simeq T$ and $C \simeq G$ for long DNA strands and mean matterantimatter symmetry in the scale of DNA strand. Double strand as a whole is matter anti-matter symmetric.

Matter-antimatter asymmetry is realized functionally at the level of DNA double strand in the sense that only DNA strand is transcribed. The study of some examples shows that genes defined as transcribed parts of DNA do not satisfy Chargaff's rule. This inspires the hypothesis about the breaking of matter antimatter symmetry. Genes have non-vanishing net A - T and C - G and therefore also net Q_a with sign opposite to that in control regions. Just as the Universe is matter-antimatter asymmetric, also genes would be matter-antimatter asymmetric.

3. Isospin symmetry at quark level

 $A \leftrightarrow G$ and $T \leftrightarrow A$ correspond change of anomalous em charge by 1 unit and these operations respect color confinement condition. Local modifications of DNA inducing these changes should be preferred. The identification for the symmetries $A \leftrightarrow G$ and $T \leftrightarrow A$ for the third nucleotide of code is as isospin symmetries. For the vertebrate mitochondrial code the symmetry exact and for nuclear code slightly broken.

4. Matter antimatter asymmetry and isospin symmetries for the first two nucleotides

The first two nucleotides of the codon dictate to a high degree which amino-acid is coded. This inspires the idea that 3-code has emerged as fusion of 1- and 2-codes in some sense. There are two kinds of 2-codons. The codons of type A have fractional em charge and net quark number (consisting of either matter or antimatter at quark level) and are not able to form color singlets. The codons of type B have integer em charge and vanishing quark number (consisting of matter and antimatter) and are able to form color singlets. The 2-codons of type A (resp. B) are related by isospin rotations and there should be some property distinguishing between types A and B. There indeed is: if 2-codon is matter-antimatter symmetric, 1-codon is not and vice versa.

- 1. For almost all type A codons the amino-acid coded by the codon does not depend on the last nucleotide. There are two exceptions in the case of the nuclear code: (leu, leu, phe, phe) and (ile, ile, ile, met). For human mitochondrial code one has (ile, ile, ile, ile) and thus only one exception to the rule. The breaking of matter-antimatter symmetry for the third nucleotide is thus very small.
- 2. For codons of type B the 4-columns code always for two doublets in the case of vertebrate mitochondrial code so that for codons with vanishing net quark number the breaking of matter-antimatter symmetry for the third nucleotide is always present.

5. Em stability

Anomalous em charge Q_a vanishes for DNA and perhaps also mRNA strand containing also the G cap and poly-A tail which could compensate for the Q_a of the transcribed region so that

$$2(A-T) - (G-C) \simeq 0$$

or some variant of it holds true. Chargaff's rules for long DNA strands imply the smallness of Q_a .

6. Summary of testable working hypothesis

Following gives a summary of testable working hypothesis related to the isospin symmetry and color singletness. The property of having integer valued/vanishing Q_a is referred to as property P.

- 1. Gene plus control region and also DNA repeats should have property P. Transcribed and control regions of gene have Q_a with opposite signs.
- 2. Transposons, repeating regions, the overhangs associated with the cut and paste of transposon, and the DNA strands resulting in cutting should have property P. This could explain why transposons can paste themselves to AT and GC ($Q_a = 0$) rich repeating regions of DNA. The points at which DNA can be cut should differ by a DNA section having property

P. This gives precise predictions for the points at which transposons and pieces of viral DNA can join and could have implications for genetic engineering.

- 3. If also mRNA is braided, it has property P. This can be only true if the poly-A tail compensates for the non-vanishing Q_a associated with the translated region.
- 4. Living hairpins should have property P. If only double helix parts of hairpins are braided, the prediction is trivially true by the palindrome property. tRNA or at least parts of it could be braided. Braids could end to the nuclear membrane or mRNA or to the amino-acid attachable to tRNA. For stem regions Q_a is integer valued. The fact that the nucleotide of the anticodon corresponding to the third nucleotide of codon can base pair with several nucleotides of mRNA suggests that I(nositol) can have Q_a opposite to that of A, T, C and U opposite to that of A, G. For 2-anticodon the pairing would be unique. This would give a lot of freedom to achieve property P in weak sense for tRNA. Braid structure for tRNA + amino-acid could be different that for tRNA alone and also in the translation the braid structure could change.
- 5. Telomeres [L224] are of special interests as far as anomalous em charge is considered. Chromosomes are not copied completely in cell replication, and one function of telomeres is to guarantee that the translated part of genome replicates completely for sufficiently many cell divisions. Telomeres consists of 3-20 kilobases long repetitions of TTAGGG, and there is a 100-300 kilobases long repeating sequence between telomere and the rest of the chromosome. Telomeres can form can also 4-stranded structures. Telomere end contains a hair-pin loop as a single stranded part, which prevents the action of DNA repair enzymes on the chromosome end. Telomerase is a reverse transcriptase enzyme involved with the synthesis of telomeres using RNA strand as a template but since its expression is repressed in many types of human cells, telomere length shortens in each cell replication. In the case of germ cells, stem cells and white blood cells telomerase is expressed and telomere length preserved. Telomere shortening is known to relate to ageing related diseases. On the other hand, overactive telomere expression seems to correlate with cancer.

If telomeres possess braid strands, the compensation of Q_a might provide an additional reason for their presence. If this the case and if telomeres are strict multiples of TTAGGG, the shortening of telomeres generates a non-vanishing Q_a unless something happens for the active part of DNA too. Color singletness condition should however remain true: the disappearance of 3n multiples of TTAGGG in each replication is the simplest guess for what might happen. In any case, DNA strands would become unstable in cell replication. Q_a could be reduced by a partial death of DNA in the sense that some portions of braiding disappear. Also this would induce ill functioning of TQC harware perhaps related to ageing related diseases. Perhaps evolution has purposefully developed this ageing mechanism since eternal life would stop evolution.

6. Also amino-acids could be braided. Q_a could vary and correspond to Q_a for one of the codons coding for it. The amino-acid sequences of catalysts attaching to DNA strand should have opposite Q_a for each codon-amino-acid pair so that amino-acid would attach only to the codons coding for it. The TGD based model for nerve pulse [K92] inspires the proposal that magnetic flux tubes connecting microtubules to the axonal membrane allow TQC during nerve pulse propagation when axonal membrane makes transition from gel like phase to liquid crystal phase. Amino-acids of tubulin dimers would be connected by 3-braids, smallest interesting braid, to groups of 3-lipids in axonal membrane and tubulin dimers would define fundamental TQC modules.

Empirical rules about DNA and mRNA supporting the symmetry breaking picture

Somewhat surprisingly, basic facts which can be found from Wikipedia, support the proposed vision about symmetry breaking although, the mechanism of matter antimatter symmetry breaking is more complex than the first guess. I am grateful for Dale Trenary for references which made possible to realize this. Before continuing some comments about the physical picture are in order.

- 1. The vanishing of the induced Kähler field means that the space-time sheet of DNA is a highly unstable vacuum extremal. The non-vanishing of the induced Kähler electric field is thus a natural correlate for both the stability and the non-vanishing quark number density (matter antimatter asymmetry). The generation of matter antimatter asymmetry induces a net density of anomalous em charge, isospin, and quark number in the portion of DNA considered. This in turn generates not only longitudinal electric field but also a longitudinal Kähler electric field along DNA.
- 2. Weak electric fields play a key role in living matter. There are electric fields associated with embryos, central nervous system, individual neurons, and microtubules and their direction determines the direction of a process involved (head-to-tail direction, direction of propagation of nerve pulse, ...).
- 3. Same mechanism is expected to be at work also in the case of DNA and RNA. In the case of gene the direction of transcription could be determined by the direction of the electric field created by gene and telomeres at the ends of chromosomes carrying a net anomalous quark number could be partially responsible for the generation of this field. In the case of mRNA the direction of translation would be determined in the similar manner. The net anomalous em charges of poly-A tail and the transcribed part of mRNA would have opposite signs so that a longitudinal electric field would result.

It will be found that this picture is consistent with empirical findings about properties of DNA.

7. Breaking of matter antimatter symmetry and isospin symmetry for entire genome

Chargaff's rules are not exact and the breaking gives important information about small breakings of isospin and matter-antimatter symmetries at the level of entire genome. The basic parameters are em charge per nucleotide, isospin per nucleotide, the amount of quark number per nucleotide, and the ratio of u and d type matters coded by (G + C)/(A + T) ratio. Recall that there are four options for the map of A, T, C, G to quarks and antiquarks and for option 3) resp. 4) the anomalous em charge is opposite to that for 1) resp. 2).

Table 2.2 gives A, T, C, G contents (these data are from Wikipedia [I6]) provides interesting data about DNA It will be found that so called Szybalski's rules can be interpreted as saying that for coding regions there is breaking of the approximate matter antimatter asymmetry.

Note that matter antimatter asymmetry in the scale of entire genome has largest positive value for human genome and negative value only for yeast genome: this case the magnitude of the asymmetry is largest.

For option 2) the amount of anomalous charge is about .0057e per nucleotide and thus about $3 \times 10^7 e$ for entire human DNA having length of about 1.8 meters. The inspection of tables of [L224] shows that the anomalous em charge for the repeating sequence defining the telomere is always non-vanishing and has always the same sign. Telomeres for human chromosomes consist of TTAGGG repetitions with anomalous em charge with magnitude 5e/3 for all options and have a length measured in few kbases. Human genome as has 24 chromosomes so that the total anomalous em charge of telomeres is roughly $24 \times (5/18) \times x10^3 e \sim .8 \times 10^3 x e$, 1 < x < 10. The anomalous em charge of telomeres is three orders of magnitude smaller than that of entire DNA but if DNA is quantum critical system the change the total anomalous em charge and quark number due to the shortening of telomeres could induce instabilities of DNA (due to the approach to vacuum extremal) contributing to ageing. Note that the small net value of quark number in all the cases considered might be necessary for overall stability of DNA. Telomeres are also known to prevent the ends of chromosomes to stick to each other. This could be partially due to the Coulomb repulsion due to the anomalous em charge.

According to [I6] Chargaff's rules do not apply to viral organellar genomes (mitochondria [I30], plastids) or single stranded viral DNA and RNA genomes. Thus approximate matter antimatter symmetry fails for DNA: s of organelles involved with metabolism. This might relate to the fact that the coding portion of DNA is very high and repeats are absent. Chargaff's rule applies not only to nucleotides but also for oligonucleotides which corresponds to DNA or RNA sequences with not more than 20 bases. This means that for single strand oligonucleotides and their conjugates appear in pairs. Matter antimatter asymmetry would be realized as presence

	Human	Chicken	Grass-	Sea	Wheat	Y east	E.Coli	
			hopper	Urchin				
p(A)	0.3090	0.2880	0.2930	0.3280	0.2730	0.3130	0.2470	
p(T)	0.2940	0.2920	0.2930	0.3210	0.2710	0.3290	0.2360	
p(C)	0.1990	0.2050	0.2050	0.1770	0.2270	0.1870	0.2600	
p(G)	0.1980	0.2170	0.2070	0.1730	0.2280	0.1710	0.2570	
$\frac{dq_1}{dr}$	0.0103	-0.0067	-0.0007	0.0060	0.0010	-0.0053	0.0083	(2.3.8)
$\frac{dq_2}{dn}$	0.0057	-0.0093	-0.0013	0.0050	-0.0000	0.0053	0.0057	
an								
$\frac{dI_3}{dn}$	0.0080	-0.0080	-0.0010	0.0055	0.0005	0.0000	0.0070	
$\frac{d(q-\overline{q})}{dn}$	0.0140	0.0080	0.0020	0.0030	0.0030	-0.0320	0.0080	
un								
$\frac{p(A+T)}{p(G+C)}$	1.5189	1.3744	1.4223	1.8543	1.1956	1.7933	0.9342	

Table 2.2: The table gives A, T, C, G contents (these data are from Wikipedia [I6]), the amount of quark charge per nucleotide for the options 1) resp. 2) given by $dq_1/dn = p[2(A-T) - G - C)]/3$ resp. $dq_2/dn = p[A - T - 2(G - C)]/3$, the amount $dI_3/dn = p(A - G + C - T]/2$ of isospin per nucleotide, the amount $d(q - \bar{q})/dn = p(A - T + G - C)$ of quark number per nucleotide, and (A + T)/(C + G) ratio for entire genomes in some cases.

of matter blobs and their conjugates. This might relate to the mechanism how the sequences of oligonucleotides are generated from DNA and its conjugate.

8. Breaking of matter antimatter symmetry for coding regions

As noticed, one can consider three type of symmetry breaking parameters for DNA in DNA as TQC model. There are indeed three empirical parameters of this kind. Chargaff rules have been already discussed and correspond to approximate matter antimatter symmetry. The second asymmetry parameter would measure the asymmetry between $u\bar{u}$ and $d\bar{d}$ type matter. p(G+C) corresponds to the fraction of $d\bar{d}$ type quark matter for option 1) and $u\bar{u}$ matter for option 2). It is known that G+C fraction p(G+C) characterizes genes [I131] and the value of p(G+C) is proportional to the length of the coding sequence [I25, I131].

Besides Chargaff rules holding true for entire genome also Szybalski's rules [I6] hold true but only for coding coding regions. The biological basis of neither rules is not understood. The interpretation of Chargaff's rules would be in terms of approximate matter antimatter symmetry and the vanishing of net isospin at the level of quarks whereas Szybalski's rule would state the breaking of these symmetries non-coding regions. Hence all the three basic empirical rules would have a nice interpretation in DNA as TQC picture.

Consider now Szybalski's rules in more detail.

1. In most bacterial genomes (which are generally 80-90 % coding) genes are arranged in such a fashion that approximately 50 % of the coding sequence lies on either strand. Note that either strand can act as a template (this came as a surprise for me). Szybalski, in the 1960s, showed that in bacteriophage coding sequences purines (A and G) exceed pyrimidines (C and T). This rule has since been confirmed in other organisms and known as Szybalski's rule [I6, I132]. While Szybalski's rule generally holds, exceptions are known to exist.

Interpretation. A breaking of matter antimatter symmetry occurs in coding regions such that the net breakings are opposite for regions using different templates and thus different directions of transcription (promoter to the right/left of coding region).

2. One can actually characterize Szybalski's rules more precisely. By Chargaff's rules one has $p(A+T) \simeq 1 - p(G+C)$). In coding regions with low value of p(G+C) p(A) is known to be higher than on the average whereas for high value of p(G+C) p(G) tends to higher than on the average.

Interpretation. These data do not fix completely the pattern of breaking of the approximate matter antimatter symmetry.

i) It could take place for both kinds of quark matter $(u\overline{u} \text{ and } d\overline{d})$: both p(A) and p(G) would increase from its value for entire genome but the dominance of A over G or vice versa would explain the observation.

ii) The breaking could also occur only for the dominating type of quark matter $(u\overline{u} \text{ or } d\overline{d})$ in which case only p(A) or p(G) would increase from the value for entire genome.

Also a net isospin is generated which is of opposite sign for short and long coding sequences so that there must be some critical length of the coding sequences for which isospin per nucleotide vanishes. This length should have biological meaning.

3. For mRNA A + G content is always high. This is possible only because the template part of the DNA which need not be always the same strand varies so that if it is strand it has higher A + G content and if it is conjugate strand it has higher T + C content.

Interpretation. mRNA breaks always matter antimatter symmetry and the sign of matter antimatter asymmetry is always the same. Thus mRNA is analogous to matter in observed universe. The poly-A tail added to the end of mRNA after transcription to stabilize it would reduce the too large values of isospin and anomalous em charge per nucleon due to the fact that mRNA does not contain regions satisfying Chargaff's rules. It would also generate the needed longitudinal electric field determining the direction of translation. In the case of DNA the breaking of matter antimatter symmetry is realized at the functional level by a varying direction of transcription and variation of template strand so that matter antimatter symmetry for the entire DNA is only slightly broken. Direction of transcription would be determined by the direction of the electric field. The stability of long DNA sequences might require approximate matter antimatter symmetry for single DNA strand if it is long. In the case of simple genomes (mitochondrial, plastid, and viral) the small size of the genome, the high fraction of coding regions, and the absence of repeating sequences might make approximate matter antimatter symmetry un-necessary. An interesting working hypothesis is that the direction of transcription is always the same for these genomes.

One can try to use this information to fix the most probable option for nucleotide quark correspondence.

- 1. In nuclear physics the neutron to proton ratio of nucleus increases as nucleus becomes heavier so that the nuclear isospin becomes negative: $I_3 < 0$. The increase of the nuclear mass corresponds to the increase for the length of the coding region. Since G/A fraction increases with the length of coding region, G should correspond to either d quark (($Q_a < 0, I_3 = -1/2$)) or its charge conjugate d_c ($Q_a < 0$). Hence option 1) or its charge conjugate would be favored.
- 2. If one takes very seriously the analogy with cosmic matter antimatter asymmetry then matter should dominate and only $(A, G, T, C) \rightarrow (u, d, \overline{u}, \overline{d})$ option would remain.

Szybalski's findings leave open the question whether non-coding regions obey the Chargaff rules in good approximation or whether also they appear as pairs with opposite matter antimatter asymmetry. Introns are belong to coding regions in the sense that they are transcribed to mRNA. Splicing however cuts them off from mRNA. It is not clear whether introns break the approximate matter antimatter symmetry or not. If breaking takes place it might mean that introns code for something but not chemically. On the other hand, the absence of asymmetry might serve at least partially as a signal telling that introns must be cut off before translation. Many interesting questions represent itself. For instance, how the symmetry breaking parameters, in particular matter antimatter asymmetry parameter, depend on genes. The correlation with gene length is the most plausible guess.

Genetic codes and TQC

TGD suggests the existence of several genetic codes besides 3-codon code [K60, ?]. The experience from ordinary computers and the fact that genes in general do not correspond to 3n nucleotides encourages to take this idea more seriously. The use of different codes would allow to tell what kind of information a given piece of DNA strand represents. DNA strand would be like a drawing

of building containing figures (3-code) and various kinds of text (other codes). A simple drawing for the building would become a complex manual containing mostly text as the evolution proceeds: for humans 96 per cent of code would corresponds to introns perhaps obeying some other code.

The hierarchy of genetic codes is obtained by starting from n basic statements and going to the meta level by forming all possible statements about them (higher order logics) and throwing away one which is not physically realizable (it would correspond to empty set in the set theoretic realization). This allows $2^n - 1$ statements and one can select 2^{n-1} statements consistent with a given atomic statement (1 bit fixed) (half of the full set of statements) and say that these are true and give kind of axiomatics about world. The remaining statements are false. DNA would realize only these statements.

The hierarchy of Mersenne primes $M_n = 2^n - 1$ with $M_{n(next)} = M_{M_n}$ starting from n = 2 with $M_2 = 3$ gives rise to 1-code with 4 codons, 3-code with 64 codons, and $3 \times 21 = 63$ -code with 2^{126} codons [K60] realized as sequences of 63 nucleotides (the length of 63-codon is about 2L(151), roughly twice the cell membrane thickness. It is not known whether this Combinatorial Hierarchy continues ad infinitum. Hilbert conjectured that this is the case.

In the model of pre-biotic evolution also 2-codons appear and 3-code is formed as the fusion of 1- and 2-codes. The problem is that 2-code is not predicted by the basic Combinatorial Hierarchy associated with n = 2.

There are however also other Mersenne hierarchies and the next hierarchy allows the realization of the 2-code. This Combinatorial Hierarchy begins from Fermat prime $n = 2^k + 1 = 5$ with $M_5 = 2^5 - 1 = 31$ gives rise to a code with 16 codons realized as 2-codons (2 nucleotides). Second level corresponds to Mersenne prime $M_{31} = 2^{31} - 1$ and a code with $2^{30=15\times2}$ codons realized by sequences of 15 3-codons containing 45 nucleotides. This corresponds to DNA length of 15 nm, or length scale 3L(149), where L(149) = 5 nm defines the thickness of the lipid layer of cell membrane. L(151) = 10 nm corresponds to 3 full 2π twists for DNA double strand. The model for 3-code as fusion of 1- and 2-codes suggests that also this hierarchy - which probably does not continue further - is realized.

There are also further short Combinatorial hierarchies corresponding to Mersenne primes [A9].

- 1. n = 13 defines Mersenne prime M_{13} . The code would have $2^{12=6\times 2}$ codons representable as sequences of 6 nucleotides or 2 3-codons. This code might be associated with microtubuli.
- 2. The Fermat prime $17 = 2^4 + 1$ defines Mersenne prime M_{17} and the code would have $2^{16=8\times 2}$ codons representable as sequences of 8 nucleotides.
- 3. n = 19 defines Mersenne prime M_{19} and code would have $2^{18=9\times 2}$ codons representable as sequences of 9 nucleotides or three DNA codons.
- 4. The next Mersennes are M_{31} belonging to n = 5 hierarchy, M_{61} with $2^{60=30\times2}$ codons represented by 30-codons. This corresponds to DNA length L(151) = 10 nm (cell membrane thickness). M_{89} (44-codons), M_{107} (53-codons) and M_{127} (belonging to the basic hierarchy) are the next Mersennes. Next Mersenne corresponds to M_{521} (260-codon) and to completely super-astrophysical p-adic length scale and might not be present in the hierarchy.

This hierarchy is realized at the level of elementary particle physics and might appear also at the level of DNA. The 1-, 2-, 3-, 6-, 8-, and 9-codons would define lowest Combinatorial Hierarchies.

2.4 Constraints On The Fermionic Realization Of Genetic Code From The Model For Color Qualia

The original model for DNA as topological quantum computer assigns to DNA nucleotides quarks at ends of flux tubes or quark pairs at the ends of wormhole flux tubes. This is only the realization that came first to my mind in TGD Universe where dark variants of quarks can define QCD like physics even in cellular length scales. One can actually imagine several realizations of the genetic code and the first realization is far from being the simplest one. It is enough to have four different particles or many-particle quantum states to build at least formally a map from A, T, C, G to four states. It is obvious that the number of possible formal realizations is limited only by the imagination of the theoretician. Additional conditions are required to fix the model.

2.4.1Fermionic Representation

Consider first the fermionic representations in the general case without specifying what fermions are.

1. The original proposal was that DNA nucleotides correspond to flux tubes with quark q and antiquark \overline{q} at the ends of the parallel flux sheets extremely near to each other. Second options relies on wormhole magnetic flux tubes in which case quark pair $q\bar{q}$ is at both ends. Quarks u, d and their antiquarks would code for A, T, C, G. The spin of quarks is not taken into account at all in this coding: why not restrict the consideration to single quark. The total quark charge at given end of flux tube pair vanishes and flux tube ends carry opposite quark charges.

The nice feature of this option is that one could understand the generation of color qualia in the model of sensory receptor in simple manner to be discussed below. Even if one accepts the arguments supporting the view that dark quarks in cell scale are natural outcome of the hierarchy of Planck constants, one could argue that the presence of both quarks and antiquarks does not conform with matter antimatter asymmetry (not that one can however identify the analog of matter antimatter asymmetry at DNA level).

- 2. Spin states for fermion pairs assigned with two parallel magnetic flux tubes with the magnetic field generated by spin provide much simpler representation for nucleotides. Similar fermion pair would reside at the second end of flux tube pair.
 - (a) It is sessential that rotational symmetry is broken and reduces to rotational symmetry around the direction of flux tubes so that spin singlet and spin 0 state of triplet mix to form states for which each fermion is in spin eigenstate. The states must be antisymmetric under exchange of the protons and spin 1/0 states are antisymmetric/symmetric in spatial degrees of freedom (wave functions located to the ends of flux tubes). The states with definite spin for given flux tube are mixtures of s=1 states with vanishing spin projection and s=0 state.
 - (b) It is not quite clear whether one should treat fermion pairs as identical bosons with 3+1spin states since in TGD framework one considers disjoint partonic 2-surfaces and the situation is not that of QFT in M^4 . This interpretation would require totally symmetry of the states under permutations of bosonic states defined by the 3+1 spin states. Coding by spin requires that each nucleotide corresponds to a state with a well defined spin. In field theory language the state would be obtained by applying bosonic oscillator operators generating states of given spin localized to a given nucleotide position.
 - (c) The classical correlate for the permutations of coordinates of fermions has interpretation as braiding for the flux tubes of the flux tube pair. In the similar manner the permutation of the flux tube pairs associated with nucleotides has interpretation as braiding of the 3-braids formed form from flux tube pairs. Braiding therefore gives a representation of spin analogous to the well-known orientation entanglement relation invented by Dirac and providing geometric representation of spin 1/2 property.

2.4.2Various Options For The Fermionic Representation Of A, T, C, G

Fermionic representations allows several options since fermion can be electron, u or d quark, or proton. Wormhole magnetic fields would not be needed in this case.

1. The problem of electron and proton options is that it does not allow realization of color qualia. There is also the well-known problem related to the stability of DNA caused by the phosphate charge of -2 units per nucleotide. Somehow this charge should be screened. In any case, the charge -2 should correspond to the electron pair at the DNA end of the flux tube for electron option. For proton option the charge would be screened completely. One could

of course consider also the large \hbar color excitations of ordinary protons instead of quark at its nucleotide ends. This option would however require the modification of quark wave functions inside proton and this option will not be discussed here.

- 2. Quark option would give rise to both color and allow also to reduce the electronic charge of -2 units by 4/3 units to -2/3 units in the case of u quark pair. This would help to stabilize DNA. In the case of d quarks the charge would increase to -10/3 units and is not favored by stability argument. Flux tube pairs assigned to single nucleotide define diquarks with spin 1 or spin 0.
 - (a) Diquarks behave ass identical bosons with 3+1 spin states and 3 × 3 color states. They form formally super-multiplet of N = 2 SUSY. The states with well defined symmetry properties in spin degrees of freedom have such properties in spatial degrees of freedom. This means that one obtains a superposition of flux tube pairs with are either braided or unbraided. Triplet/singlet state is symmetric/antisymmetric and total asymmetry could be guaranteed by assuming symmetry/antisymmetry in spatial degrees of freedom and antisymmetry/symmetry in color degrees of freedom. This would give anti-triplet/6-plet in color degrees of freedom. Spatial symmetry would favor antitriplet and diquark would behave like antiquark with respect to color. Let us assume antitriplet state for definiteness.
 - (b) DNA codon corresponds to three-di-quark state. This state must be totally symmetric under the exchange of bosons. One can have total symmetry in both spatial and color degrees of freedom or total antisymmetry/symmetry in spatial and total antisymmetry/symmetry in color degrees of freedom. The first option gives 10-dimensional color multiplet and the second one color singlet. Braiding is maximal and symmetric/antisymmetric in these case. One can consider also mixed symmetries. In this case one has color octet which is antisymmetric with respect to the first nucleotide pair and symmetric with respect to first nucleotide pair and third nucleotide. The braiding of the first two nucleotides must be antisymmetric and the braiding of this pair with third nucleotide. The conclusion would be that color multiplets correspond to well defined braidings and one would therefore have directed connection with topological quantum computation. Color octet is especially interesting concerning the representation of color qualia.

The challenge of all these options (note that the representability of color selects quark option) is to find a good justification for why the assignment of A, T, C, G to quark states or spin states is unique dynamically. Stability argument is expected to help here.

2.4.3 Realization Of Color Qualia For Quark Option

Consider now how one could understand the generation of qualia for quark option.

- 1. The generation of qualia involves interaction with external world giving rise to a sensory percept. In the case of visual colors it should correspond to a measurement of quark color and should give rise to eigenstages of color at the ends of flux tubes at DNA nucleotides for a nucleus or cell of photoreceptor. A modification of capacitor model is needed. Color polarization is still essential but now polarization in nucleus or cell scale is transformed in the generation of color quale to a polarization in longer length scale by the reconnection of flux tubes so that their ends attach to "external world". The nucleus/cell becomes color and state function reduction selects well defined quantum numbers. It is natural to assume that the entanglement in other degrees of freedom after color measurement is negentropic.
- 2. Does the "external world" corresponds to another cell or to the inner lipid layers of the cell membrane containing the nucleus. In the first case flux tubes would end to another cell. If the nuclei of receptor cells are integrate to a larger structure by magnetic flux sheets traversing through them one can also consider the possibility that the polarization in the scale of cell nucleus (recall that the nucleus has also double lipid layer) is transformed to a polarization in cell scale so that similar process in cell scale gives rise to qualia.

The entire receptor unit must have net color charge before the state function reduction. This requires that there are flux tubes connecting the receptor unit to a unit representing "external world" and having vanishing color charge. If second cell is the "external world" these flux tubes must go through the pair of lipid layers of both cell membrane and end up to the nucleus of cell in the environment. If external world correspond to the complement of nucleus inside cell the inner layers of cell membrane represents external world. Cell membrane indeed serves as sensory receptor in cell length scale. One can of course have sensory qualia in various length scales so that both options are probably correct and a kind of fractal hierarchy is very natural giving rise also to our qualia at some higher level. Living matter as conscious hologram metaphor suggests a fractal hierarchy of qualia.

After state function reduction reducing the entanglement the flux tubes split and the receptor becomes un-entangled with external world and has vanishing color charges. At the level of conscious experience this means that there can be only memory about the quale experience. The sensation of quale lasts with respect to subjective time as long as the negentropic entanglement prevails. There is an obvious analogy with Orch-OR (see http://tinyurl.com/ylfv6pp) proposal of Hameroff and Penrose in which also conscious experience ends with state function reduction.

- 3. Consider now how the color qualia are generated.
 - (a) There must be two flux tube states. In the first state there are two flux tube beginning from cell nucleus A and ending to the inner lipid layer a_1 and flux tube beginning from the outer lipid layer a_2 and ending cell nucleus B. Both flux tubes have vanishing net color so that cells have vanishing net colors. This could be regarded as the resting state of the receptor. The lipids in layers a_1 and a_2 are connected by another short flux tube. Same for b_1 and b_2 .
 - (b) The second flux tube state corresponds to long flux tubes connecting the nuclei of cells A and B. The ends carry opposite color charges. In this case the net color of both A and B is non-vanishing. This state would be an outcome of a reconnection process in which the flux tubes from A to a_1 and B to a_2 re-connect with the short flux tube connecting lipid layers a_1 and a_2 .
 - (c) When these flux tubes carry opposite colors numbers at their ends, the cell possess net color charge and can represent color quale. Or rather, creation of this kind of flux tube connections would give rise to the color charging of the receptor cell with external world carrying opposite color charge.

One can argue that this mechanism is not quite in spirit with color capacitor model. Polarization is still essential but now polarization in receptor scale is transformed to polarization in longer length scale by the reconnection of flux tubes. The analog of di-electric breakdown however still applies in the sense that its analog induces large polarization. Several mechanisms generating larger polarization are of course possible. One can ask how essential the electromagnetic polarization of cell membrane is for the generation of qualia at cell level. Note also that biomolecules are quite generally polar molecules.

The unexpected prediction of the model is that braiding would correlate directly with qualia. This would mean also a connection between quantum computation and qualia. This condition emerges from Fermi/Bose-Einstein statistics correlating braiding with symmetric properties of color states and spin states. Quite generally, the correlation of braiding with the symmetries of wave functions as functions of points of braid end points would allow to have direct geometric correlate between induced entanglement and braiding as naïve intuitive expectations have suggested.

This model is not consistent with the naïve expectation that the quale is generated after state function reduction. Rather, the beginning of sensation of quale means beginning of negentropic entanglement and fusion with external world and state function usually associated with the quantum measurement would mean the end of the sensation and separation from the external world! Maybe one can say that state function reduction means that experience is replaced with a memory "I had the sensation of quale" ! Krishnamurti would certainly agree!

2.5 Realization Of Genetic Code In Terms Of Dark Baryons

Either dark baryon code or code based on u, d and their anti-quarks could be involved with various pairings. For dark baryon code DNA would not decompose into codons. For latter code this would be the case. One could also consider the possibility that the regions genes realized the dark baryon code and the regions between them are realized in terms of udubardbar code. The latter code could be also involved with TQC.

2.5.1 Dark Nuclear Strings As Analogs Of DNA-, RNA- and Amino-Acid Sequences and Baryonic Realization Of Genetic Code?

Water memory is one of the ugly words in the vocabulary of a main stream scientist. The work of pioneers is however now carrying fruit. The group led by Jean-Luc Montagnier, who received Nobel prize for discovering HIV virus, has found strong evidence for water memory and detailed information about the mechanism involved [L1, K62, K118], [L1], [I91]. The work leading to the discovery was motivated by the following mysterious finding. When the water solution containing human cells infected by bacteria was filtered in purpose of sterilizing it, it indeed satisfied the criteria for the absence of infected cells immediately after the procedure. When one however adds human cells to the filtrate, infected cells appear within few weeks. If this is really the case and if the filter does what it is believed to do, this raises the question whether there might be a representation of genetic code based on nano-structures able to leak through the filter with pores size below 200 nm.

The question is whether dark nuclear strings might provide a representation of the genetic code. In fact, I posed this question year before the results of the experiment came with motivation coming from attempts to understand water memory. The outcome was a totally unexpected finding: the states of dark nucleons formed from three quarks can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. Since baryons consist of 3 quarks just as DNA codons consist of three nucleotides, one might ask whether codons could correspond to baryons obtained as open strings with quarks connected by two color flux tubes. This representation would be based on entanglement rather than letter sequences. The question is therefore whether the dark baryons constructed as string of 3 quarks using color flux tubes could realize 64 codons and whether 20 amino-acids could be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner.

The following model indeed reproduces the genetic code directly from a model of dark neutral baryons as strings of 3 quarks connected by color flux tubes.

1. Dark nuclear baryons are considered as a fundamental realization of DNA codons and constructed as open strings of 3 dark quarks connected by two colored flux tubes, which can be also charged. The baryonic strings cannot combine to form a strictly linear structure since strict rotational invariance would not allow the quark strings to have angular momentum with respect to the quantization axis defined by the nuclear string. The independent rotation of quark strings and breaking of rotational symmetry from SO(3) to SO(2) induced by the direction of the nuclear string is essential for the model.

Baryonic strings could form a helical nuclear string (stability might require this) locally parallel to DNA, RNA, or amino-acid) helix with rotations acting either along the axis of the DNA or along the local axis of DNA along helix. The rotation of a flux tube portion around an axis parallel to the local axis along DNA helix requires that magnetic flux tube has a kink in this portion. An interesting question is whether this kink has correlate at the level of DNA too. Notice that color bonds appear in two scales corresponding to these two strings. The model of DNA as topological quantum computer [K7] allows a modification in which dark nuclear string of this kind is parallel to DNA and each codon has a flux tube connection to the lipid of cell membrane or possibly to some other bio-molecule.

2. The new element as compared to the standard quark model is that between both dark quarks and dark baryons can be charged carrying charge $0, \pm 1$. This is assumed also in nuclear string

model and there is empirical support for the existence of exotic nuclei containing charged color bonds between nuclei.

3. The net charge of the dark baryons in question is assumed to vanish to minimize Coulomb repulsion:

$$\sum_{q} Q_{em}(q) = -\sum_{flux \ tubes} Q_{em}(flux \ tube) \ . \tag{2.5.1}$$

This kind of selection is natural taking into account the breaking of isospin symmetry. In the recent case the breaking cannot however be as large as for ordinary baryons (implying large mass difference between Δ and nucleon states).

4. One can classify the states of the open 3-quark string by the total charges and spins associated with 3 quarks and to the two color bonds. Total em charges of quarks vary in the range $Z_B \in$ $\{2, 1, 0, -1\}$ and total color bond charges in the range $Z_b \in \{2, 1, 0, -1, -2\}$. Only neutral states are allowed. Total quark spin projection varies in the range $J_B = 3/2, 1/2, -1/2, -3/2$ and the total flux tube spin projection in the range $J_b = 2, 1, -1, -2$. If one takes for a given total charge assumed to be vanishing one representative from each class (J_B, J_b) , one obtains $4 \times 5 = 20$ states which is the number of amino-acids. Thus genetic code might be realized at the level of baryons by mapping the neutral states with a given spin projection to single representative state with the same spin projection. The problem is to find whether one can identify the analogs of DNA, RNA and amino-acids as baryon like states.

States in the quark degrees of freedom

One must construct many-particle states both in quark and flux tube degrees of freedom. These states can be constructed as representations of rotation group SU(2) and strong isospin group SU(2) by using the standard tensor product rule $j_1 \times j_2 = j_1 + j_2 \oplus j_1 + j_2 - 1 \oplus ... \oplus |j_1 - j_2|$ for the representation of SU(2) and Fermi statistics and Bose-Einstein statistics are used to deduce correlations between total spin and total isospin (for instance, J = I rule holds true in quark degrees of freedom). Charge neutrality is assumed and the breaking of rotational symmetry in the direction of nuclear string is assumed.

Consider first the states of dark baryons in quark degrees of freedom.

- 1. The tensor product $2 \otimes 2 \otimes 2$ is involved in both cases. Without any additional constraints this tensor product decomposes as $(3 \oplus 1) \otimes 2 = 4 \oplus 2 \oplus 2$: 8 states altogether. This is what one should have for DNA and RNA candidates. If one has only identical quarks *uuu* or *ddd*, Pauli exclusion rule allows only the 4-D spin 3/2 representation corresponding to completely symmetric representation -just as in standard quark model. These 4 states correspond to a candidate for amino-acids. Thus RNA and DNA should correspond to states of type uud and ddu and amino-acids to states of type *uuu* or ddd. What this means physically will be considered later.
- 2. Due to spin-statistics constraint only the representations with (J, I) = (3/2, 3/2) (Δ resonance) and the second (J, I) = (1/2, 1/2) (proton and neutron) are realized as free baryons. Now of course a dark -possibly p-adically scaled up - variant of QCD is considered so that more general baryonic states are possible. By the way, the spin statistics problem which forced to introduce quark color strongly suggests that the construction of the codons as sequences of 3 nucleons - which one might also consider - is not a good idea.
- 3. Second nucleon like spin doublet call it 2_{odd} has wrong parity in the sense that it would require L = 1 ground state for two identical quarks (*uu* or *dd* pair). Dropping 2_{odd} and using only $4 \oplus 2$ for the rotation group would give degeneracies (1, 2, 2, 1) and 6 states only. All the representations in $4 \oplus 2 \oplus 2_{odd}$ are needed to get 8 states with a given quark charge and one should transform the wrong parity doublet to positive parity doublet somehow. Since open string geometry breaks rotational symmetry to a subgroup SO(2) of rotations acting

along the direction of the string and since the boundary conditions on baryonic strings force their ends to rotate with light velocity, the attractive possibility is to add a baryonic stringy excitation with angular momentum projection $L_z = -1$ to the wrong parity doublet so that the parity comes out correctly. $L_z = -1$ orbital angular momentum for the relative motion of *uu* or *dd* quark pair in the open 3-quark string would be in question. The degeneracies for spin projection value $J_z = 3/2, ..., -3/2$ are (1, 2, 3, 2). Genetic code means spin projection mapping the states in $4 \oplus 2 \oplus 2_{odd}$ to 4.

States in the flux tube degrees of freedom

Consider next the states in flux tube degrees of freedom.

- 1. The situation is analogous to a construction of mesons from quarks and anti-quarks and one obtains the analogs of π meson (pion) with spin 0 and ρ meson with spin 1 since spin statistics forces J = I condition also now. States of a given charge for a flux tube correspond to the tensor product $2 \otimes 2 = 3 \oplus 1$ for the rotation group.
- 2. Without any further constraints the tensor product $3 \otimes 3 = 5 \oplus 3 \oplus 1$ for the flux tubes states gives 8+1 states. By dropping the scalar state this gives 8 states required by DNA and RNA analogs. The degeneracies of the states for DNA/RNA type realization with a given spin projection for $5 \oplus 3$ are (1, 2, 2, 2, 1). 8×8 states result altogether for both *uud* and *udd* for which color bonds have different charges. Also for *ddd* state with quark charge -1 one obtains $5 \oplus 3$ states giving 40 states altogether.
- 3. If the charges of the color bonds are identical as the are for uuu type states serving as candidates for the counterparts of amino-acids bosonic statistics allows only 5 states (J = 2 state). Hence 20 counterparts of amino-acids are obtained for uuu. Genetic code means the projection of the states of $5 \oplus 3$ to those of 5 with the same spin projection and same total charge.

Analogs of DNA, RNA, amino-acids, and of translation and transcription mechanisms

Consider next the identification of analogs of DNA, RNA and amino-acids and the baryonic realization of the genetic code, translation and transcription.

- 1. The analogs of DNA and RNA can be identified dark baryons with quark content uud, ddu with color bonds having different charges. There are 3 color bond pairs corresponding to charge pairs $(q_1, q_2) = (-1, 0), (-1, 1), (0, 1)$ (the order of charges does not matter). The condition that the total charge of dark baryon vanishes allows for uud only the bond pair (-1, 0) and for udd only the pair (-1, 1). These thus only single neutral dark baryon of type uud resp. udd: these would be the analogous of DNA and RNA codons. Amino-acids would correspond to uuu states with identical color bonds with charges (-1, -1), (0, 0),or (1, 1). uuu with color bond charges (-1, -1) is the only neutral state. Hence only the analogs of DNA, RNA, and amino-acids are obtained, which is rather remarkable result.
- 2. The basic transcription and translation machinery could be realized as processes in which the analog of DNA can replicate, and can be transcribed to the analog of mRNA in turn translated to the analogs of amino-acids. In terms of flux tube connections the realization of genetic code, transcription, and translation, would mean that only dark baryons with same total quark spin and same total color bond spin can be connected by flux tubes. Charges are of course identical since they vanish.
- 3. Genetic code maps of $(4\oplus 2\oplus 2) \otimes (5\oplus 3)$ to the states of 4×5 . The most natural map takes the states with a given spin to a state with the same spin so that the code is unique. This would give the degeneracies D(k) as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies D = 1, 2, 3, 4, 6 are predicted. The numbers N(k) of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3]$$
.

The correct numbers for vertebrate nuclear code are (N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3). Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result (2, 9, 1, 5, 3)!

- 4. Stopping codons would most naturally correspond to the codons, which involve the $L_z = -1$ relative rotational excitation of uu or dd type quark pair. For the 3-plet the two candidates for the stopping codon state are $|1/2, -1/2\rangle \otimes \{|2,k\rangle\}$, k = 2, -2. The total spins are $J_z = 3/2$ and $J_z = -7/2$. The three candidates for the 4-plet from which two states are thrown out are $|1/2, -3/2\rangle \otimes \{|2,k\rangle, |1,k\rangle\}$, k = 1, 0, -1. The total spins are now $J_z = -1/2, -3/2, -5/2$. One guess is that the states with smallest value of J_z are dropped which would mean that $J_z = -7/2$ states in 3-plet and $J_z = -5/2$ states 4-plet become stopping codons.
- 5. One can ask why just vertebrate code? Why not vertebrate mitochondrial code, which has unbroken A - G and T - C symmetries with respect to the third nucleotide. And is it possible to understand the rarely occurring variants of the genetic code in this framework? One explanation is that the baryonic realization is the fundamental one and biochemical realization has gradually evolved from non-faithful realization to a faithful one as kind of emulation of dark nuclear physics. Also the role of tRNA in the realization of the code is crucial and could explain the fact that the code can be context sensitive for some codons.

If the pairing is based on the assumption that total quark spins and total flux tube spins are identical, the pairing of dark variants of DNA and its conjugate and DNA and mRNA are are not unique at the level of dark matter but respect the genetic code. Divisor code to be discussed later and equivalent with dark baryon code in realization based on magnetic flux tubes predicts similar non-uniqueness.

Is the genetic code a composite of $64 \rightarrow 40$ and $40 \rightarrow 20$ codes?

As found, dark baryon counterpart of tRNA could correspond to the multiplet of states containing 40 states. According to [I40] most organisms have fewer the 45 species of tRNA. Typical value of anticodons is around 30 and in some organisms the number is as low as 22. This means that the number of different anticodons in tRNA is not larger than 45 and could be at most 40. Unfortunately I do not know what the real situation is. The realization of mRNA-tRNA pairing is known to be based on wobble base pairing [I40]. This means that the pairing is not unique for the third nucleotide of the anticodon so that all mRNA codons can pair with tRNA in a way consistent with the genetic code.

This finding suggests that tRNA could correspond to a 40-plet of anticodons at the level of dark matter then for tRNA-amino-acid genetic code the numbers of codons N(k) with given degeneracy k would be $(N(1), N(2), N(3)) = \{5, 10, 5\}$. The interpretation would be as $DNA \rightarrow$ tRNA dark baryon genetic code projection of states of $4 \oplus 2 \oplus 2$ to states of 4 with the same spin in color bond degrees of freedom to a state with same spin in J = 2 multiplet with 5 states. Numbers of dark aminocids with given degeneracy k would $(N(1), N(2)) = \{16, 24\}$. Ordinary genetic code would result as a composite of the projections associated with these codes. If the identification in terms of 40-plet makes sense one might consider the possibility that the evolution for tRNA-dtRNA correspondence has not yet achieved the ideal situation in which tRNA anti-codons would be in 1-1 correspondence with their dark counterparts.

Objections

Consider next some particle physicist's objections against this picture.

1. The realization of the code requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one has a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states can be scaled up.

- 2. Both the absolute and relative mass differences between Δ and N resp. ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller say of the same order of magnitude as fine structure constant 1/137 so that the mass splittings could be so small as to make decays impossible.
- 3. Dark hadrons could have lower mass scale than the ordinary ones if scaled up variants of quarks in p-adic sense are in question. Note that the model for cold fusion that inspired the idea about genetic code requires that dark nuclear strings have the same mass scale as ordinary baryons. In any case, the most general option inspired by the vision about hierarchy of conscious entities extended to a hierarchy of life forms is that several dark and p-adic scaled up variants of baryons realizing genetic code are possible.
- 4. A heavy objection relates to the addition of $L_z = -1$ excitation to $S_z = |1/2, \pm 1/2\rangle_{odd}$ states which transforms the degeneracies of the quark spin states from (1, 3, 3, 1) to (1, 2, 3, 2). The most plausible answer is that the breaking of the full rotation symmetry induced by nuclear string reduces SO(3) to SO(2). Also the fact that the states of massless particles are labeled by the representation of SO(2) might be of some relevance.

The conclusion is that genetic code can be understood as a map of stringy baryonic states induced by the projection of all states with same spin projection to a representative state with the same spin projection. Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin. Charge neutrality is essential for having only the analogs of DNA, RNA and amino-acids and would guarantee the em stability of the states.

2.5.2 DNA As Topological Quantum Computer Hypothesis And Dark Genetic Code

The coding of DNA codons by assigning to A, G *resp.* T, C of u and d quarks *resp.* their anti-quarks works nicely in the model of DNA as topological quantum computer. One can however consider also the option for which dark baryons code for entire DNA codons.

- 1. DNA as TQC using dark baryons to represent DNA codons would require that DNA strand is accompanied by a nuclear string parallel to it. If the pairing of baryons at the ends of string requires only opposite total quark spins and total flux tube spins the map would obey genetic code rather than being 1-1. The situation changes if dark baryon states are in 1-1 correspondence with the integers (n_a, n_b) labeling the page of book at which magnetic body of the codon resides.
- 2. The condition that the other end of flux tube beginning from the DNA codon contains nuclear string made from anti-baryons is natural but matter antimatter asymmetry if present also for dark matter does not favor this while mesonic strings with quarks at their ends are natural.
- 3. Rotating kinks assignable to 16 codons might be problematic from the point of TQC unless they represent codons with some special significance and play some special role - perhaps representing control commands in TQC program.
- 4. The flux tubes assignable to codons -instead of nucleotides as for earlier realization would be basic units connected to lipids. The entanglement between dark baryon states of dark nuclear string would replaced the entanglement between quarks and anti-quarks at the ends of the flux tubes.
- 5. Only the portions of DNA having interpretation as gene have a natural decomposition to codons. Hence the dark baryon representation of codons is not attractive idea in intronic portions of the genome forming the most plausible candidates for quantum computing part of

DNA since the portion of introns has been increasing during evolution and highest variation of this portion is encountered in human brain [I41]. Hence one might think that TQC as relatively late outcome of the evolution and that only this part of genome is responsible for TQC so that the mpa of nucleotides to quarks would realize genetic code. Furthermore, braiding matters in TQC much more than the colors of braid strands determined by nucleotides so that intronic portions could quite well be repeating sequences without any obvious as information carriers in standard sense and therefore interpreted as junk DNA. There would be also an analogy between emergence of written language meaning that words as holistic entities were replaced with sequences of letters having as such no meaning.

2.6 Could One Find A Geometric Realization For Genetic And Memetic Codes?

Many-sheeted space-time makes possible large deviations from gravitation predicted by GRT, which in TGD framework can be seen as a description of gravitation at the long length scale limit. A fundamental distinction between GRT and TGD is that in TGD framework gravitational constant and cosmological constant - actually space-time dependent cosmological "constants" emerge as predictions of the theory rather than as fundamental constants of Nature.

For almost two decades ago I deduced by purely dimensional considerations a formula for gravitational constant G in terms of p-adic length scale and exponent of Kähler action for CP_2 type vacuum extremal defining the line of generalized Feynman diagram representing graviton [K81]. The prediction was that G should have an entire spectrum of values and approach p-adic length scale squared $L_p^2 = pR_{CP_2}^2$ when the action of the deformed CP_2 type vacuum extremal becomes small: this happens at short length scale limit. In particular, hadronic strings would correspond to strong gravitation limit, and TGD predicts fractally scaled up variants of ordinary hadron physics so that a rich spectrum of strong gravities follows as a prediction. This means that in TGD Universe the the gravitational effects on space-time geometry can be rather dramatic even in condensed matter length scales whereas in GRT the effects are extremely small.

The cosmic honeycomb having voids with size of order 10^8 ly as basic building bricks is one possible quasi-lattice like structure suggested by these considerations. In condensed matter length scales strong gravitation could allow similar quasi-lattice like structures and icosahedral water clusters having tetrahedrons as building bricks could be examples of structures of this kind.

Cosmic honeycombs and their possible counterparts for water clusters modeled as consisting of icosahedral pieces of S^3 bring in mind foams (see http://tinyurl.com/3a29pz). Soap film foam is perhaps the most familiar example about foam. Plateau's laws (see http://tinyurl.com/ y7rrstej) govern the structure of many foams. Mean curvature is constant for each film and physically derives from area minimization assuming constant pressure difference over the film. 3 films meet at angle of 120 degrees along a line known as Plateau border and 4 Plateau borders meet at each vertex at tetrahedral angle of $arcos(-1/3) \simeq 109.47$ degrees (tetrahedral angle is defined as the angle between radii drawn from the center of tetrahedron to its vertices). This suggests spherical tetrahedron as a basic building brick in a model as a honeycomb built from pieces of S^3 . Plateau's laws can be derived mathematically for foams, for which films are minimal surfaces (pressure difference vanishes).

The idea that icosahedral structures assignable to water clusters could define a geometric representation of some kind of code is very intriguing. Genetic code is of course the code that comes first in mind. The observation that the number of faces of tetrahedron (icosahedron) is 4 (20) raises the question whether genetic code might have a geometric representation and the following piece of text is inspired by this question. In TGD framework also a second code emerges: I have christened it memetic code [K60]. Also memetic code could have a geometric realization. Another purely TGD-based notion is that of dark DNA allowing to assign the states of dark protons with DNA, RNA, tRNA and amino-acids and to predict correctly the numbers of DNA codons coding for a given amino-acid in vertebrate genetic code [L1].

In the following some observations suggesting that this kind of geometric representation might exist are first discussed. After that a proposal for how genetic and memetic codes could be realized geometrically is considered.

2.6.1 The Notions Of Memetic Code And Dark Genetic Code

Before going to the topic two TGD inspired concepts must be introduced, namely the notions of memetic code and dark genetic code. From the perspective of standard biology the talk about codes in plural might sound highly speculative. If one takes serious the analogy of living matter with a computing system, it becomes easier to imagine that genetic code could have generalizations and that these codes could have several representations just as computers use an almost unlimited number of different languages. Living matter would in this picture consist of sub-systems emulating each other just as ordinary computers do.

The notion of memetic code

The notion of memetic code introduced for more than 20 years ago allows to interpret the sequences of 21 DNA codons as memetic codons [K60]. The starting point is so called Combinatorial Hierarchy [A33]. Mersenne integers are defined as numbers $M_n = 2^n - 1$. For some values of n, which belong to a subset of primes, one obtains Mersenne primes. In particular the lowest members in the hierarchy defined by the recursive formula $M(n + 1) = M_{M(n)}$ with M(1) = 1, one obtains the sequence M(1) = 1, M(2) = 3, M(3) = 7, M(4) = 127, $M(5) = 2^{127} - 1$, All the explicitly listed Mersenne integers M(n), n > 1, are Mersenne primes. An unproven conjecture by Hilbert is that all numbers M(n), n > 1 in the sequence are Mersenne primes.

What makes this sequence so interesting is that the M(n) + 1 as a power of 2 defines the number of elements for a Boolean algebra. One can say that in a structure with M(n) elements one has thrown single element out from the Boolean algebra. This procedure is natural if Boolean algebra is represented as subsets of a set: the subset which is empty is not realizable physically and must be thrown out. One can say that Combinatorial Hierarchy corresponds to an abstraction hierarchy with levels consisting of statements, statements about statements, statements about.... The geometric analog of this hierarchy would be a fractal structure consisting of geometric objects consisting of points, geometric objects consisting of points replaced with geometric objects, Something like this one might expect in living systems.

Furthermore, in Boolean algebra each element has negation and only half of the elements can represent statements, which are simultaneously true. Therefore for a Boolean algebra with 2^n elements only 2^{n-1} elements can represent mutually consistent truths, "axioms". For the Combinatorial Hierarchy the numbers of "axioms" would be 1, 2, 4, 64, 2^{126} , At the third level one obtains the number 4 of DNA nucleotides, at the next level the number 64 of DNA codons, and at the next level one obtains the number $(2^6)^{21} = 2^{126}$ of DNA sequences obtained from 21 DNA codons. This led to the proposal that there might exist a hierarchy of analogs of the genetic code and that the highest physically realized code in the sequence could be "memetic code" assignable to M_{127} .

The notions of dark nucleus and dark genetic code

The notions of dark nucleus and dark genetic code belong to the most speculative ideas of TGD inspired quantum biology. The original motivation for the notion of dark proton came from the observations suggesting that in atto-second time scale 1/4: th of protons of water molecules are dark in the sense that are not visible in electron scattering and neutron diffraction [D11, D10, D12].

The proposed TGD-based interpretation is that the protons are dark in the sense of having large value of effective Planck constant assignable to their magnetic body [L1]. The varying fraction of dark protons could explain the rich spectrum of anomalous temperature and pressure dependences of many observables related to water.

A model for dark nucleons as consisting of 3 dark quarks leads to a completely unexpected connection with genetic code. One can group the states of the dark nucleon (proton) to groups such that these groups correspond to DNA, mRNA, tRNA, and amino-acids and there is a natural map realizing vertebrate genetic code in the sense that the numbers of dark DNA codons mapped to a given dark amino-acid is the same as for vertebrate genetic code.

The recent work of Persinger's group [J20, J21, J22] combined with the observation of Hu and Wu [J30] that the magnetic interaction energy between protons assigned to the opposite sides of cell membrane corresponds to frequency in EEG range led to the conjecture that the pair of cell membrane lipid layers is accompanied by a pair of dark proton strings analogous to DNA double

strand and indeed representing double DNA strand. There is also a close connection with the model of DNA as topological quantum computer [K7]: in this model magnetic flux tubes connecting nucleotide with lipids are responsible for braiding defining the quantum computer programs.

2.6.2 Could The Faces Of Tetrahedron Correspond To The Four DNA Nucleotides?

Consider first the intriguing observations suggesting that tetrahedral and icosahedral geometries relate to genetic code and its generalization to memetic code [K60]

- 1. The opening solid angle for each of the 20 tetrahedrons in S^3 icosahedron is $\Psi = 4\pi/20$. On the other hand, in DNA strand this angle corresponds in a good approximation to the twist angle for a single nucleotide from the fact that 30 DNA nucleotides (10 codons corresponds to twist angle of 6π (and to a length of 10 nm for DNA strand). For twist angle of 2π the number of nucleotides is not divisible by 3 (integer number of codons). This could be seen as a hint that S^3 icosahedral water clusters are biologically important.
- 2. Tetrahedron has 4 faces. Could they somehow correspond to the 4 DNA nucleotide? In order to distinguish between codons one must be able to distinguish between the faces of the tetrahedra mark them , to assign to given face a unique DNA, and to select one of the faces of tetrahedron to "activate" it. In the case of DNA double strand this could mean that two of the faces of a given tetrahedron are glued to the precedessor and successor of the nucleotide in the DNA strand. The third face would be paired with conjugate strand by hydrogen bonds so that one open face would remain and would represent DNA nucleotide.

The marking of the faces of the S^3 tetrahedron would require a breaking of SO(3) symmetry. Symmetry breaking could take place when one looks the tetrahedron in E^3 geometry. One could say that SO(4) symmetry of S^3 geometry breaks the $SO(3) \times T^3$ symmetry of E^3 (emergence of high space-time symmetry is not consistent with high embedding space symmetry). For instance, the faces of the tetrahedron could have different areas in E^3 metric. The breaking of symmetries could be due to the shift of the S^3 tetrahedron from North Pole of S^3 to some other point, and due to the breaking of translational invariance of E^3 for S^3 tetrahedron. The external face of an icosahedral tetrahedron can be distinguished from the other three faces which are internal even without the breaking of SO(3) symmetry (only breaking of SO(4) symmetry of S^3).

2.6.3 Could The 20 Outer Faces/Tetrahedrons Of The Icosahedron Correspond To Amino-Acids?

 S^3 icosahedron has 20 faces. Could they somehow correspond to 20 different amino-acids? To achieve this two conditions must be satisfied.

1. One must be able to distinguish between the outer faces of the icosahedron so that one can associate to a given face only single amino-acid. As already explained, symmetry breaking allowing to distinguish between the faces is possible in E^3 geometry if the S^3 icosahedron is moved from the origin of S^3 to some other point.

For instance, the areas of the faces could be different and if the amino-acid is glued only to the face which it "fits" (recall the analogy with lock and key mechanism) one would have the desired 1-1 correspondence with amino-acids and icosahedrons. The outcome could be that only single amino-acid can be glued to a given face. Note that magnetic flux tubes could realize the correspondence between amino-acids and icosahedral outer faces in very concrete manner: this mechanism is proposed as a general mechanism of bio-catalysis making it possible for two reacting molecules to find each other in the thick molecular soup [K7, K44].

2. One must also be able to "activate" a given face, perhaps by gluing something to it. This "something" could be amino-acid but also something else, say additional tetrahedron representing a genetic codon.

Dark DNA codon corresponds to dark proton identified as 3-quark state. Could this 3quark state have a geometric representation? The decomposition of icosahedral surface to triangles suggests that triangle is a natural geometric object for DNA, and in the sequel a geometric model for dark DNA codons based on a repeated division of equilateral triangle to equilateral triangles is considered. One must however keep in mind that this kind of representation might not be necessary. It is enough to assume single dark proton per each tetrahedral building brick of icosahedron. Dark protons would in turn be connected to nuclear string.

2.6.4 Icosahedral Realization Of The Memetic Code?

In the presence of symmetry breaking allowing to distinguish between the 20 icosahedral tetrahedrons the external faces of the icosahedron can be in 1-1 correspondence with amino-acids. One can consider even more ambitious option. The icosahedron + tetrahedron structures with 20 icosahedral tetrahedrons plus 1 tetrahedron glued to some icosahedral face could be perhaps interpreted as memetic codons if each tetrahedron represents a genetic codon. A crucially important constraint is that the icosahedral tetrahedrons have a unique linear ordering.

These memetic codons could be also associated with real amino-acids if a given amino-acid can attach only to single face of the icosahedron and there is a mechanism which selects which face is "active". This particular amino-acid would be naturally coded by the 21^{st} DNA codon at the surface of the icosahedron so that one would kill to flies with single blow obtaining both the a representation of memetic codons and assign to the 21^{st} DNA codon corresponding amino-acid. If so, water clusters could represent immense amount of dark biological information.

How could one realize dark memetic codons as dark nuclei? The obvious possibility is as strings of 21 dark protons: in this case the linear ordering of protons would be essential for the realization of the code. A realization inspired by the conventional nuclear physics framework leads naturally to the icosahedral structure.

- 1. A nucleus carrying 20 protons or neutrons is a magic nucleus (exceptionally stable). For instance, the biologically important ion Ca^{++} corresponds to double magic nucleus has 20 protons and 20 neutrons. Also neutrons are present in ordinary nuclei, and I have proposed that protons and neutrons could correspond to different space-time sheets: perhaps these space-time sheets could correspond to Northern and Southern hemispheres of S^3 .
- 2. The information about the ordering of dark nucleons is not lost if icosahedral nucleus + single proton is obtained by a convolution of a dark proton nuclear string. The icosahedral core of S^3 icosahedral dark nucleus consisting of 20 dark protonic tetrahedra would be magic and analogous to a closed shell of an atom.

From the net representation (see http://tinyurl.com/yatsguy5) of icosahedron obtained by cutting the icosahedron open, it is clear that there are at least two paths of this kind but differing only by orientation. Each of them can be regarded as a union of 5 4-triangle paths of the net combining to form a connected triangle path at the surface of icosahedron when appropriate identifications of the edges are made. The step between neighboring triangles corresponds to reflecting with respect to the common edge. Each 4-triangle path corresponds to a path containing vertices of "big" tetrahedron (not one of the twenty tetrahedrons with one vertex at the center of icosahedron) shared also by icosahedron. This sequence corresponds to the orbit of the icosahedral isometry group, which is the alternating group A_5 (60 even permutations of 5 letters) acting transitively so that the orbit visits all triangles at the isosahedral surface. A good guess is that these two oppositely oriented orbits and their images under A_5 define the only ways to fill the icosahedral surface by single path. The number of images is 12 since each of the 12 vertices of icosahedron defines one tetrahedron. Note that this identification for the folded DNA sequence allows also to think that it traverses the surface of the icosahedron rather than filling the entire icosahedron.

3. In chemistry valence electrons dictate the chemistry and in complete analogy with this the 21st dark proton at the surface of the icosahedron would code for the amino-acid attached to it. This icosahedral folding of the nuclear string would be analogous to the folding of protein to a globular shape in its resting state. This folding could indeed characterize the resting

state of dark DNA and when dark DNA becomes active - say during a transcription like process - unfolding would occur. Similar unfolding takes place also for the ordinary DNA.

If each icosahedral tetrahedron corresponds to one particular amino-acid, one can argue that a given tetrahedron can be associated only to those DNA codons which code the aminoacid associated with the tetrahedron. As following arguments show, this correspondence leads to problems.

- 1. If the genetic code dictates the correspondence between tetrahedra and DNA codons, then the three stopping sign codons cannot be contained by the memetic codons so that memetic code would not be fully realised.
- 2. The allowed memetic codons would code for sequence of 20 different amino-acids and there would be strong correlations between neighboring amino-acids in the sequence since the DNA sequence would define a non-self-intersection path visiting every triangle at the surface of the icosahedron only once, and a given amino-adic would have as edge neighbors only three amino-acids. If only single sequence is possible as proposed above, then only single amino-adic sequence containing all amino-acids would be allowed and the number of memetic codons coding for it would be product of numbers of codons coding for the 20 amino-acids.

2.6.5 Geometric Representation Of Dark DNA Codons

Could one have a concrete geometric representation for DNA codons and nucleotides in the proposed model? The fact that dark DNA codon consisting of 3 quarks corresponds to triangle (or corresponding icosahedral tetrahedron) is highly suggestive.

- 1. Icosahedral surface triangle would naturally correspond to a triplet defining DNA codon and the vertices of the triangle to the letters A, T, C, G. This could be achieved geometrically by dividing a given icosahedral surface triangle, call it T, to 4 equilateral triangles T_i , i = 1, 2, 3, 4and assigning the three letters of the codon to the resulting three triangles T_i , i = 1, 2, 3, 4sharing a vertex with T. The inner triangle T_4 would remain unpopulated.
- 2. How to represent codon geometrically for T and perhaps also the letter A, T, C, G for T_i ? One manner to achieve the latter goal is to divide T_i to further equilateral triangles T_{ij} , j = 1, 2, 3, 4 and assign A, T, C, G to T_i by some kind of symmetry breaking distinguishing between them geometrically. The dark codon consisting of 3 quarks could select somehow this triangle. The simplest possibility is that the spatial wave function of i^{th} quark of proton is located inside one T_{ij} , i = 1, 2, 3, j = 1, 2, 3, 4. The connection with quark model of nucleon would be that the quarks are at the vertices of triangle T_i and are connected to the centre of T_i by color flux tubes. Inside T_i the location of quark is inside T_{ij} . An alternative option is that quarks are connected by color flux tubes directly to each other.

A couple of remarks are in order.

- 1. The model for dark DNA does *not* allow to represent the counterparts of DNA codons as unentangled products of 3-quark states: the states are quantum superpositions of 3-quark states and the decomposition of codon to letters is not possible. This means that DNA codons are "irreducible". One can however deduce correspondence between codons and amino-acids and it corresponds to the vertebrate genetic code. The geometric representation for the codons as mapping of DNA codons to geometric objects however still make sense if the positions of quarks obey the above rule for a given entangled quark triplet.
- 2. The model for dark DNA [L1] assumes that dark DNA strand is linear so that symmetry breaking of rotational symmetry to SO(2) consisting of rotations around the strand takes place. In the recent situation similar breaking of symmetry must take place and the natural axis is no the axes defined by the normal of the triangle defining dark DNA codon.
- 3. One can also wonder what might be the geometric counterparts of dark mRNA, tRNA, and amino-acids.

2.6.6 Could Water Clusters Represent Memetic Code?

Could the dark protons realizing dark genetic codons as nuclear strings be associated with water molecules or clusters of them? One can imagine two alternative realizations of the icosahedral memetic codons.

1. It is known that water molecules themselves have tetrahedral structure with 2 lone electron pairs and H_+ nuclei are at the vertices of the tetrahedron (maybe regular S^3 tetrahedron). There is chemical symmetry breaking since the faces come in two types: 2 faces of type $H_+H_+(2e)$ and 2 faces of type $H_+(2e)(2e)$. If the second proton is of the water molecule is dark, a further symmetry breaking takes place and one has faces of 3 types. The symmetry of $H_+H_+(2e)$ faces could be broken if they correspond the two lone electron pairs are located the center of icosahedron and it surface. The chemical symmetry breaking and perhaps also magnetic flux tubes would help to assign to unique amino-acid to one of the tetrahedrons.

Icosahedron would consists of a folded linear sequence of tetrahedral water molecules - formed perhaps perhaps by hydrogen bonding. The representation of memetic codon as a single icosahedral cluster of 21 water molecules would predict single dark proton per water molecule. Recall that the average in atto-second time scale would be 1/4 dark protons per water molecule. I do not know whether icosahedral clusters of this kind exist.

2. It is however known that known (see http://tinyurl.com/yb9waklg) that 14 water molecules indeed combine to form tetrahedral structures (see http://tinyurl.com/yb19eqt9 [D11], and that these in turn combine to form icosahedral structures. The size scale of the 14 molecule cluster is nearer to the size scale of single DNA nucleotide so that perhaps this option is more realistic. If these structures provide a representation of memetic codons with tetrahedral structure of 14 water molecules representing single DNA codon or amino-acid, there are 14 water molecules per single dark proton representing dark DNA codon.

2.7 About Physical Representations of Genetic Code in Terms of Dark Nuclear Strings

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas. One can argue that genetic code is realized in several ways just like bits can be represented in very many ways. Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony involving icosahedral and tetrahedral geometries. Second model has two variants based on dark nuclear strings: the original version maps codons do dark nucleons, the more recent version maps codons to dark 3-nucleon states. Both models predict correctly the numbers of DNA codons coding for a given amino-acid but the model based on dark 3-nucleon triplets is favoured by some recent findings suggesting a pairing between DNA nucleotides and dark nucleons. Also the counterparts of RNA,tRNA, and amino-acids are predicted. In the sequel the updated nuclear string variant is summarized and also its connection with the model of harmony is discussed.

2.7.1 Background

The view about evolution as a random process suggests that genetic code is pure accident. My own view is that something so fundamental as life cannot be based on pure randomness. TGD has led to several proposals for genetic code, its emergence, and various realizations based on purely mathematical considerations or inspired by physical ideas (see chapters of [K59] and [L1, K62]). One can argue that genetic code is realized in several ways just like bits can be represented in very many ways.

Two especially interesting proposals have emerged. The first one is based on geometric model of music harmony [L16] involving icosahedral and tetrahedral geometries. Second one having two variants is based on dark nuclear strings. Both models predict correctly the numbers of DNA codons coding for a given amino-acid. In the sequel the nuclear string variant and also its connection with the model of harmony is discussed in detail.

It is good to start with an overall view about physical realization of genetic code that I have discussed during last twenty years.

Genetic code and Combinatorial Hierarchy

The first proposal [K60] was purely mathematics inspired and in terms of so called Combinatorial Hierarchy consisting of certain Mersenne primes $M_k = 2^k - 1$ via the formula $M(n+1) = M_{M(n)}$ having interpretation in terms of abstraction. The list beginning from M(1) = 2 is $2, M_2 = 3, M_3 = 7, M_7 = 127, M_{127} = 2^{127} - 1$: it is not known whether subsequent integers are Mersenne primes. The idea is that the $2^k - 1$ points define almost full Boolean algebra spanned by k bits- one visualization is as a polygon. The algebra defined k - 1 bits is maximal full Boolean sub-algebra having interpretation as maximal number of mutually independent statements, which can hold true simultaneously. For M_7 (k = 3) one would have 2 bits and 4 codons. For M_7 one would have k = 7 and 6 bits and genetic code. For M_{127} one would have 126 bits and one would have "memetic" code realizable in terms of sequences of 21 DNA codons.

Geometric theory of harmony and genetic code

The idea that the 12-note scale could allow mapping to a closed path going through all vertices of icosahedron having 12 vertices and not intersecting itself is attractive. Also the idea that the triangles defining the faces of the icosahedron could have interpretation as 3-chords defining the notion of harmony for a given chord deserves study. The paths in question are known as Hamiltonian cycles and there are 1024 of them [A7]. There paths can be classified topologically by the numbers of triangles containing 0, 1, or 2 edges belonging to the cycle representing the scale. Each topology corresponds to particular notion of harmony and there are several topological equivalence classes.

In the article [L21] I introduced the notion of Hamiltonian cycle as a mathematical model for musical harmony and also proposed a connection with biology: motivations came from two observations. The number of icosahedral vertices is 12 and corresponds to the number of notes in 12-note system and the number of triangular faces of icosahedron is 20, the number of aminoacids. This led to a group theoretical model of genetic code and replacement of icosahedron with tetra-icosahedron to explain also the 21st and 22nd amino-acid and solve the problem of simplest model due to the fact that the required Hamilton's cycle does not exist. The outcome was the notion of bioharmony.

All icosahedral Hamilton cycles with symmetries $(Z_6, Z_4, Z_2^{rot} \text{ and } Z_2 refl$ turned out to define harmonies consistent with the genetic code. In particular, it turned out that the symmetries of the Hamiltonian cycles allow to to predict the basic numbers of the genetic code and its extension to include also 21st and 22nd amino-acids Pyl and Sec: there are actually two alternative codes - maybe DNA and its conjugate are talking different dialects! One also ends up with a proposal for what harmony is leading to non-trivial predictions both at DNA and amino-acid level.

The conjecture is that DNA codons correspond to 3-chords perhaps realized in terms of dark photons or even ordinary sound. There are 256 different bio-harmonies and these harmonies would give additional degrees of freedom not reducing to biochemistry. Music expresses and creates emotions and a natural conjecture is that these bio-harmonies are correlates of emotions/moods at bio-molecular level serving as building bricks of more complex moods. Representations of codons as chords with frequencies realized as those of dark photons and also sound is what suggests itself naturally. This together with adelic physics involving hierarchy of algebraic extensions of rationals would explain the mysterious lookin connection between rational numbers defined by ratios of frequencies with emotions.

Letter-wise representations of genetic code in terms of single particle states

The model for DNA-cell membrane system as topological quantum computer with lipids and DNA nucleotide or codons connected by flux tubes led to a proposal for the correspondence of letters of genetic code with particle states.

- 1. The original proposal was that the 4 letters A,T,C,G correspond to dark u and d quark and their antiparticles \overline{u} and \overline{d} . Quarks and their antiparticles would reside at the ends of the flux tube. Spin would not matter in this model. The obvious criticism is that introducing dark antiquarks is too far fetched.
- 2. One can also consider a variant for which one has u and d quarks and spin matters.
- 3. TGD based model of bio-superconductivity assumes that flux tubes appear as pairs with members of Cooper pair at parallell flux tubes [K89, K90]. This suggests that electron pairs at in spin 1 and spin 0 states could realize the code. The spin of the electrons would matter and one would obtain 4 states two qubits in correspondence with A,T,C,G.

Also the model of dark nuclear strings allows to imagine letter-wise representations of the genetic code. The model for cold fusion based on the findings of Prof. Holmlid and his group [C2, L48] leads to the idea that Pollack's EZs [L20] are accompanied by dark nuclear strings consisting of dark protons connected by color flux tubes analogous to mesons [L27, L48]. Color bonds would have quark and antiquark at their ends [L1]. This leads to non-trivial predictions and nuclear anomalies giving support for the notion of nuclear string have emerged, the latest anomaly is so called X boson with mass of 17 MeV [L51, C4] having identification as p-adically scaled analog of pion.

Dark protons could also decay to neutrons by dark weak decays rapidly since dark weak bosons are effectively massless below dark Compton length. Furthermore, proton plus negatively charged color bond could behave like neutron as far as chemistry is considered. The X boson anomaly of nuclear physics [L51] suggests that the flux tubes in the ground state correspond to pion-like states which can be colored: this could bind the nucleons to form a nucleus. The evidence for the occurrence of cold fusion in living matter gives support for the role of dark nuclear strings [K72] [L48].nOne can consider several representations of the genetic code in this framework.

Consider first models for which letters are represented separately.

- 1. Dark protons and neutrons have 4 spin states and could correspond to letter A,T,C,G. In this case dark color bonds would not matter. A rather convincing proposal for a pathway leading to a selection purines as DNA nucleotides has been proposed [I68]. TGD based model [L45] suggests that acidic solutions contain dark protons and purine results when the precursor amine combines with dark proton such that the proton remains dark. Could DNA nucleotide pair with dark protons and neutrons (resulting in dark beta decay from dark proton strings yielded by Pollack's mechanism)?
- 2. Also the 4 states of dark color bonds between dark nucleons (3 pion-like states and one eta meson like state: spin 1 bonds would be analogous to ρ and ω mesons and have higher mass) correspond to letters A,T,C,G. Now the dark protons and neutrons would not matter. This option would require that the character of the nucleotide correlates with the color flux tube attached to the dark proton. They would have at their ends charge conjugate color bonds. The states would be of form $u\overline{u}, d\overline{d}, u\overline{d}, d\overline{u}$ with the ordering of q and \overline{q} correlating with the direction in which transcription and replication take place being thus same or opposite). For conjugate strand the direction of strand would be opposite in the sense that one would have $\overline{u}u, \overline{d}u, \overline{d}u, \overline{u}u$.

For this option one could consider the strands of dark DNA double strand being connected by flux tube pairs resulting when U-shaped color flux tube have reconnected. If color flux tubes are colored, color confinement could bind the dark protons to dark nucleus. Similar mechanism could be at work for the ordinary nuclei.

The basic problem of all the proposals based on letter-wise correspondence is that they do not even try to explain the numbers of DNA codons coding for a given amino-acid and are also silent about tRNA.

Codon-wise representations of genetic code realized in terms of dark strings

For this option entire codons rather than letters would be represented. The difference between two representations is analogous to that between spoken and written languages. In spoken languages words are not analyzed further to letters. These models are able to predict also the numbers of codons coding for a given amino-acid successfully.

- 1. The geometric theory of harmony represents codons as 3-chords without assigning fixed notes to A,T,C,G and explains also DNA-amino-acid correspondence.
- 2. The map of codons to the dark nucleon states of dark nucleon consisting of dark u and d type quarks does the same and also predicts the degeneracies successfully.
- 3. This model can be modified by replacing u and d by dark nucleon states p and n without any change in predictions related to genetic code. The evidence that DNA codons indeed couple to dark nucleon states [L45] supports this option.

In the sequel I consider the models mapping DNA codons to dark nucleons and then generalize the model so that it applies to triplets of dark nucleons.

2.7.2 Codons as dark quark-triplet strings

Water memory is one of the ugly words in the vocabulary of the main stream scientist. The work of pioneers is however now carrying fruit. The group led by Jean-Luc Montagnier, who received Nobel prize for discovering HIV virus, has found strong evidence for water memory and detailed information about the mechanism involved [K62, K118], [I91]. The work leading to the discovery was motivated by the following mysterious finding. When the water solution containing human cells infected by bacteria was filtered in purpose of sterilizing it, it indeed satisfied the criteria for the absence of infected cells immediately after the procedure. When one however adds human cells to the filtrate, infected cells appear within few weeks. If this is really the case and if the filter does what it is believed to do, this raises the question whether there might be a representation of genetic code based on nano-structures able to leak through the filter with pores size below 200 nm.

The question is whether dark nuclear strings might provide a representation of the genetic code. In fact, I posed this question year before the results of the experiment came with motivation coming from the attempts to understand water memory. The outcome was a totally unexpected finding: the states of dark nucleons formed from three quarks can be grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

Could DNA and amino-acids correspond to dark quark triplet strings

The dark model emerged from the attempts to understand water memory [K62]. The outcome was a totally unexpected finding [L1, K62]: the states of dark nucleons formed from three quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, 20 amino-acids, and tRNA and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks - just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η .

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino-acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would be not be anymore separable to letters but entangled states of 3 quarks.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics and maybe even in ordinary nuclear physics if the nucleons of ordinary nuclear physics are linear nucleons. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

The ability of the model to explain genetic code in terms of spin pairing is an impressive achievement, which I still find difficult to take seriously.

1. The original model identifying codons to dark nucleon states assumed the overall charge neutrality of the dark proton strings: the idea was that the charges of color bonds cancel the total charge of dark nucleon so that all states uuu, uud, udd, ddd can be considered. The charge itself would not affect the representation of codons. Neutrality assumption is however not necessary. The interpretation as dark nucleus resulting from dark proton string could quite well lead to the formation the analog of ordinary nucleus via dark beta decays [L48] so that the dark nucleus could have charge. Isospin symmetry breaking is assumed so that neither quarks nor flux tubes are assigned to representations of strong SU(2).

There is a possible objection. For ordinary baryon the mass of Δ is much larger than that of proton. The mass splitting could be however much smaller for linear baryons if the mass scale of excitations scales as $1/h_{eff}$ as indeed assumed in the model of dark nuclear strings [L27, L48].

2. The model assumes that the states of DNA can be described as tensor products of the four 3-quark states with spin content $2 \otimes 2 \otimes 2 = 4 \oplus 2_1 \oplus 2_2$ with the states formed with the 3 spin triplet states $3 \otimes 3 = 5 \oplus 3 \oplus 1$ with *singlet state dropped*. The means that flux tubes are spin 1 objects and only spin 2 and spin 1 objects are accepted in the tensor product. One could consider interpretation in terms of ρ meson type bonding or gluon type bonding. With these assumptions the tensor product $(2 \otimes 2 \otimes 2) \otimes (5 \oplus 3)$ contains $8 \times 8 = 64$ states identified as analogs of DNA codons.

The rejection of spin 0 pionic bonds looks strange. These could however occur as bonds connecting dark codons and could correspond to different p-adic length scale as suggested by the successful model of X boson [L51].

One can also ask why not identify dark nucleon as as closed triangle so that there would be 3 color bonds. In this case $3 \otimes 3 \otimes 3$ would give 27 states instead of 8 ($\oplus 1$). This option does not look promising.

- 3. The model assumes that amino-acids correspond to the states 4×5 with $4 \in \{4 \oplus 2 \oplus 2\}$ and $5 \in \{5 \oplus 3\}$. One could tensor product of spin 3/2 quark states and spin 2 flux tube states giving 20 states, the number of amino-acids.
- 4. Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino-acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allow immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4\oplus 2\oplus 2) \otimes (5\oplus 3)$ to the states of 4×5 with same or opposite spin projection. This would give the degeneracies D(k) as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies D = 1, 2, 3, 4, 6 are predicted. The numbers N(k) of amino-acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3]$$

The correct numbers for vertebrate nuclear code are (N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3). Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result (2, 9, 1, 5, 3)! This simple observation would suggest that genetic code could be realized already at the level of dark or even ordinary nuclear physics and bio-chemistry is only a kind of shadow of dark matter physics.

Objections against the identification of codons as dark quark triplets

Consider next some particle physicist's objections against the option mapping codons to dark nucleon states.

- 1. The realization of the model of codon as dark quark triplet requires the dark scaled variants of spin 3/2 baryons known as Δ resonance and the analogs (and only the analogs) of spin 1 mesons known as ρ mesons. The lifetime of these states is very short in ordinary hadron physics. Now one would have a scaled up variant of hadron physics: possibly in both dark and p-adic senses with latter allowing arbitrarily small overall mass scales. Hence the lifetimes of states could be scaled up.
- 2. Both the absolute and relative mass differences between Δ and N resp. ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller say of the same order of magnitude as fine structure constant 1/137 so that the mass splittings could be so small as to make decays impossible.

The color magnetic spin interaction energy give rise to hyperfine splitting of quark in perturbative QCD is of form $E_c \propto \hbar g B/m$, where *m* is mass parameter which is of the order of baryon mass. Magnetic flux scales as \hbar by flux quantization and if flux tube thickness scales as \hbar^2 , one has $B \propto 1/\hbar$. Mass splittings would not depend on \hbar , which does not make sense. Mass splitting becomes small for large \hbar if the area of flux quantum scales as \hbar^{2+n} , n > 0 so that color magnetic hyper-fine splitting scales as $1/\hbar^n$ from flux conservation. The magnetic energy for a flux tube of length *L* scaling as \hbar and thickness $S \propto \hbar^{2+n}$ has order of magnitude $g^2 B^2 LS$ and does not depend on \hbar for n = 1. Maybe this could provide first principle explanation for the desired scaling.

The size scale of DNA would suggest that single DNA triplet corresponds to 3 Angstrom length scale. Suppose this corresponds to the size of dark nucleon. If this size scales as $\sqrt{\hbar}$ as p-adic mass calculations suggest, one obtains a rough estimate $\hbar/\hbar_0 = 2^{38}$. The proton- Δ mass difference due to hyper-fine splitting would be scaled down to about $2^{-38} \times 300$ MeV $\sim 10^{-9}$ eV, which is completely negligible in the metabolic energy scale .5 eV. If the size of dark nucleon scales as \hbar the mass difference is about 12 eV which corresponds to the energy scale for the ionization energy of hydrogen. Even this might be acceptable.

For these reasons the option mapping codons to dark nucleon triplets is clearly favored and will be discussed in the following.

2.7.3 Codons as dark nucleon-triplet strings?

The assumption that entire codon rather than letter corresponds to a state of dark proton does not conform with the model for the origin of purines as DNA nucleotides [L45] assuming that purines, and in fact all nucleotides, are combined with dark proton unless one assumes that 3 nucleotides combine with the same dark proton. This looks somewhat artificial but cannot be excluded.

The arguments of the model involve only the representations of rotation group and since p and n have same spin as u and d, the arguments generalize to 3- nucleon states (ppp, ppn, pnn, nnn) connected by two color bounds and organized to linear structures. Concerning genetic code, exactly the same predictions follow in the recent formulation of the model. In this case quark color is not present. One could however use the 1-dimensionality and the ordering of dark nucleons as already described.

The model with linear quark triplets generalizes by replacing dark u and d quarks with dark nucleons p and n. The analogs of ρ mesons would correspond to 2 bonds also now. Irrespective of changes of nucleons, all states would have decomposition $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ corresponding to the degrees of freedom associated with 3 nucleon spins and 2 neutral ρ meson spins.

ppp could correspond to DNA and RNA and proton charges would neutralize the negative charges of ordinary DNA codons. The singlet formed by bonds would be neglected. nnn triplets could correspond to amino-acids and trNA. Amino-acids could correspond to $4 \times 5 = 20$ and the remaining states $4 \otimes 3 \oplus (2 \oplus 2) \otimes 5 \oplus 3$. could correspond to 44 tRNAs. Also other options are possible and have net charges 2 and 1.

This variant has several nice features. The model is consistent with the model for dark nucleon strings consisting of nucleons and color bonds between them. There is no need to introduce Δ type nucleon states and colored states are not needed in fermionic sector. Color bonds must be colored if one wants ordinary bosonic statistics for flux tubes but here braid statistics might help. Colored bonds could of course have some important function.

Could dark DNA, RNA, tRNA and amino-acids correspond to different charge states of codons?

If dark codons correspond to dark nucleon triplets as assumed in the following considerations there are 4 basic types of dark nucleon triplets: *ppp*, *ppn*, *pnn*, *nnn*. Also dark nucleons could represent codons as *uuu*, *uud*, *udd*, *ddd*: the following discussion generalizes as such also to this case. If strong isospin/em charge decouples from spin the spin content is same independently of the nucleon content. One can consider the possibility of charge neuralization by the charges assignable to color flux tubes but this is not necessarily. In any case, one would have 4 types of nucleon triplets depending on the values of total charges.

Could different dark nucleon total charges correspond to DNA,RNA, tRNA and aminoacids? Already the group representation content - perhaps correlating with quark charges - could allow to distinguish between DNA, RNA, tRNA, and amino-acids. For amino-acids one would have only 4×5 and ordinary statistics and color singlets. For DNA and RNA one would have full multiplet also color non-singlets and for tRNA one could consider $(4 \oplus 2_1 \oplus 2_2) \times 5$ containing 40 states. 31 is the minimum number of tRNAs for the realization of the genetic code. The number of tRNA molecules is known to be between 30-40 in bacterial cells. The number is larger in animal cells but this could be due to different chemical representations of dark tRNA codons.

If the net charge of dark codon distinguishes between DNA,RNA, tRNA, and amino-acid sequences, the natural hypothesis to be tested is that dark ppp, ppn, pnn, and nnn sequences are accompanied by DNA,RNA, tRNA, and amino-acid sequences. The dark beta decays of dark protons proposed to play essential role in the model of cold fusion [?]ould transform dark protons to dark neurons. Peptide backbones are neutral so that dark nnn sequence could be also absent but the dark nnn option is more natural if the general vision is accepted. There is also the chemically equivalent possibility that only dark protons are involved: dark proton + neutral color bond would represent proton and dark proton + negatively charged color bond would represent neutron. At this moment it is not possible to distinguish between these two options.

Is this picture consistent with what is known about charges of amino-acids DNA,RNA, tRNA, and amino-acids? Consider first the charges of these molecules.

- 1. DNA strand has one negative charge per nucleotide. Also RNA molecule has high negative charge. This conforms with the idea that dark nucleons accompany both DNA and RNA. DNA codons could be accompanied by dark ppp implying charge neutralization in some scale and RNA codons by dark ppn. The density of negative charge for RNA would be 2/3 for that for DNA.
- 2. Arg, His, and Lys have positively charged side chains and Asp,Glu negative side chains (see http://tinyurl.com/jsphvgt). The charge state of amino-acid is sensitive to the pH value of solution and its conformation is sensitive to the counter ions present. Total charge for amino-acid in peptide however vanishes unless it is associated with the side chain: as in the case of DNA and RNA it is the backbone whose charge is expected to matter.
- 3. Amino-acid has central C atom to which side chain, NH_2 , H and COOH are attached. For free amino-acids in solution water solution $NH_2 \rightarrow NH_3^+$ tends to occur pH=2.2 by receiving possibly dark proton whereas COOH tends to become negatively charged above pH= 9.4 by donating proton, which could become dark. In peptide OH attach to C and one H attached to N are replaced with peptide bond. In the pH range 2.2-9.4 amino-acid is zwitterion for
which both COOH is negatively charged and NH_2 is replaced with NH_3^+ so that the net charge vanishes. The simplest interpretation is that the ordinary proton from negatively ionized COOH attaches to NH_2 - maybe via intermediate dark proton state.

- 4. The backbones of peptide chains are neutral. This conforms with the idea that dark aminoacid sequence consists of dark neutron triplets. Also free amino-acids would be accompanied by dark neutron triplets. If the statistics is ordinary only 4 dark nnn states are possible as also 5 dark color flux tube states.
- 5. tRNA could involve dark pnn triplet associated with the codon. An attractive idea is secondary genetic code assigning RNA codons to tRNA-amino-acid complex and projecting $8 \otimes (5 \oplus 3)$ containing 64 dark RNA spin states to $8 \otimes 5$ containing 40 dark tRNA spin states with same total nucleon and flux tube spins. Dark tRNA codons would in turn be attached to dark amino-acids by a tertiary genetic code projecting spin states $8 \otimes 5$ to $4 \otimes 5$ by spin projection. In the transcription dark tRNA would attach to dark mRNA inducing attachment of dark amino-acid to the growing amino-acid sequence and tRNA having only dark tRNA codon would be left. The free amino-acids in the water solution would be mostly charged zwitterions in the pH range 2.2-9.4 and the negative charge of COO⁻ would be help in the attachement of the free amino-acid to the dark proton of tRNA codon. Therefore also the chemistry of free amino-acids would be important.

An interesting question is why pnn triplets for tRNA would only 5 in flux tube degrees of freedom entire 8 in nucleon degrees of freedom. For RNA consisting of ppn triplets also 3 would be possible. What distinguishes between ppn and pnn?

The model should explain the widely different properties of DNA, RNA, tRNA, and amino-acids. There are two options.

- 1. DNA/RNA/amino-acid codons could correspond to ppp/ppn/nnn and tRNA would correspond to pnn (order is not necessarily this). Different charge or dark codons explain why DNA (RNA) has H (OH) in 2' position. The repulsive Coulomb energy between dark codons would be stronger for DNA and the compensation of this forces by the magnetic tension associated with the flux tube pair connecting codon and anticodon this might have something to do with the stability of DNA double strand.
 - (a) The instability of RNA as compared to DNA would result from the instability of the ribose in RNA (deoxiribose in DNA) as indeed believed. The absence of RNA double strands could be due to the instability of the flux tube pair assignable to n-n. This trivially implies absence of replication and transcription if it is based on same mechanism as in the case of DNA.
 - (b) pnn structure could explain why tRNA does not form sequences and allow to understand wobble pairing, which states that the third mRNA codon does not correspond to unique tRNA anticodon but one has $C,A,U \rightarrow I$ and $U \rightarrow I$. Due to the symmetries of the third letter of the codon, this is consistent with the genetic code. The physical explanation for wobble base pairing could relate to pnn structure of tRNA. If the charge ordering is random one would have nnp,npn,pnn and $C,A,U \rightarrow I$ could correspond to these 3 situations whereas for $U \rightarrow I$ the correspondence would not depend on the ordering. Also for RNA one would have ppn,pnp, npp degeneracy but in this case one would have charge independence.

A possible charge pairing between RNA and tRNA would be $p \leftrightarrow n$. The charge pairing between DNA and RNA could be $p \rightarrow n$ for the third least significant letter of DNA. This would minimize the coding errors possibly induced this pairing.

- (c) One can criticize the charge assignment ppn (possibly allowing permutations) for RNA codons. Could dark weak beta decays give rise to 1-D lattice like structure? Could the repetitive structure be due to energy minimization.
- 2. Could the correspondence be letterwise? For DNA A,T,C,G would correspond to p, and for RNA A,C,G to p and U to n. Codons not containing U wold be ppp type codons and one can

wonder why the oxiribose for them is not replaced with de-oxiribose. The possible presence of n in dark codons could explain why RNA sequences are highly unstable and why they do not replicate and transcribe.

Objections based on group theory and statistics

The quark-triplet model and its generalization replacing u, d with nucleon states p, n works nicely but is better to try to invent objections against the proposal and try to find inconsistencies. Fermi and Bose statistics are the most obvious providers of killer arguments.

1. The basic objection is that if the quarks are organized in linear structures, one cannot talk about representation of 3-D rotation group since symmetry breaking to SO(2) acting along common axis which could be either the local axis along dark DNA helix of the axis of the entire helix. The linear ordering of the quarks is not consistent with the full harmonics. Rather, harmonics restricted to half space $0 \le \theta \le \pi/2$ ($\pi \ge \theta \ge \pi/2$) should characterize the "upper" ("lower") flux tube direction at the position of quark in the middle.

If reflection along quantization axis and SO(2) generate the symmetries one still has labelling of the states by angular momentum projection and states form doublets (m, -m). The representations of SO(3) split into these representation and the numbers of states with given spin projection remain the same. Therefore the predictions for the numbers of DNA codons coding given aminoacid are not changed. It is quite possible that braid statistics made possible by 1-dimensionality is needed to realize the idea about ordering and this would allow to have full DNA multiplets.

- 2. In quark model one forms tensor product of tensor products of 3 quark spin states and 3 quark isospin states and by color singletness requires that the state is completely antisymmetric in quark degrees of freedom. The state is completely symmetric in the non-colored degrees of freedom. One obtains only two representations $\Delta \leftrightarrow (3/2, 3/2)$ and N = (1/2, 1/2) with positive parity. In quark model context the presence of other tensor products in $(4 \oplus 2_1 \oplus 2_2)_S \otimes (4 \oplus 2_1 \oplus 2_2)_I$ is forbidden. One reason is that spatial wave function is assumed to be symmetric in ground state. This forbids 2_2 in spin degrees of freedom. Symmetrization leaves only the Δ and N (Note that the total number of these state is 20!). Now strong isospin is broken and it is natural to not include it to the tensor product.
- 3. The presence of 2_2 would be forbidden in quark model since it would require antisymmetric spatial wave function to compensate for the antisymmetry of 2_2 . In the recent case the situation is 1-dimensional and the ordering along nuclear string forces localization of quarks and one cannot have identical wave functions for quarks.

1-D situation also suggests strongly braid statistics. Perhaps the situation could be understood in terms of fermionic oscillator operators along nuclear string having anti-commutation relations corresponding to non-trivial braid statistics - maybe making the statistics commutative. This could naturally allow anti-symmetrization along nuclear string for 2_2 states.

4. If one assumes ordinary statistics, one could one take care of the statistics of the 16 states in 2₂ ⊗ (5 ⊕ 3) by assuming that for 2₂ the color state is symmetric and thus 10-D representation of SU(3). The state associated with color flux tubes cannot compensate this color (triality is 1) since it must correspond to triality zero representation. If the colors of DNA strand and conjugate correspond to 10 and 10 and color entanglement could guarantee color singletness for the codon pairs. This would however require anti-quarks for the conjugate strand.

3 10:s associated with 3 codons contains in their tensor product a singlet (see http://tinyurl.com/zjxxqhj). Minimal color singlet dark DNA sequence would requite 3 color codons. One can of course wonder whether the presence of 3 decouplet codons - 2 at the beginning and 2 at end and one in the middle could define genes as basic units.

5. The statistics problem is encountered also for the flux tubes. 5 (and 1) as symmetric representation is allowed by statistics but triplet is antisymmetric and thus not allowed. Again braid statistics might help. If one assumes that the flux tubes are colored - say color octets and color wave function for flux tube pairs is antisymmetric, one can achieve Bose statistics for 3. Flux tube pair would correspond to $8 \in \{8 \times 8\}$ and minimum of two flux codons would be needed for color singletness in flux tube degrees of freedom.

6. For the counterparts of amino-acids one has only 4⊗5 allowed also by statistics considerations assuming color singlets. Could distinction between DNA/RNA and amino-acids related to statistics, perhaps braid statistics. The suggested role of braid strands possibly connecting DNA double strands and DNA double strands and lipid layers of cell membrane encourages the question whether the DNA strand and its conjugate entangle via via the reconnection of the color flux tubes defining U-shaped "tentacles" to a flux tube pair connecting the strands. For amino-acids they would not be needed. Same could happen in the transcription process of DNA to mRNA and in the translation process for mRNA tentacles and those associated with tRNA.

Ordinary or braid statistics?

There are four options to consider: ordinary/braid statistics (1/2) and dark nucleon as dark quark/nucleon triplet as representation of DNA codon (a/b). One has options 1a,1b,2a,2b. Options 1b and 2b are at this moment the only options, which can be taken seriously: the reason is that dark protons would neutralize the negative charges of ordinary DNA nucleotides.

- 1. Option 1a: codons as quark-triplets with ordinary statistics. For the ordinary statistics amino-acid like dark nucleons are color singlets. Part of DNA codons are represented as dark nucleons and would be colored and 10-D representation of SU(3). Dark amino-acids need not have color bonds with dark parts of other colored biomolecules like DNA,RNA, with exception possible formed by dark tRNA. DNA double strand could realize color confinement via the reconnection of color flux tubes.
- 2. Option 1b: codons as nucleon-triplets with ordinary statistics. Option 1b requires in ordinary statistics for antisymmetric doublet and antisymmetric wave function for the 3 nucleons not allowing constant valued wave function also disfavored by the linear ordering. This condition might have the same implications as braid statistics.
- 3. Options 1a and 1b. DNA is the only molecule that appears as double strands. A possible explanation is that codons and anticodons are paired by U-shaped flux tubes associated with the color bonds of dark DNA to form color singlets. Nucleonic colors would sum up to zero along the strand.
- 4. Option 2a. For braid statistics it could be possible to avoid colored states of nucleon and flux tubes.
- 5. Option 2b. The 3-nucleon codons would have no color and amino-acids could obey braid statistics reducing to ordinary statistics. This would not be the case for DNA/RNA.

It must be admitted that the situation is unsatisfactory as far as statistics is considered. For the option 1b) with codons identified as dark proton triplets one can however consider the following variant to satisfy statistics requirement.

- 1. Years after writing the above comments it has become clear that adelic physics [L66] brings in additional discrete degrees of freedom assignable to the group algebra of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele.
- 2. Galois group acts on the space of space-time surfaces, and one can say that one has wave function at the orbit of the Galois group consisting of space-time sheets. At quantum level quantum states correspond to wave functions in the group algebra of Galois group of extension.
- 3. The role of color in helping to achieve correct statistics could be taken by Galois degrees of freedom. One can even consider the notion of Galois confinement as a generalization of color confinement [L139] binding codons as dark proton triplets to dynamical units. Even genes as sequences of codons could be bound to dynamical units as Galois singlets.

2.7.4 Further considerations

Replication, transcription, translation

The formation of flux tube pairs between molecules would be central in replication and transcription and in all bio-catalysis. Dark DNA would replicate first to dark DNA or mRNA. This requires that the building bricks of dark DNA and mRNA emerge from environment perhaps by mechanism involving reconnection for the magnetic tentacles and reduction of h_{eff} bringing the molecules near each other. Flux tube pairs between dark DNA codonsandtheir conjugates (individual dark RNA codons) would be formed during replication (transcription). The formation of flux tube pair between mRNA and dark tRNA part of tRNA would bring tRNA to mRNA, where amino-acid would associate with the growing amino-acid sequence.

For options 1a and 1b based on ordinary statistics color singletness condition could play an important role in the replication and transcription.

- 1. If the value of h_{eff} before reconnection and contraction of flux tube dictating the scale of color confinement is large enough, colored dark nucleons could float as free possibly colored states in the environment for option 1a). For option 1b dark nucleons could be present in environment this could relate directly to the ionization in electrolyte. For options 1a and 1b dark codons representing dark tRNA molecules would accompany them.
- 2. For options 1a) and 1b) color confinement in flux tube degrees of freedom by forming dark color flux tube pairs between dark DNA and its conjugate in codon-wise manner could give rise to DNA double strands as chemical shadows of dark double strands. The coupling between codon and anticodon would be defined by the condition that the total color bond spins of paired codons are opposite. Quark color could be compensated for option 1a along DNA strand: 3 10:s give singlet. One can of course ask whether dark DNA RNA sequences exist rather than being built during replication and transcription.

Are sound-like bubbles whizzing around in DNA essential to life?

I got a link to a very interesting article [I77] about sound waves in DNA (see http://tinyurl. com/z7hod9b). The article tells about THz de-localized modes claimed to propagate forth and back along DNA double strand somewhat like bullets. These modes involve collective motion of many atoms. These modes are interpreted as a change in the stiffness of the DNA double strand leading to the splitting of hydrogen bonds in turn leading to a splitting into single strands. The resulting gap is known as transcriptional bubble propagating along double strand is the outcome. I do not how sound the interpretation as sound wave is.

It has been proposed that sound waves along DNA give rise to the bubble. The local physical properties of DNA double strand such as helical structure and elasticity affect the propagation of the waves. Specific local sequences are proposed to favor a resonance with low frequency vibrational modes, promoting the temperary splitting of the DNA double strand. Inside the bubble the bases are exposed to the surrounding solvent, which has two effects.

Bubbles expose the nucleic acid to reactions of the bases with mutagens in the environment whereas so called molecular intercalators may insert themselves between the strands of DNA. On the other hand, bubbles allow proteins known as helicases to attach to DNA to stabilize the bubble, followed by the splitting the strands to start the transcription and replication process. The splitting would occur at certain portions of DNA double strand. For this reason, it is believed that DNA directs its own transcription.

The problem is that the strong interactions with the surrounding water are expected to damp the sound wave very rapidly. Authors study experimentally the situation and report that propagating bubbles indeed exist for frequencies in few THz region. Therefore the damping deo not seem to be effective. How this is possible? As an innocent layman I also wonder how this kind of mechanism can be selective: it would seem that the bullet like sound wave initiates transcription at many positions along DNA. The transcription should be localized to a region assignable to single gene. What could guarantee this?

Can TGD say anything interesting about the mechanism behind transcription and replication?

- 1. In TGD magnetic body controls and coordinates the dynamics. The strongest hypothesis is that basic biochemical process are induced by those for dark variants of basic bio-molecules (dark variants of DNA, enzymes,...). The belief that DNA directs its own transcription translates to the statement that the dark DNA consisting most plausibly from sequences of dark proton triplets ppp at dark magnetic flux tubes controls the transcription: the transcription/replication at the level of dark DNA induces that at the level of ordinary DNA.
- 2. If the dark DNA codons represented as dark proton triplets (*ppp*) are connected by 3 flux tube pairs, the reverse of the reconnection should occur and transform flux tube pairs to two U-shaped flux tubes assignable to the two dark DNA strands. Dark proton sequences have positive charge +3e per dark codon giving rise to a repulsive Coulomb force between them. There would be also an attractive force due to magnetic tension of the flux tubes. These two forces would compensate each other in equilibrium (there also the classical forces due to the negatively charged phosphates associated with nucleotides but these would not be so important).

If the flux tube pairs are split, the stabilizing magnetic force however vanishes and the dark flux tubes repel each other and force the negatively charged DNA strands to follow so that also ordinary DNA strand splits and bubble is formed. The primary wave could therefore be the splitting of the flux tube pairs: whether one can call it as a sound wave is not clear to me. Perhaps the induced propagating splitting of ordinary DNA double strand could be regarded as an analog of sound wave.

The splitting of flux tube pairs for a segment of DNA would induces a further splitting of flux tubes since repulsive Coulomb force tends to drive the flux tubes further away. The process could be restricted to DNA if the "upper" end of the split DNA region has some dark DNA codons which are not connected by flux tubes pairs. This model reason why for dark proton sequences.

3. This model does not yet explain how the propagating splitting wave is initiated. Could a quantum phase transition increasing the value of h_{eff} associated with the flux tube pairs occur for some minimal portion of dark DNA "below" the region associated with gene and lead to the propagating wave induced by the above classical mechanism? That the wave propagates in one direction only could be due to chirality of DNA double helix.

An interesting question is how the RNA world vision (see http://tinyurl.com/gpmxcmk) relates to this general picture.

- 1. There are strong conditions on the precedessor of DNA and RNA satisfies many of them: reverse transcription to DNA making possible transition to DNA dominated era is possible. Double stranded RNA exists http://tinyurl.com/y9mex4v7 in cells and makes possible RNA genome: this would however suggest that cell membrane came first. RNA is a catalyst. RNA has ability to conjugate an amino-acid to the 3' end of RNA and RNA catalyzes peptide bond formation essential for translation. RNA can self-replicate but only relatively short sequences are produced.
- 2. TGD picture allows to understand why only short sequences of RNA are obtained in replication. If the replication occurs at the level of dark ppn sequences as it would occur for DNA in TGD framework, long RNA sequences might be difficult to produce because of the stopping of the propagation of the primary wave splitting the flux tube pairs. This could be due to the neuron pairs to which there is associated no Coulomb repulsion essential for splitting.
- 3. In TGD framework RNA need not be the precedessor of DNA since the evolution would occur at the level of dark nucleon strings and DNA as the dark proton string is the simpest dark nucleon string and might have emerged first. Dark nuclear strings would have served as templates and biomolecules would have emerged naturally via the transcription of their dark counterparts to corresponding bio-polymers.

Is bio-catalysis a shadow of dark bio-catalysis based on generalization of genetic code?

Protein catalysis and reaction pathways look extremely complex (see http://tinyurl.com/kp3sdlm) as compared to replication, transcription, translation, and DNA repair. Could simplicity emerge if biomolecules are identified as chemical shadows of objects formed from dark nuclear strings consisting of dark nucleon triplets and their dynamics is shadow of dark stringy dynamics very much analogous to text processing?

What if bio-catalysis is induced by dark catalysis based on reconnection as recognition mechanism? What if contractions and expansions of U-shaped flux tubes by h_{eff} increasing phase transitions take that reactants find each other and change conformations as in the case of opening of DNA double strand? What if codes allowing only the dark nucleons with same dark nuclear spin and flux tubes spin to be connected by a pair of flux tubes?

This speculation might make sense! The recognition of reactants is one part of catalytic action. It has been found in vitro RNA selection experiments that RNA sequences are produced having high frequency for the codons which code for the amino-acid that these RNA molecules recognize (http://tinyurl.com/kp3sdlm. This is just what the proposal predicts!

Genetic codes DNA to RNA as $64 \rightarrow 64$ map, RNA to tRNA as $64 \rightarrow 40$, tRNA to aminoacids with $40 \rightarrow 20$ map are certainly not enough. One can however consider also additional codes allowed by projections of $(4 \oplus 2_1 \oplus 2_2) \otimes (5 \oplus 3(\oplus 1))$ to lower-dimensional sub-spaces defined by projections preserving spins. One could also visualize bio-molecules as collections of pieces of text attaching to each other along conjugate texts. The properties of catalysts and reactants would also depend by what texts are "visible" to the catalysts. Could the most important biomolecules participating biochemical reactions (proteins, nucleic acids, carbohydrates, lipids, primary and secondary metabolites, and natural products, see http://tinyurl.com/jlfxags) have dark counterparts in these sub-spaces.

The selection of bio-active molecules is one of the big mysteries of biology. The model for the chemical pathway leading to the selection of purines as nucleotides [L45] assumes that the precedessor of purine molecule can bind to dark proton without transforming it to ordinary proton. A possible explanation is that the binding energy of the resulting bound state is higher for dark proton than the ordinary one. Minimization of the bound state energy could be a completely general criterion dictating which bio-active molecules can pair with dark protons. The selection of bio-active molecules would not be random after all although it looks so. The proposal for DNAnuclear/cell membrane as topological quantum computer with quantum computations coded by the braiding of magnetic flux tubes connecting nucleotides to the lipids wlead to the idea that flux tubes being at O=-bonds [K7].

Comparing TGD view about quantum biology with McFadden's views

McFadden [I124] has very original view about quantum biology: I have written about his work for the first time for years ago, much before the emergence of ZEO, of the recent view about self as generalized Zeno effect, and of the understanding the role of magnetic body containing dark matter [?]. The pleasant surprise was that I now understand McFadden's views much better from TGD viewpoint.

- 1. McFadden sees decoherence as crucial in biological evolution: here TGD view is diametric opposite although decoherence is a basic phenomenon also in TGD.
- 2. McFadden assumes quantum superpositions of different DNAs. To me this looks an unrealistic assumption in the framework of PEO. In ZEO it is quite possible option.
- 3. McFadden emphasizes the importance of Zeno effect (in PEO). In TGD the ZEO variant of Zeno effect is central for TGD inspired theory of consciousness and quantum biology. Mc Fadden suggests that quantum effects and Zeno effect are central in bio-catalysis: the repeated measurement keeping reactants in the same position can lead to an increase of reaction rate by factors of order billion. McFadden describe enzymes as quantum mousetraps catching the reactants and forcing them to stay in same position. The above description for how catalysis catches the reactants using U-shaped flux tube conforms with mousetrap picture.

McFadden discusses the action of enzymes in a nice manner and his view conforms with TGD view. In ZEO the system formed by catalyst plus reactants could be described as a negentropically entangled sub-self, and self indeed corresponds to a generalized Zeno effect. The reactions can proceed in shorter scales although the situation is fixed in longer scales (hierarchy of CDs): this would increase the length of the period of time during which reactions can proceed and lead to catalytic effect. Zeno effect in ZEO plus hierarchies of selves and CDs would be essentially for the local aspects of enzyme action.

4. Protons associated with hydrogen bonds and electronic Cooper pairs play a universal role in McFadden's view and the localization of proton in quantum measurement of its position to hydrogen bond is the key step of enzyme catalysis. Also TGD dark protons at magnetic flux tubes giving rise to dark nuclear strings play a key role. For instance, McFadden models enzyme catalysis as injection of proton to a very special hydrogen bond of substrate. In TGD one has dark protons at magnetic flux tubes and their injection to a properly chosen hydrogen bond and transformation to ordinary proton is crucial for the catalysis. Typical places for reactions to occur are C=O type bonds, where the transition to C-OH can occur and would involve transformation of dark proton to ordinary proton. The transformation of dark proton to ordinary one or vice versa in hydrogen bonds would serve as a biological quantum switch allowing magnetic body to control biochemistry very effectively.

What about electronic Cooper pairs assumed also by McFadden. They would flow along the flux tube pairs. Can Cooper pairs of electrons and dark protons reside at same flux tubes? In principle this is possible although I have considered the possibility that particles with different masses (cyclotron frequencies) reside at different flux tubes.

McFadden [I124] has proposed quantum superposition for ordinary codons: This does not seem to make sense in PEO since the chemistries of codons are different) but could make sense in ZEO. In TGD one could indeed imagine quantum entanglement (necessary negentropic in p-adic degrees of freedom) between dark codons. This NE could be either between additional degrees of freedom or between spin degrees of freedom determining the dark codons. In the latter case complete correlation between dark and ordinary DNA codons would imply also the superposition of their tensor products with ordinary codons.

The NE between dark codons could also have a useful function: it could determine physically gene as a union of disjoint mutually entangled portions of DNA. Genes are known to be highly dynamical units, and after pre-transcription splicing selects the portions of the transcript translated to protein. The codons in the complement of the real transcript are called introns and are spliced out from mRNA after the pre-transcription (see http://tinyurl.com/gmphzzy).

What could be the physical criterion telling whether a given codon belongs to exonic or intronic portion of DNA? A possible criterion distinguish between exons and introns is that exons have NE between themselves and introns have no entanglement with exons (also exons could have NE between themselves). Introns would not be useless trash since the division into exonic and exonic region would be dynamical. The interpretation in terms of TGD inspired theory of consciousness is that exons correspond to single self.

Is there a connection between geometric model of harmony and nuclear string model of genetic code?

There should exists a connection between the geometric model of harmony and genetic code and the model of genetic code discussed.

- 1. Dark DNA strands could be connected by color flux tubes to form a double strand by reconnections of U-shaped color flux tubes. What would induce a codon-wise or letter-wise pairing of DNA codons and their conjugates represented as dark quark triplets to form double DNA strand? Cyclotron resonance could accompany reconnection (magnetic field strength would be identical and reconnection could occur).
- One has the correspondence codon ↔ state of dark nucleon or codon ↔ state of dark nucleon triplet. The geometric model of harmony and genetic code [L16] represents the codons as 3-chords. The 3-chord would be represented in terms of cyclotron frequencies of dark photons

assignable to the 3 dark quarks (nucleons) in the state. Each quark-color bond pair (including the pion-like bond) could be in 12 states with corresponding cyclotron frequency mappable to the basic octave. The cyclotron frequency triplets would be same for codons and conjugates. The only manner to understand the scale is in terms of spectrum of magnetic field strengths for U-shaped flux tube pairs.

This would require 3 pairs of flux tubes between the dark codons of DNA strands. If the quarks inside linear dark proton are connected by color flux tubes (like protons in the model of dark nucleus). Reconnection for U-shaped flux tube connecting quarks would give rise to the double strand formed by dark proton strings. The magnetic field strength of the 3-flux tubes would be determined by the state of dark proton and would be same for DNA and RNA codons and also for RNA codons and corresponding tRNA-amino-acid complexes. The cyclotron frequencies would define a scaled up variant of Pythagorean scale projected to the basic octave [L16]. This option does not favor the idea about separater 4-letter code.

- 3. The geometric model for harmony is formulated in terms of orbits of the subgroups of the isometry groups of tetrahedral and icosahedral geometries. The DNAs coding particular amino-acid correspond correspond to the orbit of the triangle of icosahedron corresponding to the amino-acid. The decomposition $60 \rightarrow 20 + 20 + 20$ suggests strongly decomposition of I to $20 Z_3$ cosets containing 3 elements each other and in correspondences with the triangular faces of icosahedron.
- 4. The model of the genetic code just discussed relies on the model of dark nucleon based on group theory. The symmetric groups of Platonic solids are in turn associated with inclusion of hyper-finite factors and appear in Mc Kay correspondence, whose proof involves decompositions of SU(2) representations to the representations of the discrete subgroups of Platonic solids. A further observation is that the numbers of elements for isometries of icosahedron and tetrahedron are 60 and 4 respectively: the sum is 64. Could the action of Z_3 leaving face invariant could be posed as an additional condition on amino-acids and reduce the amino-acid representation to $4 \otimes 5$.
- 5. In the geometric model of harmony genetic icosahedral 20+20+20 part of the code involves a combination of three different Hamilton's cycles mapping 60 DNAs to 20 amino-acids: in terms of icosahedral group I and its coset space I/Z_3 these maps correspond to coset projections. Could the decomposition $(4 \oplus 2_1 \oplus 2_2) \otimes (5 \otimes 3)$ be understood in terms of a reduction to icosahedral and tetrahedral subgroups of rotation group or of their spin coverings.

In this process finite-dimensional representation of SO(3) decomposes to a direct sum of representations of the discrete subgroup if its dimension is larger than any of the dimensions of representations of the finite sub-group (for basic facts about these see http://tinyurl.com/ho4onbs). One might hope that the decomposition of the representations of SO(3) appearing in the above formula under icosahedral group and or tetrahedral group could allow to understand the emergence of DNA, RNA, tRNA, and amino-acids as kind of symmetry breaking.

6. In the geometric model of harmony 64-codon code [L16] is obtained as a fusion 60-codon code assignable to icosahedron + 4 codon code assignable to tetrahedron. There are actually two codes corresponding to tetrahedron and icosahedron as disjoint entities and tetrahedron glued to icosahedron along one face. The model explains the two additional amino-acids Pyl and Sec coded for a variant of the genetic code.

How could these two successful models relate to each other? In p-adic physics of cognition Platonic solids and polygons can be seen as discrete approximation for sphere [L46] and biomolecules could be understood as cognitive representation in the intersection of real and p-adic space-time surface consisting of algebraic points. Could one assign icosahedron and tetrahedron to a codon in some concrete manner? Could the attachment of tetrahedron to icosahedron along one face have concrete meaning? The answer seems to be negative.

1. One can about the interpretation of the 12 vertices of the icosahedron - how number 12 could be assigned with the genetic code? The vertices correspond to notes perhaps represented as magnetic field strength at the flux tubes assignable to color bonds. This field strength should be determined by the spin state of dark 3-nucleon. No concrete nuclear string counterpart seems to exist for the closed Hamiltonian cycle consisting of 12 notes and in case of tetrahedral extension of 13 notes. 12 vertices of icosahedron correspond to 12 notes and 20 faces to 3chords so that there is not need for more concrete correspondence.

2. The attachment of tetrahedron to icosahedron would bring in further note very near to one of the notes of Pythagorean scale and corresponding 3-chords. This has concrete interpretation and there is no need to make this more concrete at the level of geometry of DNA. If icosahedron and tetrahedron are disjoint one obtains four additional codons. It seems that all these 4 3-chords be assigned with the 3 color bonds, one note for each of them. What distinguishes at the level of dark nucleon string the situations in which tetrahedron is attached and non-attached to the color bond? In presence of attachment there would be 1 shared 3-chord corresponding to stop codon assignable with the shared face. The 13:th note appearing in 4 3-chords differs very little from one of the notes of the icosahedral scale: this corresponds to the fact that 12 perfect quints do not quite give 7 octaves as already Pythagoras realized. Crazy question: Could this small difference relate to the small relative mass difference $(m_p - m_n)/m_p \simeq .0014$ making itself possible visible in cyclotron frequency scale? The idea does not seem plausible: $[(3/2)^{12} - 2^7]/2^7 \simeq .014$ is 10 times larger than $(m_p - m_n)/m_p \simeq .0014$.

The conclusion is that genetic code can be understand as a map of stringy nucleon states induced by the projection of all states with same spin projections to a representative state with the same spin projections (total quark spin and total flux tube spin). Genetic code would be realized at the level of dark nuclear physics and biochemical representation would be only one particular higher level representation of the code. A hierarchy of dark baryon realizations corresponding to p-adic and dark matter hierarchies can be considered. Translation and transcription machinery would be realized by flux tubes connecting only states with same quark spin and flux tube spin.

Chapter 3

About the Correspondence of Dark Nuclear Genetic Code and Ordinary Genetic Code

3.1 Introduction

The idea about the realization of genetic code in terms of dark proton sequences giving rise to dark nuclei is one of the key ideas of TGD inspired quantum biology [L36]. This vision was inspired by the totally unexpected observation that the states of three dark protons (or quarks) can be classified to 4 classes in which the number of states are same as those of DNA, RNA, tRNA, and amino-acids. Even more, it is possible to identify genetic code as a natural correspondence between the dark counterparts of DNA/RNA codons and dark amino-acids and the numbers of DNAs/RNAs coding given amino-acid are same as in the vertebrate code [L36]. What is new is that the dark codons do not reduce to ordered products of letters.

During years I have considered several alternatives for the representations of genetic code. For instance, one can consider the possibility that the letters of the genetic code correspond to the four spin-isospin states of nucleon or quark or for spin states of electron pair. Ordering of the letters as states is required and this is problematic from the point of view of tensor product unless the ordering reflects spatial ordering for the positions of particles representing the letters. One representation in terms of 3-chords formed by 3-photon states formed from dark photons emerges from the model of music harmony [L16]. By octave equivalence the ordering of the notes is not needed.

3.1.1 Insights

The above observations inspire several speculative insights.

- 1. The emergence of dark nuclei identified as dark proton sequences would relate to Pollack's effect in which irradiation of water generates in presence of gel phase bounding the water what Pollack calls exclusion zones (EZs). EZs are negatively charged and water has effective stoichiometry $H_{1.5}O$. EZs deserve their name: somehow they manage to get rid of various impurities: this might be very important if EZs serve as regions carrying biologically important information. The protons of water molecules must go somewhere and the proposal is that they go to the magnetic body of some system consisting of flux tubes. The flux tubes contain the dark protons as sequences identifiable as dark nuclei.
- 2. Since nuclear physics precedes chemistry, one can argue that prebiotic life is based on these dark biomolecules serving as a template for ordinary biomolecules. To some degree biochemistry would be shadow dynamics and dark dynamics would be extremely simple as compared to the biochemistry induced by it. In particular, DNA replication, transcription, and translation would be induced by their dark variants. One can even extend this vision: perhaps

also ordinary nuclear physics and its scaled up counterpart explaining "cold fusion" are parts of evolutionary hierarchy of nuclear physics in various scales.

3. Nature could have a kind of R&D lab allowing to test various new candidates for genes by using transcription and translation at the level of dark counterparts of the ordinary basic biomolecules.

3.1.2 Conditions on the model

The model must satisfy stringent conditions.

 Both the basis A, T, C, G and A, U, C, G as basic chemical building bricks of RNA and DNA must have emerged without the help of enzymes and ribozymes. It is known that the biochemical pathway known as pentose-phosphate pathway (see http://tinyurl.com/ y9akkwok) generates both ribose and ribose-5-phosphate defining the basic building brick of RNA. In DNA ribose is replaced with de-oxiribose obtained by removing one oxygen.

Pyrimidines U, T, and C with single aromatic ring are are reported by NASA to be generated under outer space conditions (see http://tinyurl.com/y7sh9zk4). Carell *et al* [I68] (see http://tinyurl.com/z65kpyo) have identified a mechanism leading to the generation of purines A and G, which besides pyrimidines A,T (U) are the basic building bricks of DNA and RNA. The crucial step is to make the solution involved slightly acidic by adding protons. TGD inspired model for the mechanism involves dark protons [L45] [?].

Basic amino-acids are generated in the Miller-Urey type experiments (see http://tinyurl. com/4q2arv). Also nucleobases have been generated in Miller-Urey type experiments [I72].

Therefore the basic building bricks can emerge without help of enzymes and ribozymes so that the presence of dark nuclei could lead to the emergence of the basic biopolymers and tRNA.

- 2. Genetic code as a correspondence between RNA and corresponding dark proton sequences must emerge. Same true for DNA and also amino-acids and their dark counterparts. The basic idea is that metabolic energy transfer between biomolecules and their dark variants must be possible. This requires transitions with same transition energies so that resonance becomes possible. This is also essential for the pairing of DNA and dark DNA and also for the pairing of say dark DNA and dark RNA. The resonance condition could explain why just the known basic biomolecules are selected from a huge variety of candidates possible in ordinary biochemistry and there would be no need to assume that life as we know it emerges as a random accident.
- 3. Metabolic energy transfer between molecules and their dark variants must be possible by resonance condition. The dark nuclear energy scale associated with biomolecule could correspond to the metabolic energy scale of .5 eV. This condition fixes the model to a high extent but also other dark nuclear scales with their own metabolic energy quanta are possible. In fact, the dark nuclear binding energy for k = 151 scaled up from the typical value of the ordinary nuclear binding energy about 1 MeV is .5 eV.

3.1.3 Vision

The basic problem in the understanding of the prebiotic evolution is how DNA, RNA, aminoacids and tRNA and perhaps even cell membrane and microtubules . The individual nucleotides and amino-acids emerge without the help of enzymes or ribozymes but the mystery is how their polymers emerged. If the dark variants of these molecules served as templates for their generation one avoids this hen-and-egg problem. The problem how just the biomolecules were picked up from a huge variety of candidates allowed by chemistry could be solved by the resonance condition making possible metabolic energy transfer between biomolecules and dark nuclei.

The basic question is to what p-adic length scales L(k) DNA, RNA and amino-acids correspond. The original hypothesis was that the p-adic length scale assignable to dark DNA is consistent with the radius of ordinary DNA. It however turned out that this implies that the binding energy scale of corresponding dark nuclear physics is too high for the recent biology. Also the assumption that the dark variant of DNA double strand is horizontally scaled up variant of ordinary DNA strand excludes this identification since it requires that the horizontal size scale of dark DNA strand is larger than that of ordinary DNA strand.

DNA coil has radius L(151) = 10 nm and this suggests that dark DNA radius does not correspond to the radius of ordinary DNA (as assumed in the original version of this text) but to the p-adic length scale L(151), where k = 151 corresponds to first Gaussian Mersenne prime belonging to the group k = 151, 157, 163, 167. The primes k > 151 would correspond to higher level coilings of DNA. From this hypothesis one ends up to the proposal that RNA, tRNA, and amino-acids correspond to k = 149. This picture follows essentially from the contraints posed by various biological anomalies.

Also the smaller primes k = 127, 131, 137, 139 can be present in pre-biotic evolutions. This hierarchy of dark nuclear physics leads to a vision about how prebiotic evolution led via RNA era to the recent biology. Unidentified infrared bands (UIBs) from interstellar space identified in terms of transition energies of dark nuclear physics support this vision and one can compare it to PAH world hypothesis.

The vision about dark matter as a controller of biomatter leads to ask whether cell membrane and microtubules could correspond to 2-D analogs of RNA strands associated with dark RNA codons forming lattice like structures related to by radial scaling to their counterparts at the level of ordinary biomatter. This is supported by p-adic length scale hypothesis and thermodynamical considerations. These 2-D structures could represent 2-D variants of 1-D structures represented by DNA, RNA, and amino-acids with each node of lattice representing code letter.

Thermal constraints allow cell membrane of thickness about 5 nm as am additional realization of k = 149 level with $n = 2^{22}$ in terms of lipids as analogs of RNA codons. For k = 149metabolic energy quantum is predicted to be .5 eV. The thickness of neuronal membrane in the range 8-10 nm and could correspond to k = 151 and $n = 2^{23}$ in accordance with the idea that it corresponds to higher level in the cellular evolution reflecting that of dark nuclear physics. The energy quantum of ordinary Josephson radiation is just at the verge of thermal threshold. This could be understood in terms of minimization of metabolic resources. For bosonic singly charged ions the Josephson energy would be below the thermal threshold. The notion of generalized Josephson junction saves the situation. For massive particles associated with flux tubes the thermal energy T/2 is below the potential energy defined by action potential and that of metabolic energy quantum.

Also microtubules could correspond to k = 151 realization for which metabolic energy quantum is $E_{ex}(151) = .25eV$. Of course, the replacement of $E_{ex} = 1$ MeV for ordinary nuclei with $E_{ex} = 2$ MeV would give $E_{ex}(151) = .5$ eV so that one must take these estimates as order of magnitude estimates only. Also a proposal for how microtubules could realize genetic code with the 2 conformations of tubulin dimers and 32 charges associated with ATP and ADP accompanying the dimer thus realizing the analogs of 64 analogs of RNA codons is made.

The great vision would be that hierarchy of dark variants of DNA, RNA, amino-acids and their replication, transcription, and translation would be behind biological replication in various scales. Ordinary bio-chemistry would be shadow dynamics doing its best to mimic what happens at the level of dark matter. The reduction of bio-physics to that of dark matter level would mean a huge simplification of the vision about living matter.

The picture that I discussed in the original version of this chapter involved several uncertainties and open questions. During the years, TGD itself has developed and I decided to add to end of the chapter the recent view about the genetic code as a section title "Genetic code in terms of dark nucleon triplets". This is the year 2022 view about dark nucleon realization of the genetic code.

3.2 About dark variants of DNA, RNA, and amino-acids

To make progress one must construct a concrete model for the dark nuclei. The recent picture relies strongly on various anomalies to which TGD provides a solution. The TGD inspired model for "cold fusion" leads to the notion of dark nuclear physics - actually hierarchy of them labelle by the values of $h_{eff}/h = n$ and corresponding p-adic length scales. Second basic idea [L20]

is that cylindrical variants of EZs discovered by Pollack [L20] give rise to the dark counterparts of DNA, RNA, and amino-acids as dark proton sequences. tRNAs would be analogs of tritium and ³He. Pollack effect serves as a strong constraint for the model. Also the effects of ELF em fields on vertebrate brain [J7] combined with the rather recent finding about clustering of RNA II polymerase molecules [I69] exhibiting Comorosan effect [I169] provide valuable constraints on the model [L80]. The outcome of the arguments is that single strand of DNA, mRNA, tRNA and amino-acids most naturally correspond to k = 149 and double stranded DNA to k = 151.

Remark: The following argumentation is kind of Sherlock-Holmes-ing using all possible hints as constraints to select between imagined options rather than glorious march from axioms to theorems and thus not science in the usual sense.

3.2.1 Dark variant of DNA

Concerning the identification of the size scale of dark DNA one can consider several options. The first guess was that the scale is same as for ordinary DNA: L(141)=.34 nm obtained by scaling from the distance of protons in the k = 127 dark nucleus implicated by the findings of Holmlid *et al* [C2, L48] [L27]. It however turns out that the p-adic length scale assignable to dark DNA is most naturally k = 151 corresponding to the thickness 10 nm of DNA coil. The hypothesis that the integer k labelling p-adic length scale is prime is attractive working hypothesis leaving very few options under consideration. The options k = 137 and k = 149 are excluded since the pairing of dark DNA and ordinary DNA would not be possible without the coiling of ordinary RNA around dark DNA. This leaves only options for which $k \ge 149$ for prime values of k.

Remark: The p-adic length scale associated with a system is defined to be L(k) if the size of the system is in the half open interval [L(k), L(k+1)). One can also consider the possibility that p-adic length scale corresponds to the upper end of [L(k-1), L(k)).

General considerations

Consider first some background.

1. The TGD based model leads to the proposal for a formation of this kind of dark nuclear strings such that the distance between protons is rather precisely electron Compton length $L_e \simeq .4 \times 10^{-12}$ meters explains "cold fusion" in terms of dark nucleosynthesis which should have preceded ordinary nucleosynthesis by heating the material to the temperature required by it [L56] [K30].

Dark nucleosynthesis would have produced part of heavier nuclei outside stars. The binding energy scale for dark nuclear physics would be scaled down like 1/length and 2.6 MeV binding energy per nucleon for ³He of the ordinary nuclei would be scaled down by a factor 2^{-11} to 1.3 keV. Note however that it is excitation energies of order 1 MeV what matters and would scale down to .5 keV. This level does not yet correspond to biology as we know it but could be one step in the evolutionary hierarchy leading from nuclear physics also based on nuclear strings to biology involving increase of Planck constant $h_{eff}/h = n$ identifiably as the dimension of algebraic extension of rationals characterizing the complexity of the dynamics.

- 2. These dark nuclei have $h_{eff}/h = n = 2^{11}$ (or near to it) and cannot be those responsible for the dark variants of biomolecules since the distances of dark protons given by electron Compton length are much shorter than the distance between DNA nucleotides about .34 nm, which is roughly 142 times the electron Compton length 2.4×10^{-3} nm.
- 3. The distance between the dark protons appearing as counterparts of DNA nucleotides should be larger than that between ordinary DNA nucleotides. The simplest assumption that dark DNA coil is a horizontally scaled variant of DNA coil with same twisting angle so that DNA nucleotides are projected horizontally to their dark counterparts at the surface of a cylinder. Once the p-adic length scale of this cylinder is given, the distance between dark protons is fixed by p-adic scaling from the distance between dark protons for k = 127 case - that is electron Compton length. In the case of uncoiled RNA/AA one could have also a coil rotating around the ordinary RNA/AA.

The distance between dark nucleotides must be longer than the distance $3 \times .34 \sim 1$ nm taken by single ordinary DNA codon. If k is prime this leaves only k = 149 or k = 151 into consideration.

4. The negative charge of DNA and RNA assignable to one oxygen of phosphate combining with ribose and DNA/RNA base could come from the tubular EZ formed in the formation of DNA. The negative charge of phosphates and the positive charge of dark protons could guarantee the stability of pairs of dark proton sequences and ordinary RNA and DNA.

DNA strand has radius of R = 1 nm. The Debye length R_D of DNA gives rough idea about the scale above which the negative charge of DNA nucleotides associated with the phosphates screened. R_D should be longer than R: otherwise it is not possible to speak about charge of DNA only atomic length scales. One should have $R_D > R$: otherwise it does not make sense to assign negative DNA charge except in atomic length scales. The simplest option is that dark DNA has size scale L(151).

Remark: The rough estimates depend on how one identifies p-adic length scale. For the identification as $L(k) = \sqrt{5}L_e(k)$ motivated by the mass formula for electron, one would have $L(k) = \sqrt{5}L_e(k)$ giving L(141) = 0.67 nm. With this interpretation the estimate for the screening radius would be still shorter than R.

Remark: Scaled up hadron physics would be associated with flux tubes of the magnetic body of the codon at which one would have nucleons as 3-quark color singlets. I have already earlier proposed that scaled variants of hadron physics [K58] appear in TGD inspired biology. One motivation comes from honeybee dance [A20]!

The pairing dark AAs with positive charge with ordinary AAs might lead to problems since 16 AAs are neutral. The only charged AA residues are Lys (+), Arg (+), Asp (-) and Glu (-).

1. The formation mechanism for dark proton sequences gives for dark AAs a large positive charge. AAs are however not accompanied by negatively charged phosphate ions. Does charge neutrality require that the dark bonds between dark proton has negative charge so that one has effectively neutron?

Dark weak interactions correspond to large value of n [L56] so that in DNA length scale their proceed as fast as electromagnetic interactions (weak bosons would behave like massless particles below scaled up weak scale). This could make possible β decays changing the charges of the bonds between dark protons or dark neutrons [L56] and lead to a stability by β emission.

2. Proteins in water environment have a charge due to protons or electrons attaching to them. This charge depends on pH and becomes negative above certain critical pH. One might think that the limit of very large pH (no protons) corresponds to the situation in which the electrons of EZ attach to AAs.

Dark codons do not have decomposition to letters whereas ordinary codons have. In a well-defined sense one could say that dark code is "holistic" whereas the ordinary code is "reductionistic".

- 1. This brings in mind western written language in which words decompose to letters. In some eastern languages the symbols of written language correspond to entire words. Do these differences correspond at deeper level to ordinary and dark genes. Could the analytic and holistic aspects of cognition relate to the differences between ordinary and dark code.
- 2. One cannot exclude the entanglement between codons and evolution as emergence of entanglement even suggests this. Could this kind of entanglement give rise to basic units of DNA, in particular genes and introns. Could the decomposition of gene into coding regions and introns correspond to a decomposition to unentangled products of internally entangled pieces. This would increase exponentially the degrees of freedom involved and explain why organisms with practically the same code can be at so different evolutionary levels. In the splicing process when intronic portions are cut out from DNA sequence. Do the remaining

pieces of RNA get entangled or does the decomposition of dark RNA to unentangled pieces have some meaning? Note that also ordinary RNA would be entangled or entangled. Could introns provide the means for decomposing the coding RNA to unentangled pieces.

3. The most natural possibility is that entanglement contains superposition of codon sequences in which each sequence codes for the same AA. The chemical codons appearing in the superposition have different masses and chemical properties but in zero energy ontology (ZEO) this is possible. Situation would be like for a superconductor in which coherent state means superposition of states with different numbers of Cooper pairs and thus different fermion number in standard ontology but in ZEO this problem disappears.

Why one must have k = 151 for dark DNA

It was already found that for prime values of k the options k < 149 are not possible for dark DNA since ordinary DNA should coil around dark DNA. There is also second objection against prime k < 149 from energetics inspiring the hypothesis DNA corresponds to k = 151.

- 1. The scaling of the dark nuclear binding energy $E_b \sim 7$ MeV per nucleon as L(107)/L(k) predicts very high binding energies for primes k < 149. For instance, k = 139 would correspond to the scaled binding energy $E_b(139) = E_bL(107)/L(139)$, $E_b \sim 7$ MeV, which is typical nuclear binding energy. This gives $E_b(139) = E_b/2^{(139-107)/2} = .14$ keV. For k = 139 the typical nuclear excitation energy $E_{ex} = 1$ MeV scales dow to 20 eV, which is still very high but could correspond to energies of atomic transitions. For k = 151 it E_b scales down to 3.5 eV. The typical dark excitation energy for k = 151 is $E_{ex}(151) = .5$ eV and the identification as a nominal value of metabolic energy quantum is attractive. Dark nuclear physics might therefore control biochemistry using dark nuclear transitions as a tool to provide desire energy currency.
- 2. The TGD based explanation of Pollack effect provides a consistency test for the idea [L20] [L20]. In Pollack effect IR light (besides either kinds of energy feeds) induces the formation of negative charged exclusion zones (EZs) in water bounded by gel phase. In TGD based model this would correspond to the formation of dark proton sequences at magnetic flux tubes. The scale of dark nuclear binding energy would be most naturally in eV scale. The binding energy scale of hydrogen atoms in water molecules is about 5 eV which suggests that the binding energy scale for dark protons sequences is smaller since otherwise energy would be liberated. This would suggest k = 149 as will be found.
- 3. One can imagine that an external perturbation induces
 - (a) a transition in which the proton bound to water molecule transforms to its dark variant in higher energy state or
 - (b) that the proton goes over a potential wall, whose height is measured in eV:s.

If the dark nuclear binding energy is higher than the binding energy of proton in water molecule, the process should liberate energy and could occur spontaneously unless high potential wall prevents it. Hence the first option seems the only realistic one. Note that one could consider the cancellation of dark nuclear binding energy and repulsive Coulomb energy which scale in the same manner as function of p-adic length scale so that still the net energy would scale increase in shorter p-adic length scales.

Pollack effect suggests that if k is prime, one must have k = 149 for dark proton sequences formed in Pollack effect.

1. For k = 149 one has $E_b(151) \sim E_b/2^{(149-107)/2} = 3.5$ eV for $E_b = 7$ MeV, which is in UV range slightly above the visible range. The binding energy of hydrogen atom in water is about 5 eV which would require the incoming radiation to have energy 1.5 eV which is indeed in IR range. This option looks therefore realistic.

2. For k = 151 one would have $E_b(151) \sim 7MeV/2^{(151-107)/2} = 1.75$ eV, which just above the IR energy range. Now the energy needed to transform ordinary protons to dark protons in Pollack effect would be in UV range so that this options seems to be excluded.

This argument suggests that dark proton sequences generated in Pollack effect are analogs of single DNA strand, which would naturally correspond to L(149) = L(151)/2. Also RNA would naturally correspond to this scale.

- 1. $L(151) \simeq 10$ nm is the thickness of coiled DNA double strand. The size scale of dark nucleons would be L(151) and the dark DNA strand should be horizontally scaled variant of ordinary DNA strand by a scaling factor $\lambda \sim L(151)/.33$ nm = 30. DNA double strand would be obtained by a transversal scaling from the ordinary DNA double strand.
- 2. The higher coilings of DNA could correspond to higher horizontally scaled variants of DNA corresponding to k = 157, 163, 167. k = 167 would correspond to nuclear membrane length scale of 2.5 μ m. The emergence of nuclear membrane in k = 151 length scale would have been accompanied by the emergence of dark DNA in this scale. Cell membrane could correspond to k = 173 and p-adic length scale 17.6 μ m. Neurons have size varying from 4-100 micrometers (the definition of size depends on whether one includes axons) and might correspond to k = 179, 181 and length scales of .16 mm and perhaps even .32 mm.

The only justification for this speculative picture is that it is consistent with the other basic ideas about TGD inspired quantum biology.

- 1. Cisse *et al* [I69] found that RNA II polymerase molecules cluster during transcription and their dynamics involves multiples of the time scale $\tau = 5$ seconds. Comorosan reported long time ago that just these time scales are universal bio-catalysis [I169]. The TGD inspired model [L80] for the findings of Cisse *et al* allows to sharpen the TGD based view about quantum biology considerably.
- 2. The basic parameter of the model is the value of gravitational Planck constant $\hbar_{gr} = GM_Dm/v_0$ assigned to magnetic flux tubes mediating gravitational interactions. Already earlier work gives estimates for the value M_D of dark mass and velocity parameter v_0 and the model leads to the same estimates. The identification of the values of τ as Josephson periods assuming the potential difference V along flux tubes connecting reacting molecules is universal and same as over neuronal membrane fixed the value of h_{gr} . The value of V along flux tube serving as Josephson junction would be universal and equal to membrane potential. Josephson radiation would have energies coming as multiples ot ZeV just above the thermal energy at physiological temperatures fixed by the membrane potential.
- 3. The model forces the conclusion that the endogenous magnetic field B_{end} has at its upper bound $B_{end} = .2$ Gauss deduced from the findings of Blackman about effects of ELF em fields on vertebrate brain [J7]. The earlier ad hoc hypothesis was that $B_{end} = .2$ Gauss is minimum value of B_{end} . Furthermore, for the required value of h_{gr} $B_{end} = .2$ Gauss corresponds to dark cyclotron energy of .12 keV, which is surprisingly large energy at the upper end of UV band: the earlier intuitive guess was that energy scale is in visible range.

Also harmonics of cyclotron frequencies were found to have effects so that really large energy scales are involved with the interaction of ELF radiation and one can ask whether this picture really makes sense. This raises a question about the mechanism of the interaction of ELF em radiation with living matter. One also wonder why the ELF radiation has effects on both behavior and physiology.

Assume

- (a) that dark photons with energies coming as multiples of .12 keV are in question,
- (b) that these dark photons excite dark cyclotron states in the cellular length scale deduced from flux quantization and
- (c) that the dark cyclotron photons radiated as the excited cyclotron states return to the ground states perform some control action on ordinary DNA coil this is in accordance with the basic vision about the role of magnetic body.

X rays have energy range varying from 100 eV to 100 keV and wavelengths varying from 10 nm to .01 nm. The wavelength of an ordinary photon resulting from dark photon with energy of .12 keV would be of order 10 nm, the radius of DNA coil for k = 151!

Could this energy induce an analog of standing em wave in transversal degrees of freedom of DNA perhaps transformable to many phonon state with very large number of photos and thus classical acoustic wave? This would allow to understand how cyclotron harmonics can have non-trivial effects. The effects of ELF radiation on behavior and physiology could be understood as gene expression induced by the irradiation.

Both dark cyclotron radiation and radiation generated in dark nuclear transitions could have biological effects

1. Can one relate energy scale of .12 keV associated with dark cyclotron radiation to atomic physics? The ionization energies behave as Z_{eff}^2/n^2 , where Z_{eff} is nuclear charge minus the charge of the closed shells. Z_{eff} is also reduced by electronic screening by other valence electrons. The binding energies of valence electrons decrease with the principal quantum number n so that only n = 2 row of the periodic table might allow so high ionization energies for valence electrons.

Oxygen is certainly the first candidate to consider. The ionization energy for oxygen is .12 eV from an estimate assuming that the effective nuclear charge is 6 (with the contribution of 2 valence electrons subtracted). The actual value is 68.9 eV: the reduction is due to electron screening. This value is smaller than the estimate estimate for $E_b = .12$ keV and since harmonics of this energy are involved, the interpretation in terms of ionization does not make sense.

2. Not only oxygen but also heavier elements are ionized in living matter and at least to me this has remained more or less a mystery. Could dark photons emitted by dark nuclei of MB perform control by inducing the transitions and even ionization of oxygen and other biologically important atoms. The process could proceed also in opposite direction. The energy scale would correspond to that of nuclear excitations scaled down by the above ratio of p-adic length scales. If the energy scale of ordinary nuclear excitations is taken to be about 1 MeV, the dark energy scale for k = 127 assignable to the dark nuclei created in "cold fusion" is keV. For k = 131 the scale would be 250 eV and above the ionization energy scales for valence electrons. For k = 137 the scale would be 17 keV. These dark nuclear transitions could generate dark photons inducing transitions of atoms and even ionizations.

3.2.2 What about dark variants of RNA, tRNA, and AAs?

Also RNA and AAs should have dark variants and one should understand their role. Suppose that the integer k characterizing the p-adic length scale is prime. The vision about RNA era preceding DNA era suggests that RNA accompanying dark RNA is at lower level in the evolution, and hence the value of h_{eff} is smaller for dark RNA than for dark DNA. Also the p-adic length scale for RNA would be shorter.

1. The most natural option is that RNA corresponds to k = 149 as also single DNA strand. This would conform with the above suggestion that the Pollack effect generates k = 149 dark proton sequence (dark RNA?). DNA double strand would correspond to k = 151.

The emergence of k = 151 level would mean the emergence of structures with scale characterized by L(151). This includes DNA double strand forming a coil with thickness L(151)and nuclear and cell membranes. During RNA era these structures would have been absent.Both DNA double strand and cell membrane have binary structures. Therefore single DNA strand and lipid layer could correspond to k = 149. In transcription DNA opens and double strand becomes pair of strands having naturally k = 149. Therefore mRNA should have also k = 149.

2. If AAs correspond to k = 149 then also tRNA should correspond to k = 149. On the other hand, tRNA does not form strands and should be more elementary structure than RNA.

Could tRNA corresponds to k = 139 or k = 137? This would require that also the attached AA would correspond to k = 139 or k = 137, which does not look plausible.

Remark: TGD vision assumes tRNA was present already at RNA era and the role of AA in tRNA was to catalyze RNA replication. In fact, RNA could have been just tRNA at very early stages.

What about AAs? The following arguments suggest that one has k = 149 for both AAs and RNA.

- 1. For dark AAs one can imagine p-adic evolutionary hierarchy analogous to that for DNA. In TGD inspired vision AA sequences emerged together with DNA. Proteins can appear also as coils. Since mRNA pairs with single DNA strand and AAs with mRNA, it seems that AAs should correspond to $k \geq 149$?
- 2. One could however argue that AAs are building bricks rather than information molecules and k could be rather small for dark AAs. Dark AAs should pair with proteins. Pairing without coiling is possible only if the length per letter is same as the length per AA and thus same as for DNA letter, which is longer than the length taken by k = 139 dark proton. Also this suggests k = 149 for dark AAs and their coiling around the ordinary AAs.

3.2.3 Clustering of RNA polymerase molecules and Comorosan effect

Once again I had good luck: I received a link (see http://tinyurl.com/y7bego83) to a highly interesting popular article telling about the work by Ibrahim Cisse at MIT and his colleagues [I69] (see http://tinyurl.com/y9wzt5yl) about the clustering of RNA polymerase proteins in the transcription of RNA. Similar clustering has been observed already earlier and interpreted as a phase separation giving rise to protein droplets [L88]. Now this interpretation is not proposed by experiments but they say that it is quite possible but they cannot prove it.

I have already earlier discussed the coalescence of proteins into droplets as this kind of process in TGD framework [?] [L88]. The basic TGD based ideas is that proteins - and biomolecules in general - are connected by flux tubes characterized by the value of Planck constant $h_{eff} = n \times h_0$ for the dark particles at the flux tube. The higher the value of n is the larger the energy of given state. For instance, the binding energies of atoms decrease like $1/n^2$. Therefore the formation of the molecular cluster liberates energy usable as metabolic energy.

Remark: h_0 is the minimal value of h_{eff} . The best guess is that ordinary Planck constant equals to $h = 6h_0$ [L41, L83] (see http://tinyurl.com/goruuzm and http://tinyurl.com/y9jxyjns.

TGD view about the findings

Gene control switches - such as RNA II polymerases in DNA transcription to RNA - are found to form clusters called super-enhancers. Also so called Mediator proteins form clusters. In both cases the number of members is in the range 200-400. The clusters are stable but individual molecules spend very brief time in them. Clusters have average lifetime of $5.1 \pm .4$ seconds.

Why the clustering should take place? Why large number of these proteins are present although single one would be enough in the standard picture. In TGD framework one can imagine several explanations. One can imagine at least following reasons.

1. If the initiation of transcription is quantum process involving state function reduction, clustering could allow to make this process process deterministic at the level of single gene in spite of the non-determinism of state function reduction. Suppose that the initiation of transcription is one particular outcome of state function reduction. If there is only single RNA II polymerase able to make only single trial, the changes to initiate the transcription are low. This could be the case if the protein provides metabolic energy to initiate the process and becomes too "tired" to try again immediately. In nerve pulse transmission there is analogous situation: after the passing of the nerve pulse generation the neuron has dead time period. As a matter of fact, it turns out that the analogy could be much deeper.

How to achieve the initiation with certainty in this kind of situation? Suppose that the other outcomes do not affect the situation appreciably. If one particular RNA polymerase fails to initiate it, the others can try. If the number of RNA transcriptase molecule is large enough, the transcription is bound to begin eventually! This is much like in fairy tales about princess and suitors trying to kill the dragon to get the hand of princess. Eventually comes the penniless swineherd.

- 2. If the initiation of transcription requires large amount of metabolic energy then only some minimal number of N of RNA II polymerase molecules might be able to provide it collectively. The collective formed by N molecules could correspond to a formation of magnetic body (MB) with a large value of $h_{eff} = n \times h_0$ and controlling the molecules and inducing its coherent behavior. The molecules would be connected by magnetic flux tubes.
- 3. If the rate for occurrence is determined by an amplitude which is superposition of amplitudes assignable to individual proteins the rate is proportional to N^2 , N the number of RNA II polymerase molecules. The process for the cluster is reported to be surprisingly fast as compared to the expectations something like 20 seconds. The earlier studies have suggests that single RNA polymerase stays at the DNA for minutes to hours.

Clustering could allow to speed up bio-catalysis besides the mechanism allowing to find molecules to find by a reduction of $h_{eff}/h = n$ for the bonds connecting the reactants and the associated liberation of metabolic energy allowing to kick the reactants over the potential wall hindering the reaction.

Concerning the process of clustering there are two alternative options both relying on the model of liquid phase explaining Maxwell's rule assuming the presence of flux tube bonds in liquid and of water explaining its numerous anomalies in terms of flux tubes which can be also dark (see http://tinyurl.com/ydhknc2c).

- Option I: Molecules could form in the initial situation a phase analogous to vapour phase and there would be very few flux tube bonds between them. The phase transition would create liquid phase as flux tube loops assignable to molecules would reconnect form flux tube pairs connecting the molecules to a tensor network giving rise to quantum liquid phase. The larger then value of n, the longer the bonds between molecules would be. This kind of model [?] (see http://tinyurl.com/yassnhzb) is used to explain the strange findings that a system consisting of plastic balls seems to show primitive features of life such as metabolism.
- 2. **Option II**: The molecules are in the initial state connected by flux tubes and form a kind of liquid phase and the clustering reduces the value of $h_{eff}/h = n$ and therefore the lengths of flux tubes. This would liberate dark energy as metabolic energy going to the initiation of the transcription. One could indeed argue that connectedness in the initial state with large enough value of n is necessary since the protein cluster must have high enough "IQ" to perform intelligent intentional actions.

Protein blobs are said to be drawn together by the "floppy" bits (pieces) of intrinsically disordered proteins. What could this mean in the proposed picture? Disorder would mean absence of correlations between building bricks of floppy parts of the proteins in translational degrees of freedom.

- 1. Could floppiness correspond to low string tension assignable to long flux loops with large n assignable to the building bricks of "floppy" pieces of protein? Could reconnection for these loops give rise to pairs of flux tubes connecting the proteins in the transition to liquid phase (Option I)? Floppiness would also make possible to scan the environment by flux loops to get in touch with the flux loops of other molecules and in the case of hit (cyclotron resonance) induce reconnection.
- 2. In spite of floppiness in this sense, one could have quantum correlations between the internal quantum numbers of the building bricks of the floppy pieces. This would also increase the value of n serving as molecular IQ and provide molecule with higher metabolic energy liberated in the catalysis.

About Comorosan effect and clustering of RNA II polymerase proteins

What about the interpretation of the time scales τ equal 5, 10, and 20 seconds appearing in the clustering of RNA II polymerase proteins and Mediator proteins? What is intriguing that so called Comorosan effect [I169, I56] involves time scale of 5 seconds and its multiples claimed by Comorosan long time ago to be universal time scales in biology. The origin of these time scales has remained more or less a mystery although I have considered several TGD inspired explanations for this time scale is based on the notion of gravitational Planck constant [K131] (see http://tinyurl.com/yb8fw3kq).

One can consider several starting point ideas, which need not be mutually exclusive.

1. The time scales τ associated with RNA II polymerase and perhaps more general bio-catalytic systems as Comorosan's claims suggest could correspond to the durations of processes ending with "big" state function reduction. In zero energy ontology (ZEO) there are two kinds of state function reductions [L69]. "Small" state function reductions - analogs of weak measurements - leave the passive boundary of causal diamond (CD) unaffected and thus give rise to self as generalized Zeno effect. The states at the active boundary change by a sequence of unitary time evolutions followed by measurements inducing also time localization of the active boundary of CD but not affecting passive boundary. The size of CD increases and gives rise to flow of time defined as the temporal distance between the tips of CD. Large reductions change the roles of the passive and active boundaries and mean death of self. The process with duration of τ could correspond to a life-time of self assignable to CD.

Remark: It is not quite clear whether CD can disappear and generated from vacuum. In principle this is possible and the generation of mental images as sub-selves and sub-CDs could correspond to this kind of process.

2. In [K131] I proposed that Josephson junctions are formed between reacting molecules in biocatalysis. These could correspond to the shortened flux tubes. The difference $E_J = ZeV$ of Coulomb energy of Cooper pair over flux tube defining Josephson junction between molecules would correspond to Josephson frequency $f_J = 2eV/h_{eff}$. If this frequency corresponds to $\tau_J = 5$ seconds, h_{eff} should be rather large since E_J is expected to be above thermal energy at physiological temperature.

Could Josephson radiation serve as a kind of of synchronizing clock for the state function reductions so that its role would be analogous to that of EEG in case of brain? A more plausible option is that Josephson radiation is a reaction to the presence of cyclotron radiation generated at MB and performing control actions at the biological body (BB) defined in very general sense. In the case of brain dark cyclotron radiation would generate EEG rhythms responsible for control via genome and dark generalized Josephson radiation modulated by nerve pulse patterns would mediate sensory input to the MB at EEG frequencies.

A good guess motivated by the proposed universality of the Comorosan periods is that the energy in question does not depend on the catalytic system and corresponds to Josephson energy for protein through cell membrane acting as Josephson junction and giving to ionic channel or pump. The flux tubes themselves have universal properties.

3. The hypothesis $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0 c$ of Nottale [E1] for the value of gravitational Planck constant [K101, K84, K85, ?] gives large \hbar . Here $v_0 = \beta_0 c$ has dimensions of velocity. For dark cyclotron photons this gives large energy $E_c \propto \hbar_{gr}$ and for dark Josephson photons small frequency $f_J \propto 1/h_{gr}$. Josephson time scale τ_f would be proportional to the mass mof the charged particle and therefore to mass number A of ion involved: $f_J \propto A$ possibly explaining the appearance of multiples of 5 second time scale. Cyclotron time scale does not depend on the mass of the charged particle at all and now sub-harmonics of τ_c are natural.

The time scales assignable to CD or the lifetime-time of self in question could correspond to either cyclotron of Josephson time scale τ .

1. If one requires that the multiplies of the time scale 5 seconds are possible, Josephson radiation is favoured since the Josephson time scale proportional to $h_{gr} \propto m \propto A$, A mass number of ion. The problem is that the values A = 2, 3, 4, 5 are not plausible for ordinary nuclei in living matter. Dark nuclei at magnetic flux tubes consisting of dark proton sequences could however have arbitrary number of dark protons and if dark nuclei appear at flux tubes defining Josephson junctions, one would have the desired hierarchy.

2. Although cyclotron frequencies do not have sub-harmonics naturally, MB could adapt to the situation by changing the thickness of its flux tubes and by flux conservation the magnetic field strength to which f_c is proportional to. This would allow MB to produce cyclotron radiation with the same frequency as Josephson radiation and MB and BB would be in resonant coupling.

Consider now the model quantitatively.

1. For $\hbar_{eff} = \hbar_{qr}$ one has

$$r = \frac{\hbar_{gr}}{\hbar} = \frac{GM_Dm}{c\beta_0} = 4.5 \times 10^{14} \times \frac{m}{m_p} \frac{y}{\beta_0}$$

Here $y = M_D/M_E$ gives the ratio of dark mass M_D to the Earth mass M_E . One can consider 2 favoured values for *m* corresponding to proton mass m_p and electron mass m_e .

2. $E = h_{eff} f$ gives the concrete relationship $f = (E/eV) \times 2.4 \times 10^{14} \times (h/h_{eff})$ Hz between frequencies and energies. This gives

$$x = \frac{E}{eV} = 0.4 \times r \times \frac{f}{10^{14} Hz}$$

3. If the cyclotron frequency $f_c = 300$ Hz of proton for $B_{end} = .2$ Gauss corresponds to biophoton energy of x eV, one obtains the condition

$$r = \frac{GM_Dm_p}{\hbar\beta_0} \simeq .83 \times 10^{12} x \ .$$

Note that the cyclotron energy does not depend on the mass of the charged particle. One obtains for the relation between Josephson energy and Josephson frequency the condition

$$x = \frac{E_J}{eV} = 0.4 \times .83 \times 10^{-2} \times \frac{m}{m_p} \times x \frac{f_J}{Hz} , \quad E_J = ZeV .$$

One should not confuse eV in ZeV with unit of energy. Note also that the value of Josephson energy does not depend on h_{eff} so that there is no actual mass dependence involved.

For proton one would give a hierarchy of time scales as A-multiples of $\tau(p)$ and is therefore more natural so that it is natural to consider this case first.

1. For $f_J = .2$ Hz corresponding to the Comorosan time scale of $\tau = 5$ seconds this would give ZeV = .66x meV. This is above thermal energy $E_{th} = T = 27.5$ meV at T = 25 Celsius for x > 42. For ordinary photon $(h_{eff} = h)$ proton cyclotron frequency $f_c(p)$ would correspond for x > 42 to EUV energy E > 42 eV and to wavelength of $\lambda < 31$ nm.

The energy scale of Josephson junctions formed by proteins through cell membrane of thickness L(151) = 10 nm is slightly above thermal energy, which suggests $x \simeq 120$ allowing to identify L(151) = 10 nm as the length scale of the flux tube portion connecting the reactants. This would give $E \simeq 120$ eV - the upper bound of EUV range. For x = 120 one would have $GM_E m_p y/v_0 \simeq 10^{14}$ requiring $\beta_0/y \simeq 2.2$. The earlier estimates [?] for the mass M_D give $y \sim 2 \times 10^{-4}$ giving $\beta_0 \sim 4.4 \times 10^{-4}$. This is rather near to $\beta_0 = 2^{-11} \sim m_e/m_p$ obtained also in the model for the orbits of the 4 inner planets as Bohr orbits.

For ion with mass number A this would predict $\tau_A = A \times \tau_p = A \times 5$ seconds so that also multiples of the 5 second time scale would appear. These multiples were indeed found by Comoran and appear also in the case of RNA II polymerase.

2. For proton one would thus have 2 biological extremes - EUV energy scale associated with cyclotron radiation and thermal energy scale assignable to Josephson radiation. Both would be assignable to dark photons with $h_{eff} = h_{gr}$ with very long wavelength. Dark and ordinary photons of both kind would be able to transform to each other meaning a coupling between very long lengths scales assignable to MB and short wavelengths/time scales assignable to BB.

The energy scale of dark Josephson photons would be that assignable with Josephson junctions of length 10 nm with long wavelengths and energies slightly above E_{th} at physiological temperature. The EUV energy scale would be 120 eV for dark cyclotron photons of highest energy would be fixed by flux tube length of 10 nm.

For lower cyclotron energies forced by the presence of bio-photons in the range containing visible [K20, K31] and UV and obtained for B_{end} below .2 Gauss, the Josephson photons would have energies below E_{th} . That the possible values of B_{end} are below the nominal value $B_{end} = .2$ Gauss deduced from the experiments of Blackman [J7] does not conform with the earlier ad hoc assumption that B_{end} represents lower bound. This does not change the earlier conclusions.

Could the 120 eV energy scale have some physical meaning in TGD framework? The corresponding wavelength for ordinary photons corresponds to the scale L(151) = 10 nm which correspond to the thickness of DNA double strand. Dark DNA having dark proton triplets as codons could correspond to either k = 149 or k = 151. The energetics of Pollack effect suggests that k = 149 is realized in water even during prebiotic period [L77] (see http://tinyurl.com/yalny39x). In the effect discovered by Blackman the ELF photons would transform dark cyclotron photons having $h_{eff} = h_{gr}$ and energy about .12 keV. They would induce cyclotron transitions at flux tubes of B_{end} with thickness of order cell size scale. These states would decay back to previous states and the dark photons transformed to ordinary photons absorbed by ordinary DNA with coil structure with thickness of 10 nm. Kind of standing waves would be formed. These waves could transform to acoustic waves and induce the observed effects. Quite generally, dark cyclotron photons would control the dynamics of ordinary DNA by this mechanism.

It is natural to assume that $B_{end} = .2$ Gauss corresponds to the upper bound for B_{end} since magnetic fields are expected to weaken farther from the Earth's surface: weakening could correspond to thickening of flux tubes reducing the field intensity by flux conservation. The model for hearing [K91] requires cyclotron frequencies considerably above proton's cyclotron frequency in $B_{end} = .2$ Gauss. This requires that audible frequencies are mapped to electron's cyclotron frequency having upper bound $f_c(e) = (m_p/m_e)f_c(p) \simeq 6 \times 10^5$ Hz. This frequency is indeed above the range of audible frequencies even for bats.

For electron one has $h_{gr}(e) = (m_e/mp) \times h_{gr}(p) \simeq 5.3 \times 10^{-4} h_{gr}(p)$, $\hbar_{gr}(p)/\hbar = 4.5 \times 10^{14}/\beta_0$. Since Josephson energy remains invariant, the Josephson time scales up from $\tau(p) = 5$ seconds to $\tau(e) = (m_e/m_p)\tau(p) \simeq 2.5$ milliseconds, which is the time scale assignable to nerve pulses [K92, K45].

To sum up, the model suggests that the idealization of flux tubes as kind of universal Josephson junctions. The model is consistent with bio-photon hypothesis. The constraints on $h_{gr} = GM_Dm/v_0$ are consistent with the earlier views and allows to assign Comorosan time scale 5 seconds to proton and nerve pulse time scale to electron as Josephson time scales. This inspires the question whether the dynamics of bio-catalysis and nerve pulse generation be seen as scaled variants of each other at quantum level? This would not be surprising if MB controls the dynamics. The earlier assumption that $B_{end} = 0.2$ Gauss is minimal value for B_{end} must be replaced with the assumption that it is maximal value of B_{end} .

3.3 TGD view about the emergence of chemical life

Consider first the basic assumptions.

1. Dark DNA, RNA,... emerged before chemistry and serve as templates for ordinary DNA,

RNA,... The replication, transcription, and translation for ordinary DNA, RNA,... are induced by the corresponding processes for their dark counterparts.

- 2. Dark proton sequences are associated with tubular EZs in water generated by Pollack effect.
- 3. The amount of entanglement measured by entanglement negentropy (having a well-defined meaning in adelic physics [L67]) is expected to increase gradually during evolution. Hence one expects generation of more and more entangled sequences of dark nucleons. At the bottom perhaps ordinary nuclear physics one would have the product states of dark nucleons. Perhaps dark nuclear physics with $n = 2^{11}$ came next. After that came $n = 2^{18}$ dark nuclear physics. But which came first: dark variants amino-acids, tRNA, RNA, or DNA and their chemical counterparts? And could one see even genes as entangled codon sequences coding for the same protein?

3.3.1 The quantum vision about the prebiotic evolution

The following vision about quantal prebiotic evolution beginning from amino-acids suggests itself. The basic idea is that all processes took place at dark level and induced the processes for ordinary biomolecules in water environment. Even the enzyme and ribozyme actions essential in recent biology would be replaced with corresponding actions at dark level and biochemistry would reduce to shadow dynamics.

1. Amino-acids are easiest to produce (as Miller-Urey experiment demonstrated (see http: //tinyurl.com/4q2arv)) requiring no enzymatic action and there is just single chemical amino-acid per dark RNAs coding for it. Therefore the pairs of amino-acids and their dark variants could have emerged first. Note that proteins were not yet present.

Remark: Vivo-vitro difference could mean that dark partner of biomolecule is present in vivo and missing in vitro.

2. DNA requires cell membrane. This requires RNA emerged after amino-acids. This implies that dark variants of dark tRNA, their pairing with tRNA and the pairing of dark RNA with RNA emerged next?

This picture supports that the old TGD inspired idea about the role of tRNA during RNA era. Dark tRNA would have made possible the replication of dark RNA sequences (rather than the translation of RNA to amino-acid sequence) during this era. The dark amino-acid of dark tRNA would have served as a catalyst inducing the addition of dark RNA codon to the growing RNA sequence. No chemical transcription machinery nor DNA was needed at this stage. This would solve one hen-or-egg problem.

3. After that a revolution would have occurred. For some reason dark amino-acids began to attach to the growing sequence of amino-acids and dark RNA codon was left alone. What prevented dark RNA codon to attach to the growing dark RNA sequence? Was it the emerging entanglement between dark codons giving rise to genes as entangled pieces of DNA that made this impossible.

This means entanglement also between the ordinary codons, which makes sense only in ZEO. If possible at all this entanglement should respect genetic code so that entangled superposition would involve only codons coding for the same amino-acid so that the translation to a single amino-acid sequence rather than their quantum superposition is possible. If more general superpositions are allowed the translation process would be like state function reduction to amino-acid sequence.

4. At this step the replication of both dark and ordinary RNA was lost and it seems that dark DNA-DNA pairs replicating dark DNA and transcribing it to dark RNA and inducing corresponding process at the level of chemistry must have emerged at the same time.

The emergence of DNA requires also the emergence of cell membrane. Could the emergence of cell membrane relate to the emergence of dark nuclei in the p-adic length scale L(k), k = 149 and could the double layered structure of cell membrane serve as an analog for that of DNA double strand? Could lipid layers correspond to 2-D analogs of DNA strand with lipids taking the role of codons?

5. Could the full genetic code emerged in step-wise manner as proposed earlier [K7, K122]? Genetic code can be seen in a good approximation as a fusion of 16-letter code and 4-letter code. This might be understood if the entanglement of dark codons emerges first as entanglement of only two first letters.

What gave rise to the correspondences between dark DNA, RNA, tRNA, amino-acids and their dark variants? How the amino-acids and nucleotide bases were selected?

- 1. The basic principle would be the condition that metabolic energy can be transferred between chemical and dark levels. This is possible if there identical transition energies in the spectra of biomolecules and their dark variants making possible resonance.
- 2. Metabolic energy quantum in the range .4-.5 eV should correspond to the excitation energy scale of dark dark nuclear physics if $E_{ex} = 1$ MeV is taken as the estimate for a typical nuclear excitation energy. Hydrogen bonds also correspond to this energy scale but this might be just what is needed to give rise to coherent metabolic activity.

The original proposal was that dark DNA associated with ordinary DNA corresponds to k = 141 assignable to the ordinary DNA but this proposal predicts $E_{ex}(141) = 16$ eV. This proposal turned out to be unrealistic also in other respects. k = 149 assignable to dark RNA predicts $E_{ex}(149) = .5$ eV and is a more plausible option in many other aspects. Also lower values of k than k = 149, 151 might be present - at least during the prebiotic stage. Pollack's findings however support the view that the irradiation of water with IR light generates dark proton sequences with k = 149. Does this mean that the evolutionary level of water is raised to k = 151 in presence of gel phase binding the water sample? Note that "cold fusion" [L27, L56] might be interpreted as creation of k = 127 dark proton sequences.

To sum up: for DNA,RNA, and tRNA the emergence of entanglement would have created the chemical counterparts of quantum superpositions: ZEO is necessary since in positive energy ontology superpositions are highly implausible.

There are some questions to ponder.

1. Why the decomposition into triplets? Does resonance condition for the metabolic energy transfer select triplets as basic units and also the RNA-amino-acid correspondence? Do also intronic regions have triplets as basic units?

One ends up to a prediction of vertebrate genetic code also from a model of music harmony [L16]. In fact, the model explains also its slight variation and the 2 additional amino-acids. Could this help to understand why the triplet code is so unique.

- 2. Could one imagine that also quarks and antiquarks were involved? Could dark nucleon pair with dark quark with same spin and isospin and color confinement forces dark proton triplets? Dark quarks indeed define a representation for A,T,C, G. In the model of topological computation [K7, K122]. I have actually speculated with the possibility that dark quarks and antiquarks are paired with ordinary DNA codons.
- 3. Could dark conjugate protons or their triplets of parallel dark DNA strands form Cooper pairs or does pairing of dark protons triplets (their conjugates) with dark quarks (anti-quarks) give rise to bosonic states?

3.3.2 Unidentified Infrared Bands as a test for the proposal

Unidentified Infrared Bands (UIBs) are an ill-understood phenomenon associated with radiation coming from interstellar space. There are also other analogous phenomena having no explanation in terms of molecular transitions [K17] and one can ask whether they could be seen as signatures of dark nuclear physics.

- 1. UIBs are observed around bands around IR energies $E \in \{.11, .20, .375\}$ eV.
- 2. Poly-aromatic hydrocarbons (PAHs) (see http://tinyurl.com/atx4t9a) are known to generate UIBs [K17]. Therefore the UIBs from interstellar space could originate from PAHs.

TGD based models for UIBs

TGD suggests several explanations for UIBs involving new physics related to the p-adic length scale hypothesis and $h_{eff}/h = n$ hierarchy.

1. For years ago I discussed a model for UIBs based on p-adic length scale hypothesis [K17]. The idea was that protons "drop" from atomic space-time sheet with k = 137 to a larger space-time sheet to $k_1 > 137$ space-time sheet and the difference of zero point kinetic energies is liberated as radiation [K17]. The proposal was that the zero point kinetic energies give rise to a hierarchy of metabolic energy quanta.

Second possibility is phase transition in which the size of the k = 137 space-time sheet increases to $k_1 > 137$ and liberates the difference of zero point kinetic energy. For the third option energy preserving phase transition increasing $h_{eff}/h = n$ by a factor $(k_1 - k)/2$ followed by a phase transition reducing the value of h_{eff} back to the initial one but without change of the size of the space-time sheet would liberate the difference of zero point kinetic energies.

- 2. Could dark nuclear transitions explain UIBs? For k = 149 as the p-adic length scale of DNA letters would give nuclear energy scale E = .5 eV equal to the metabolic energy quantum by scaling 1 MeV for the ordinary nuclei by factor $2^{149-107}/2 = 2^{21}$ (here the original version of text contained error: this claim was made for k = 141). This energy has correct order of magnitude but is too high an energy for UIBs but there are of course also smaller energies possible for the nuclear excitations possibly explaining the UIBs.
- 3. What about hydrogen bonds? The strength of hydrogen bond essentially the bond energy is in the range .4-.5 eV -, which as such does not correspond to the average UIB energy, which come approximately as three lowest powers of two. The range of bond energies is .1 eV is smaller than the smallest UIB energy .11 eV.

UIBs can be associated with hydrogen bonds if there are states of bond with higher bond energy. They could correspond to higher values of $n = h_{eff}/h$ for the de-localized dark proton associated with the bond (analogous to de-localized valence electron). For instance, if the energy of the bond corresponds to the cyclotron energy of proton in a magnetic field associated with the bond, it is proportional to n.

The photon energies come approximately as powers of 2. If the favored values of n are in bands around $n = 2^k$ favored by the p-adic length scale hypothesis, one has hopes of understanding the band structure in terms of transitions reducing the value of k.

Membrane potential (see http://tinyurl.com/chylvs9) plays a key role in metabolism and one can wonder whether UIBs might relate to the potential energies defining energies $E_J = ZeV$ of Josephson photons associated with membrane if it acts like Josephson junction like structures associated with the prebiotic lifeforms.

- 1. Membrane potential energy varies in the range (.04, .08) eV (cell interior is negatively charged). Excitable cells (able to generate action potentials) include neurons, muscle cells, endocrine cells, and some plant cells. The average value for them is around .06 eV and further depolarization makes these cell more excitable. This suggests that the instability is caused by thermal radiation with nearly the same energy. The threshold for the generation of the action potential E_{act} is in the range (.050, .055) eV. Interestingly, during ageing neurons become more hyperpolarized and therefore less excitable. In photoreceptors the resting potential energy can be as low as .03 eV making them very sensitive to light.
- 2. In TGD inspired quantum biology axonal membrane can be seen as a generalized Josephson junction [K89, K90, K92] decomposing nanoscopically to Josephson junctions defined by cell membrane proteins. The protein as junction would correspond to a magnetic flux tube along which various charged particles with $h_{eff} = n \times h$ flow possibly as supra currents. As a special case cell membrane acts like an ordinary Josephson junction. In this case the increment of the electrostatic energy of the Cooper pair over membrane given by $E_J = 2eV$ defines the energy of the smallest quantum of Josephson radiation.

The intensity of thermal radiation at temperature T as function of photon energy E has a peak at $E \simeq 3T$, which for room temperature about T = .03 eV gives $E_{max} = .09$ eV. The energy ZeV of Cooper pair should be larger than E_{max} . For critical action potential one has $E_{act} = 0.1$ eV, which is slightly above $E_{max} = .09$ eV so that the action potential has minimal value and thus minimizes metabolic energy costs and implies quantum criticality with temperature as a critical parameter.

Note however that for energies below E_{max} the intensity of thermal radiation decreases so that also these energies might serve as Josephson energies: this and the fact that incoming photons have intensity higher than termal background at this energy could explain why some photoreceptors can have eV = .03 eV.

3. Could also Josephson radiation relate to UIBs? The Josephson energy of Cooper pair for the membrane potential is around $E_J = 0.1$ eV, which corresponds to the lowest UIB band, which could thus correspond to action potential .05 eV of excitable membrane. The higher bands would correspond roughly to two octaves suggesting that the action potentials in these case are roughly .1 eV and .2 eV. Quantum criticality would suggest that temperatures scale like the energies of the bands slightly higher than $E_{max} \simeq 3T$.

Metabolic energy transfer between magnetic body and biological body (defined in very general sense for any system) is possible if the spectra of transition energies share common transition energies. Therefore the spectrum of transition energies assignable to hydrogen bonds could have many transition energies common with that assignable to dark nuclear transitions and second and third explanation could be consistent with each other.

Model for hydrogen bond

The explanations of UIBs in terms of hydrogen bonds encourages to consider a concrete model for the hydrogen bond as flux tube. This suggests a connection with metabolism at cellular level involving transfer of protons through cell membrane against potential gradient assumed to take place as dark protons carrying the metabolic energy and providing it to ADP-ATP process after their return.

- 1. The simplest model for the proton inside flux tube is as particle in 1-D flux tube with magnetic field. Unless the magnetic field strength and/or n is very large, the kinetic energy in the direction of flux tube dominates and phase transition would change the scale of kinetic energy proportional to n^2 for fixed flux tube length. For $n = 2^k$ this would give too strong dependence of photon energies on k.
- 2. On the other hand, if the flux tubes are flux loops of the magnetic body of molecule their lengths naturally scale as n and the longitudinal kinetic energy is not affected in the transition. The cyclotron energy proportional to n would change and for $n \sim 2^k$ one obtains qualitatively correct behavior.

For proton in magnetic field of $B_{end} = .2$ Gauss the cyclotron frequency is 300 Hz and corresponds to $E_c(B_{end}) = 1.2 \times 10^{-12}$ eV. The identification of $E_c(B) = .5$ eVs would give $E_c(B) = n(B/B_{end}) \times E_c(B_{end}) = E_c(B) = .5$ eV. An estimate for B for the flux tube of hydrogen bond comes from flux quantization: eBS = 1 holds true for unit quantum of flux and for flux tube radius of one Angstrom this would give $B/B_{end} \sim 5 \times 10^8$. This gives the estimate $n \sim 10^8 \sim 2^{27}$. The rather large value conforms with the general vision for the values of n for dark protons whereas dark electrons of valence bonds would have much smaller values. The emergence of dark protons could be seen as the transition from chemistry already involving n as characterizer of valence bonds [L62] to bio-chemistry.

3. The identification of the metabolic energy quantum in terms of cyclotron energy could apply also in the case of cellular metabolism. The model for the generation of ATP from ADP assumes that protons are pumped by the energy coming from nutrient molecules against the membrane potential.

The membrane potential correspond to energy of .05 eV but metabolic energy quantum is 10 times larger. This looks like an inconsistency, which in thermodynamical approach is resolved

by introducing of chemical potentials. In genuine quantum approach the introduction of thermodynamics quantities is not allowed.

The general vision about metabolic energy as a tool to increase $h_{eff}/h = n$ defining kind of molecular IQ suggests that the transformation to dark proton at magnetic flux tube along which proton can travel through the membrane is responsible for the most of the energy needed for pumping. After the dark proton has returned through cell membrane it transforms to ordinary proton and liberates the metabolic energy and makes possible ADP-APT transformation.

The above model assumes that the lengths of hydrogen bonds as flux loops scale like n. This makes possible the reconnection of flux loops coming from opposite sides of the membrane to pair of flux tubes along which dark protons can flow. Similar picture applies also to other biologically important ions.

The general view about superconductivity in TGD Universe [K89, K90] suggests that reconnection can give rise to a Cooper pairs of protons with members at separate flux tubes. Also Cooper pairs of electrons and biologically important ions could form by the same mechanism.

3.3.3 PAH world hypothesis from TGD point of view

The so called PAH world hypothesis (see http://tinyurl.com/ycxm9zes) has been proposed as a prebiotic era preceding RNA world. As a matter of fact, PAH world hypothesis inspired more a detailed development of TGD based model for dark nuclei.

Let us first list some properties of poly-aromatic hydrocarbons (PAHs) (see http://tinyurl.com/atx4t9a).

- 1. PAHS consist of aromatic rings glued together along sides. By definition aromatic rings have delocalized electrons. In benzene, which is the classical and simplest example of PAH, the electronic state is quantum superposition of states in which bonds and double bonds alternate along the ring but are shifted by 60 degrees with respect to each other. Naphtalene has two aromatic rings and anthracene and pnenanthtrene have 3 rings.
- 2. PAHs are very stable non-charged non-polar molecules and are very common in Earth. They are found in coal and tar deposits and produced in an incomplete combustion of organic matter. PAHs are poisonous. For instance, tobacco smoke contains PAHs with carcinogenic effects. The stability of PAHs motivates the belief that a large fraction of carbon in the interstellar space consists of PAHs.
- 3. Benzene in difficult to detect in in the interstellar space since the rotational symmetry does not allow to detect rotational transitions. Recently however nitrobenzene was detected so that benzene and more complex PAHs presumably exist in interstellar space (see http://tinyurl.com/yap9ksrg).

Benzene and more complex PAHs can give rise to more complex aromatic by hydrogenation, oxidation, carboxylation, and nitrogenation and led also to the basic building bricks of DNA and amino-acids and PAHs are proposed to have played important role in prebiotic life.

- 1. PAH world hypothesis states that the polymer like sequences of PAHs serve as scaffoldings for the formation of RNA like polymers (see http://tinyurl.com/ycxm9zes). The key motivation is that the distances between PAHs are same as between RNA and DNA bases: 3.4 nm. The proposal is that during PAH era RNA nucleosides A, U, C, G were attached to PAHs by hydrogen bonds.
- 2. Second hypothesis is that formaldehyde molecules [(H₂C)=O] formed valence bonds with RNA bases and with each other giving rise to sequences analogous to the phosphate-ribose backbone of RNA. The sequence of disjoint CO=:s was replaced with the sequence ...(C-R)-O-(C-R)-O-.. with R denoting the RNA nucleoside. After this hydrogen bonds were split and the precedessor of RNA was detached from the PAH scaffolding. Later the pre-RNA strands were folded to form double pre-RNA strands similar to ribozymes. The problem is to understand how the formaldehyde backbone was replaces with more stable phosphate-ribose backbone.

In TGD framework dark nuclei would serve as scaffolding, which however does not detach from the corresponding biomolecules. The distances between dark variants of biomolecules would explain why the two distances are the same. Very many molecules, including PAHs, can attach around dark RNA/DNA and the periodic structure would be reflect the properties of dark nuclei. This could explain UIBs as emission bands of both dark nuclei and hydrogen bonds essential for the pairing and the transfer of metabolic energy between ordinary and dark biomolecules. Also in DNA double strand hydrogen bonds could serve similar function. If thermal radiation excites higher energy states of nuclei, the emission of UIBs depends on temperature. Perhaps this could be tested.

UIBs could therefore serve as a direct signature of dark nuclear physics. If dark nuclei are not associated with PAHs in vitro or in an environment not containing water, UIBs would be absent.

3.3.4 Did RNA replicate in codon-wise manner during RNA era?

3.3.5 Did RNA replicate in codon-wise manner during RNA era?

There was an interesting popular article in Spacedaily with title "Scientists crack how primordial life on Earth might have replicated itself" (see http://tinyurl.com/y92ng5vd). The research paper [I83] is titled "Ribozyme-catalysed RNA synthesis using triplet building blocks" and published in eLife (see http://tinyurl.com/ya5qyjfn).

It is possible to replicate unfolded RNA strands in Lab by using enzymes known as ribozymes, which are RNA counterparts of enzymes, which are amino-adic sequences. In the presence of folding the replication is however impossible. Since ribozymes are in general folded, they cannot thus catalyze their own replication in this manner. The researchers however discovered that the replication using RNA triplets - genetic codons - as basic unit can be carried out in laboratory even for the folded RNA strands and with rather low error rate. Also the ribozyme involved can thus replicate in codon-wise manner. For units longer than 3 nucleotides the replication becomes prone to errors.

These findings are highly interesting in TGD framework. In TGD the chemical realization of genetic code is not fundamental. Rather, dark matter level would provide the fundamental realizations of analogs of DNA, RNA, tRNA, and amino-acids as dark proton sequences giving rise to dark nuclei at magnetic flux tubes [L77] (see http://tinyurl.com/yalny39x). Also ordinary nuclei correspond in TGD Universe to sequences of protons and neutrons forming string like entities assignable to magnetic flux tubes.

The basic unit representing DNA, RNA and tRNA codon and amino-acid would consist of 3 entangled dark protons. The essential aspect is that by entanglement the dark codons do not decompose to products of letters. This is like words of some languages, which do not allow decomposition to letters. This representation is holistic. As we learn to read and write, we learn the more analytic western view about words as letter sequences. Could the same hold true in evolution so that RNA triplets would have come first as entities pairing with dark RNA codons from from dark proton triplets as a whole? Later DNA codons would have emerged and paired with dark DNA codons. Now the coupling would have have been letter by letter in DNA replication and transcription to mRNA.

It is intriguing that tRNA consists of RNA triplets combined from amino-acids and analogs of mRNA triplets! The translation of mRNA to amino-acids having no 3-letter decomposition alone forces the holistic view but one can ask whether something deeper is involved. This might be the case. I have been wondering whether during RNA era RNA replicated using a prebiotic form of translational machinery, which replicated mRNA rather than translated RNA to protein formed from amino-acids (AAs) with AA serving as a catalyst.

- 1. During RNA era amino-acids associated with pre-tRNA molecules would served as catalysts for replication of RNA codons. The linguistic mode would have been "holistic" during RNA era in accordance with the findings of the above experiments. RNA codon would have been the basic unit.
- 2. This would have led to a smaller number of RNAs since RNA and RNA like molecules in tRNA are not in 1-1 correspondence. A more realistic option could have been replication of

subset of RNA molecules appearing in tRNA in this manner.

- 3. Then a great evolutionary leap leading from RNA era to DNA era would have occurred. AA catalyzed replication of RNA would have transformed to a translation of RNA to proteins and the roles of RNA and AA in tRNA would have changed. [Perhaps the increase of h_{eff} in some relevant structure as quantum criticality was reached led to the revolution]
- 4. At this step also (subset of) DNA and its transcription to (a subset of) mRNA corresponding to tRNA had to emerge to produce mRNA in transcription. In the recent biology DNA replicates and is transcribed nucleotide by nucleotide rather than using codon as a unit so that helicases and DNA and RNA polymerases catalyzing replication and transcription should have emerged at this step. The ability of DNA to unwind with the help of helicase enzyme helping DNA to unwind is essential for the transcription and translation of DNA. Therefore helicase must have emerged together with the "analytic linguistic mode" as an analog of written language (DNA) decomposing codons to triplets of letters. This would been a crucial step in evolution comparable to the emergence of written language based on letters. Also the counterpart of RNA polymerase and separate RNA nucleotides for transcription should have emerged if not already present.

An alternative option would involve "tDNA" as the analog of tRNA and the emergence of helicase and polymerases later as the transition from holistic to analytic mode took place.

The minimal picture would be emergence of a subset of DNA codons corresponding to RNAs associated with pre-tRNA and the emergence of the analogs of helicase and DNA and RNA polymerases as the roles of amino-acid and RNA codon in tRNA were changed.

5. How DNA could have emerged from RNA? The chemical change would have been essentially the replacement of ribose with de-oxiribose to get DNA from RNA and $U \rightarrow T$. Single O-H in ribose was replaced with H. O forms hydrogen bonds with water and this had to change the hydrogen bonding characteristics of RNA.

If the change of $h_{eff} = n \times h_0$ was involved, could it have led to stabilization of DNA? Did cell membrane emerge and allow to achieve this? I have proposed [L77] (see http: //tinyurl.com/yalny39x) that the emergence of cell membrane meant the emergence of new representation of dark genetic code based on dark nuclei with larger value of h_{eff} .

Remark: One has $h = 6 \times h_0$ in the most plausible scenario [L41, L83] (see http://tinyurl.com/goruuzm and http://tinyurl.com/y9jxyjns).

The communication between dark and ordinary variants of biomolecules involves resonance mechanism and would also involve genetic code represented as 3-chords, music of light, and it is interesting to see whether this model provides additional insights.

- 1. The proposal is that 3-chords assignable to nucleotides as music of light with allowed 64 chords defining what I have called bio-harmony is essential for the resonance [L84, L87, L83](see http://tinyurl.com/ydhxen4g, http://tinyurl.com/yd5t82gq, and http://tinyurl.com/y9jxyjns). The 3 frequencies must be identical in the resonance: this is like turning 3 knobs in radio. This 3-fold resonance would correspond to the analytic mode. The second mode could be holistic in the sense that it would involve only the sum only the sum of the 3 frequencies modulo octave equivalence assigning a melody to a sequence of 3-chords.
- 2. The proposal is that amino-acids having no triplet decomposition are holistic and couple to the sum of 3 frequencies assignable to tRNA and mRNA in this manner. Also the RNAs in tRNA could couple to mRNA in this manner. One could perhaps say that tRNA, mRNA and amino-acids codons sing whereas DNA provides the accompaniment proceeding as 3chords. The couplings of DNA nucleotides to RNA nucleotides would rely on the frequencies assignable to nucleotides.
- 3. If the sum of any 3 frequencies associated with mRNA codons is not the same except when the codons code for the same amino-acids, the representation of 3-chords with the sum of the notes is faithful. The frequencies to DNA and RNA nucleotides cannot be however independent of codons since the codons differing only by a permutation of letters would

correspond to the same frequency and therefore code for the same amino-acid. Hence the information about the entire codon would be needed also in transcription and translation and could be provided either by dark DNA strand associated with DNA strand or by the interactions between the nucleotides of the DNA codon.

4. The DNA codon itself would know that it is associated with dark codon and the frequencies assignable to nucleotides could be determined by the dark DNA codon. It would be enough that the frequency of the letter depends on its position in the codon so that there would be 3 frequencies for every letter: 12 frequencies altogether.

What puts bells ringing is that this the number of notes in 12-note scale for which the model of bio-harmony [L16, L84] (see http://tinyurl.com/yad4tqwl and http://tinyurl.com/ydhxen4g) based on the fusion of icosahedral (12 vertices and 20 triangular faces) and tetrahedral geometries by gluing icosahedron and tetrahedron along one face, provides a model as Hamiltonian cycle and produces genetic code as a by-product. Different Hamiltonian cycles define different harmonies identified as correlates for molecular moods.

Does each DNA nucleotide respond to 3 different frequencies coding for its position in the codon and do the 4 nucleotides give rise to the 12 notes of 12-note scale? There are many choices for the triplets but a good guess is that the intervals between the notes of triplet are same and that fourth note added to the triplet would be the first one to realize octave equivalence. This gives uniquely $CEG\sharp, C\sharp FA, DF\sharp B\flat$, and $DG\sharp B$ as the triplets assignable to the nucleotides. The emergence of 12-note scale in this manner would be a new element in the model of bio-harmony.

There are 4!=24 options for the correspondence between $\{A, T, C, G\}$ as the first letter and $\{C, C\sharp, D, D\sharp\}$. One can reduce this number by a simple argument.

(a) Letters and their conjugates form pyrimidine-purine pairs T, A and C, G. The square of conjugation is identity transformation. The replacement of note with note defining at distance of half-octave satisfies this condition (half-octave - tritonus - was a cursed interval in ancient music and the sound of ambulance realizes it). Conjugation could correspond to a transformation of 3-chords defined as

$$CEG \sharp \leftrightarrow DF \sharp B \flat \ , \ C \sharp FA \leftrightarrow D \sharp GB \ .$$

(b) One could have

 $\begin{array}{ll} \{T,C\} \leftrightarrow \{CEG \sharp, C \sharp FA\} &, & \{A,G\} \leftrightarrow \{DF \sharp B \flat, D \sharp GB\} &, \\ & \text{or} & \\ \{T,C\} \leftrightarrow \{DF \sharp B \flat, D \sharp GB\} &, & \{A,G\} \leftrightarrow \{CEG \sharp, C \sharp FA\} &. \end{array}$

(c) One can permute T and C and A and G in these correspondences. This leaves 8 alternative options. Fixing the order of the image of (T, C) to say $(C, C\sharp)$ fixes the order of the image of (A, G) to $(D, D\sharp)$ by the half-octave conjugation. This leaves 4 choices. Given the bio-harmony and having chosen one of these 4 options one could therefore check what given DNA sequence sounds as a sequence of 3-chords [L16].

That the position the frequency associated with the nucleotide depends on its position in the codon would also reflect the biochemistry of the codon and this kind of dependence would be natural. In particular, different frequencies associated with the first and third codon would reflect the parity breaking defining orientation for DNA.

3.4 Improved reckless speculation about higher level variants of dark genetic code

In an earlier article I represented what I called reckless speculations about higher level variants of genetic code (see [L77] for the updated version of the original article). The speculations turned out

to be not only reckless but to contain besides an unrealistic working hypothesis for p-adic length scale of dark DNA also a numerical error in the estimate of dark nuclear excitation energy scale leading to a wrong track.

The wrong working hypothesis was the assumption that ordinary DNA, RNA, etc correspond to same p-adic length scale as their dark variants. Simple argument shows that the dark scales must result via radial scaling of the typically linear structures such as DNA, RNA, etc and also 2-D structures such as membranes and microtubules giving rise to 2-D lattice like realizations of genetic code generalizing the ordinary 1-D realizations.

Also new improved picture conforms with the vision that dark realizations of genetic code at various p-adic length scales serve as controllers of the ordinary biochemistry, which is kind of shadow dynamics. Replication, certainly one of the most mysterious feats of living matter, would reduce to the replication at the level of dark DNA in various p-adic length scales involved. This would be a huge simplification.

A hierarchy of dark nuclear physics with hierarchy of $n = h_{eff}/h_0 = n$ coming as certain powers of two so that the corresponding length scales correspond to p-adic length scales is an attractive idea. I have speculated with this idea already earlier. A hierarchy of dark nuclear physics with hierarchy of $n = h_{eff}/h = n$ coming as certain powers of two so that the corresponding length scales correspond to p-adic length scales is an attractive idea. I have speculated with this idea already earlier [K65].

3.4.1 Ideas

Consider first the general ideas.

1. The assumption of prime values for k in L(k) would pose extremely tight constraints on the allowed p-adic length scales and values of h_{eff}/h_0 . One would have $k \in \{127, 131, 137, 139, 149\}$ and $k \in \{151, 157, 163, 167\}$ and $k \in \{173, ..\}$ at least at the level of dark matter. So predictive an idea deserves to be killed, if not anything else.

A further motivation for these speculations is that the Gaussian Mersenne primes $M_{G,k=}(1+i)^k - 1$ for $k \in \{151, 157, 163, 167\}$ define p-adic length scale $L(k) \propto 2^{k/2}$ between 10 nm assignable to the neuronal membrane and 2.5 μ m assignable to cell nucleus: so many Gaussian Mersenne in so short length scale range is a number theoretical miracle.

2. Cell membrane consisting of two lipid layers (see http://tinyurl.com/h9a2hsq) is a binary structure as also DNA double strand. DNAs replicate as would do also RNAs during RNA era. Also cells and therefore also cell membranes replicate so that the analogy might make sense. Since processes like translation and transcription do not occur, cell membrane might serve as 2-D as analog of RNA: the counterpart of RNA era might prevail at these levels. Neuronal membrane might correspond to 2-D analog of DNA.

So: could various 2-D structures such as nuclear membrane, cell membrane, neuronal membrane, and microtubuli correspond to a new level in the hierarchy of dark codes for which genes and their dark variants would be 2-D rather than 1-D structures? One would have 2-D lattices of codons. Could there be entire hierarchy of them assignable to certain p-adic length scales? As 2-D realizations could be paired with their dark variants so that one could speak of dark variants of various membrane like structures. This applies also to microtubuli.

The idea that dark variants of DNA, RNA, and AAs are their radially scaled up variants generalizes also. The processes like replication of cell could be induced by a much simpler replication of 2-D dark DNA. This kind of pairing hierarchy could be behind miraculous looking replication of entire organisms. p-Adic fractality and hierarchy of dark DNAs could lurk behind the curtains.

3. The structures of ordinary bio-matter and also their dark variants assumed to control them are characterized by p-adic length scales. How these p-adic length scales could relate? The natural idea inspired by scaling invariance is that the dark variants of 1-D linear structure and 2-D structures formed from ordinary bio-matter are obtained by radial scaling consistent with p-adic length scale hypothesis, and guaranteeing that the distances between building bricks are scaled to the size scales of dark variants of DNA and other basic molecules. This

rule makes sense also for the 2-D structures. For instance, it would scale up the p-adic length scale L(143) characterizing lipid to L(149) assignable to single dark RNA strand or L(151) assignable to dark double DNA strand.

- 4. One can argue that cell membrane in particular neuronal membrane is highly dynamical unlike RNA. In ZEO however dynamical evolutions of space-time surfaces as preferred extremals correlates for behaviors replace 3-D static patterns as basic entities so that the emergence of cell membrane might mean dark genetic code for dynamical patterns analogous to deterministic computer programs defining predetermined dynamical patterns. In central nervous system nerve pulse patterns coded by dark RNA could provide similar coding of behavioral patterns.
- 5. I have claimed in earlier publications that the lipid double layer defining cell membrane has thickness $L_e(151) = 10$ nm: actually the thickness is $L_e(149) = 5$ nm for ordinary cells and 8-10 nm roughly $L_e(151)$ only for neuronal membranes. Therefore the emergence of neuronal membranes could be seen as an evolutionary step in p-adic and thus number theoretic sense. Needless to say, this little difference might be absolutely crucial for undestanding why neurons are at higher evolutionary level than ordinary cells. It would be nice if this difference could correspond to an increase of $h_{eff}/h_0 = n$ and p-adic length scale of ordinary and dark membrane like structure by a factor 2.

There is double cell membrane associated with mitochondria. The thickness of the two double membranes is about 7 nm so that they might correspond to k = 149. The double membrane would have roughly the thickness 22 nm. If this structure is a functionally coherent structure it would correspond to $L_e(153)$ and could be controlled by its dark counterpart.

6. I have proposed that the flux tubes connecting the dark DNA sequences above lipid layer to those associated with DNA could make possible to realize topological quantum computation [K7, K122] in terms of braiding induced by the 2-D liquid flow induced by nerve pulse patterns at nuclear membrane. Flux tubes might be associated with cytoskeleton and define an analog of central nervous system at the level of cell. A rough estimate for the numbers of codons for human DNA of length about 1 m and the number of codons allowed by the surface of the nuclear membrane are of order 10⁹ so that the proposal might make sense.

This proposal generalizes and has many alternative forms. For instance, microtubules inside axons could be connected by flux tubes to the surface of axons.

One could also consider braidings between ordinary and dark levels, say braiding of flux tubes connecting lipid layers of neuronal membrane to 2-D analog of dark DNA. This braiding would code quantum computer programs and be part of coding of nerve pulse patterns inducing 2-D flow of lipids to memories represented as braidings. Quite generally, the braidings could be very naturally between ordinary and dark variants of structures considered.

3.4.2 Could cell membrane and neuronal membrane realize genetic codons as 2-D structures?

In the sequel I discuss in more quantitative level the idea that cell membrane and neuronal membrane realize analogs of genes as 2-D structures.

The p-adic length scales associated with the dark variants of 2-D structures?

Consider next the p-adic length scales associated with the structures considered.

- 1. The thickness of ordinary cell membrane corresponds roughly to $L_e(149) = 5$ nm whereas the coiling associated with the cell membrane corresponds to $L_e(151)$. Also neurons correspond to $L_e(151)$. Could k = 149 resp. k = 151 define levels of ordinary cell resp. neuron in the hierarchy of dark nuclear physics?
- 2. Cell membrane consists of lipid bilayer. The lipid layer has three parts (see http://tinyurl. com/h9a2hsq).

- The totally hydrated layer nearest to water is hydrophilic head group, which in the case of phospholipids contains negatively charged phosphate. This phosphate layer has thickness .7 1.0 nm.
- Below it is a partially hydrated layer of thickness .3 nm, which corresponds to L(141): this of course puts bells ringing!
- Hydrophobic lipid tail layer below it is dehydrated. The thickness of single lipid layer is 1.25-1.75 nm and would correspond to the p-adic length scale $L_e(145) = 1.2$ nm. k = 145 is not prime.
- 3. The phosphate layer analogous to phosphate-ribose backbone and the thickness L(141) of partially hydrated layer suggests that it corresponds to EZ created in Pollack effect so that there would be parallel dark RNA sequence along axon (possibly helical as for microtubules). In the case of cell membrane would have lattice like system formed from dark protons, and maybe even dark neutrons (as an analog for the neutron halo in some nuclei).
- 4. If the recent biology is the analog of RNA era for k = 149 codes, their manifestations could be seen as analogs of RNAs and the number of different lipids associated with the cell membrane could give some idea about their number. Cell membrane could perhaps be seen as a 2-D analog of RNA polymer. Cell division implying membrane replication would be induced by dark RNA replication. Even the analogs of tRNA and AAs but not proteins might be present if one takes the analogy very seriously. Could one identify pairs of lipids and some molecules analogous to proteins appearing in cell division?

What kind of general conditions can one pose on the dark variants of DNA, RNA, and AAs?

- 1. Dark variant of 2-D variants of DNA, RNA, or AAs realizing the hierarchy of dark codes should control their analogues or possibly some other molecules coded by them. The coupling would be by resonance. This suggest the hierarchy of codes uses as building bricks simpler structures by starting from 1-D structures and building from them more complex structures. Hence the natural hypothesis is that the 2-D variants of proteins consisting of a 2-D lattice like structure formed from proteins is in question.
- 2. The geometric aspect of membrane dynamics would be determined by basic dynamics of TGD determined by action, which is a generalization of charged point-like particle coupling to Maxwell field by replacing the particle orbit with 4-D surfaces. This allows as special case minimal surfaces such as deformations of cosmic strings giving magnetic flux tubes. Cell membranes should correspond to extremals for which coupling to Kähler force is non-trivial as it indeed is by membrane potential. This because static closed surfaces, in particular spherical layers, are not possible as minimal surfaces. Remarkably, these extremals are not analogs of external particles (geodesic lines) but correspond to interaction regions. This conforms with the fact that cell membrane is a self-organization pattern requiring a continual feed of metabolic energy.

The 2-D dark variants of DNA, RNA, and AAs would be involved mostly with the control the electro-chemistry of membrane like structures. Of course their geometrodynamics would induce also morphogenesis of ordinary bio-matter.

Also enzymes and ribozymes would have dark variants controlling their behavior. Folded protein represents an interesting example about possibly 3-dimensional graph like structure in which the protein forms an analog of Hamilton's cycle going through all points of the graph defined as a lattice with nearest neighbors connected by edges without self-intersections. This hypothesis is rather powerful since for Hamiltonian cycle do not necessarily exist for an arbitrary graph.

3. In the case of cell membrane membrane proteins are the natural candidate for the building bricks. They indeed have an active role and serve as both channels and pumps and in the case of the neural membrane this role is especially important. Membrane proteins are identified in TGD framework as generalized Josephson junctions. In the case of cell membranes mebrane proteins having length of about 5 nm (5 AAs) or 10 nm (10 AAs) going through the membrane

are an excellent candidate for the basic building brick. One could see the basic structure either as 2-D structure built from membrane proteins or 3-D structure build from AAs. Membrane proteins would form kind of generalized protein as a 2-D lattice of proteins and accompanied by their dark variants or of 2-D dark variants of RNA or DNA coding for them and identifiable as radial scalings of these proteins to k = 149 or k = 151.

The model for topological quantum computation [K7] suggesting that DNA codons of are connected to lipids of cell membrane could be modified so that dark DNA, RNA, or AAs associated with membrane proteins are connected to them by flux tubes which can get braided. This would allow the quantum control of the 2-D protein like structure and make it effectively single quantum coherent Josephson junction as suggested in the quantum model for nerve pulse [K92].

The original proposal was that there might exist an analog of genetic code for lipids. The number of different lipids is however too high to allow any simple correspondence. Lipids have also rather passive role in the dynamics of the cell membrane: their serve as signal pathways, provide metabolic energy, and serve as signal pathways (see http://tinyurl.com/z7d7osm). The proposal however deserves to be explained.

- 1. Both sides of the lipid bilayer of cell membrane could pair with 2-D lattice of dark RNA whose size scale would be obtained by radial scaling giving rise to what might be called dark cell membrane. In the case of neuronal membrane the dark lattice would consist of pairs of dark DNA codon and its conjugate. In the case of axon one could have the analog of dark DNA strand extended to a cylinder containing bundles of these strands at its surface. Lipid layers would be 2-D analogs of 1-D DNA strands in this case.
- 2. Lipids would be analogs of ordinary RNA codons and dark RNA codons would code for them: this would predict 64 different lipids in cell membrane. Single dark RNA would correspond to the size scale of single lipid given by L(143) = 2L(141) = .625 nm. The dark nuclear physics would correspond to k = 149. The number N of parallel dark RNA strands would be roughly the circumference of the axonal lipid layer divided by the size of single lipid about L(143) = .625 nm given by $N \sim 2\pi \times L_e(167)/L_e(143) = \pi \times 2^{24} \sim 5 \times 10^6$.

Thermodynamical constraints

Could this totally irresponsible speculation about p-adic hierarchy of dark nuclear physics and genetic codes survive thermodynamical constraints?

- 1. The condition that metabolic energy quantum is not below thermal energy at physiological temperatures poses constrains on the model. I have considered several identifications of the metabolic energy quantum. These identification need not be mutually exlusive.
 - One interpretation is as 1-D zero point kinetic energy of proton at tubular space-time sheet of atomic size with transversal length scale L(137). This energy is invariant under scalings induce by increase of h_{eff} since h_{eff}^2/L^2 is not changed.
 - Second identification of metabolic quanta would be as energies assignable to hydrogen bond and its dark variants.
 - Third identification of the metabolic energy quantum would be as scaled variant of $E_b(k) = 2^{(k-107)/2} E_b$ of typical dark nuclear binding energy $E_b = \sim 1$ MeV. The value would be about .5 eV for k = 149 and .25 eV for k = 151.
- 2. Note that the action potential assignable to k = 151 neuronal membrane is around .05 eV (the membrane potential for some photoreceptors is .03 eV). In TGD Universe the cell membrane can be seen as Josephson junction decomposing in an improved resolution to membrane proteins acting as Josephson junctions [K89, K90]. Josephson energy of Cooper pair is twice this that is $E_J = 0.1$ eV slightly above the maximum $E_{max} = 3T = .09$ eV of the thermal distribution at physiological temperature.

3. As far Josephson radiation are considered, for k = 151 membrane would be a quantum critical system. Quantum criticality could give rise to instability making possible the generation of nerve pulses. During nerve pulse the dark protons at the dark space-time sheet would return to the neuronal membrane and destroy the ionic equilibrium. Also the temperature criticality of consciousness manifesting itself as the generation of hallucinations during fever could be understood. For k = 151 the situation would be overcritical and will be discussed separately.

The Josephson energy of Cooper pair is scaled down to $E_J = .1$ eV near to $E_{max} = .09$ eV. This is slightly above the thermal energy but one could still argue that Josephson radiation cannot carry information. Or could Nature have found the means to overcome this potential problem? The notion of generalized Josephson junction central in TGD inspired theory of EEG as communications from brain to MB [K92, K45] could save the situation.

- 1. For the generalized Josephson junction the energy of quantum of Josephson radiation is $E = E_J + \Delta E_c$, where ΔE_c is the difference of cyclotron energies at the two sides of the membrane. E_c is proportional to $h_{eff} = n \times h$ and large enough value of n guarantees that E_c is above $E_{max} \simeq 3T$ irrespective of the value of the membrane potential. The variations of the membrane potential modulate Josephson frequency, and are proposed to provide a coding of sensory data defined by nerve pulse patterns communicated to MB.
- 2. $h_{eff} = h_{gr} = GMm/v_0$ hypothesis [K85, ?] guarantees the spectrum of cyclotron energies is universal and does not depend on the mass m of the charged particle being in the range of visible and UV energies of photons (this allows to deduce information about the values of mass M and velocity parameter $v_0 < c$): bio-photons would be produced in energy conserving phase transitions transforming dark photons to ordinary ones [K20, K31].
- 3. If MB itself (a structure which has size scale of Earth at EEG frequencies around 10 Hz) has low enough temperature, this would allow to overcome the limitations caused by the thermal masking of the ordinary Josephson radiation so that the frequency modulations by nerve pulse patterns could code for the sensory data. $h_{eff} = h_{gr} = GMm/v_0$ hypothesis indeed allows very large values of h_{eff} for which ordinary cyclotron energies proportional to h_{eff} would be ridiculously small for the ordinary value of h.

What about the situation for massive particles like proton? Now Maxwell-Boltzmann (Gaussian) distribution is a good approximation and for effectively D-dimensional system the value of distribution is reduced by 1/e at thermal energy $E_{cr} = DT/2$. One could argue that above this energy thermal masking can be avoided. For D = 1 at magnetic flux tubes this would give $E_{cr} = T/2 = E_{max}/6$. At $T_{phys} = .03$ eV one would have $E_{cr} = 0.15$ eV. Metabolic energy quantum would be above E_{cr} for k = 151. Even k = 153 possibly assignable to mitochondrial double membrane can be considered but represents an upper bound at physiological temperatures.

Remark: In TGD view about information processing in brain [L55] active linear neuron groups relate to verbal cognition and 2-D neuronal groups relate to the geometric cognition associated with the decomposition of perceptive field to objects. At cellular level DNA and cell membrane could perhaps be seen as counterparts for these structures. In TGD framework neuronal membrane is proposed to be a constructor of sensory representations communicated to the magnetic body (MB) using generalized Josephson radiation whereas motor control by MB has been assumed to take place via DNA [K60].

3.4.3 DNA packing problem and p-adic length scales

DNA manages to pack huge amount of DNA to single cell nucleus. For instance, human DNA as length of about 1 meter. This is achieved by a hierarchical coiling structure involving 3 levels with highest level identifiable as chromatides and the lowest level defined by nucleosomes (see http://tinyurl.com/yat5cm4y) wound around histon isomers linked together by straight portions of DNA. One can find a detailed representation of the 4-levelled packing of DNA (see http://tinyurl.com/ybxv6w4v).

There are 4 levels involved. Could they relate to the Gaussian miracle primes k = 151, 157, 163, 167? The general proposal is that the products of powers of small primes define the scale hierarchy. There is evidence that at least the powers of 2 and 3 define p-adic length scales, which would correspond also to dark scales. The simple guess is that the dark scales are identical to the ordinary p-adic scales.

- The diameter of the nucleosome is 11 nm = 1.1L(151), which suggests k = 151. Chromatosome consists of histone H_1 plus nucleosome.
- Nucleosomes coil to form a fiber of diameter d = 30 nm. This scale is 3L(151).
- At the next level loops of average length $300 \text{ nm} = 30L(151) \sim 32L(151)$. This level is only intermediate level in packing.
- These loops compress and fold to 250 nm $=25L(151) \simeq 3 \times L(157)$, L(157) = 8L(151) wide fiber. Thus third harmonic of also the miracle length scale L(157) would be involved.
- This fiber compresses a tight coil of radius 700 nm = $70L(151) \simeq 64L(151) = L(163) = 640$ nm giving rise to the chromatid fiber of chromosome. k = 163 is the third miracle length scale.
- Chromosomes have width 1400 nm which corresponds to the scale L(165).

The 3 levels k = 131, 157, 163 seem to be realized although not in the simplest manner. Nuclear membrane would correspond to $L(k = 167) = 2.5 \ \mu\text{m}$. For $n = h_{eff}/h_0$ these levels would correspond to the values n of form $n = 2^r 3^s$.

Consider next nucleosome.

- 1. DNA wraps of around histone octamers forming a cubical structure consisting of 8 smaller cubes (octamers). There are 2×4 histones forming two identical layers. The 4 histones H_{2A} , H_{2B} , H_3 , H_4 of given layer are not identical. There is also histone H_1 attached to the entire structure. The incoming DNA double strand enters to the upper end of H_1 and leaves from its lower end. H_1 is related to the secondary coiling. The wrapping gives rise nucleosomes as helices with two turns and containing about 146 base pairs making 48 codons plus 2 base pairs.
- 2. According to the standard model of nucleosome double DNA strand wraps around the analog of a spool formed from an octamer consisting of two identical units above each other consisting of 4 different histones. The incoming DNA strand enters the upper 4-histone unit and winds once around it and then does the same for the lower unit before leaving the nucleosome.

One can construct a rough TGD inspired model for this structure (not completely realistic) to get a concrete idea about what is involved.

1. The size scale of the cube like structure is L(151) = 10 nm so that single histone corresponds to a cube with side roughly about L(149) = 5 nm. One can estimate the total length Lof the wire from the equation $z = xR\phi/\pi$, $R \sim L(149)$, $\phi \in [0, 4\pi]$, as $L = \sqrt{1 + \pi^{-2}}4\pi R$. For $R \sim L(149)$ and h = L(151) this gives $L \sim 66$ nm, There are roughly 146 DNA base pairs and 48 whole codons ($144 = 3 \times 48$ base pairs) and each codon has length about 1 nm. This gives total length of 48 nm. The reduction of radius R by factor r = 48/66 = 3/4 to R = 3L(149)/4 would give a correct value of L

According to the representation for the hierarchy of packings (see http://tinyurl.com/ ybxv6w4v), the diameter of the structure is d = 1.1L(151) rather than small and the height of the structure is smaller in the illustration. This width is however not consistent with the helix structure for any value of the height.

2. If the double DNA strand is accompanied by a dark double strand of radius L(149), the situation is like having a band of width L(151) going around the spool. The dark double strand covers an area, which is 4/3 times the spool area. The horizontal thickness of the entire dark structure is about $d_D = (7/4)L(151)$. If the radius of DNA double strand is r = L(151) the area covered by the double strand is roughly twice the area of the spool. This suggests that one should identify the p-adic length scale of DNA double strand as its diameter about L(151) rather than its radius.
Remarks:

- 1. While trying to understand nucleosomes in TGD framework, I encountered an interesting side result related to Hamiltonian face paths and Hamiltonian cycles on octahedron, which to my best understanding must correspond to Hamiltonian paths and cycles on cube. The octahedral face paths can be identified as closed paths connecting the middle points of the centers of a cube. The 8 histones define a decomposition of the entire cube to 8 sub-cubes. The idea was that Hamiltonian face cycles in these cubes could give up to tight packing of 6 codons. The number of the Hamiltonian paths for cube is 64 (see http://tinyurl.com/ybqw6zpt) and the number of cycles is 6! Single genetic codon would dictate the choice of the Hamiltonian path on cue! Although the idea did not work (the length of, it led to ask whether the Hamiltonian cycles on octahedron or their duals at cube might have some biological relevance.
- 2. A further interesting finding is that the sequence of 8 quints defines a piece of 12-note scale proceeding by quints as steps between nearest neighbor vertices (using octave equivalence) in the icosahedral model of harmony [L16, L92] based on 12-note scale could be interpreted as cubic Hamiltonian cycle giving rise to the notes $F, C, G, D, A, E, H, F\sharp$. This gives the notes of C major scale with 7 notes plus tritonus $F\sharp$ defining half-octave as 8:th note. One could also identify the cycles as consisting of the notes of 8-note scale along cycle in the usual order $C, D, E, F, G, A, H, F\sharp$ based on standard notion of nearness for which neighboring vertices correspond to neighboring notes of the scale. Allowed 3-chords would correspond to triplets containing no neighboring notes. The Hamiltonian cycle for cube is unique apart from isometries as also for tetrahedron and dodecahedron.

3.4.4 Microtubules as quantum critical systems

Also microtubules (see http://tinyurl.com/y8km9vve) are 2-D structures having a strong resemblance with the lipid layers of cell membrane. Could a higher level representation of genetic code similar to the one proposed for cell membranes make sense for them. Also now one can imagine that the microtubular surface is accompanied by its dark variant realizing 2-D dark genes, dark RNA, or dark proteins with scaled up size. The p-adic prime should correspond to k > 151 so that higher level realization of genetic code would be in question. In the case of axons a possible identification for the dark scale would be as the radius of the axonal membrane.

- 1. Microtubules are hollow cylinders with outer *resp.* inner diameter equal to 24 *resp.* 12 nm (the scales differ by factor 2) so that their thickness is 12 nm is same as the inner radius and would correspond to L(151) = 10 nm. They decompose to 13 parallel helical filaments consisting of 13 tubulin proteins having size scale of order $L_e(151)$.
- 2. Tubulins are dimers of α and β tubulin and the pairs are oriented along the helical filament. One can estimate the size of α and β tubulin by diving the circumference of 24 nm of the microtubule with the number of filaments, which is 13. This gives for the size scale of tubulin the estimate $R_{tub} \sim 12$ nm not far from L(151). This supports the view that p-adic length scale L(151).

The size scale of the transversal volume associated with lipid is roughly .62 nm that is L(143) = 2L(141) so that they could correspond to $k \in \{141, 143\}$, presumably k = 141. Therefore one could see microtubules as scaled up variants of cell membrane with scaling factor $2^{(151-141)/2} = 2^5 = 32$. Similar scaling would take place for the value of $n = h_{eff}/h$ giving $n = 2^{23}$ so that microtubules would represent a higher level of evolution identified as increase of n. Microtubules have indeed emerged after cell membrane.

3. It has been proposed that the α and β conformations of tubulin give rise to bit or even qubit. If this were the case, single helical filament rotating one full turn would have 2^{13} states and carry 13 bits of information. 13 independent filaments would have $2^{26} \simeq 64 \times 10^6$ states and carry 26 bits of information. One could also think of codon as sequence of 13 filaments with the states of filaments representing 2^{13} letters of the code. 4. Microtubular surface has rather high charge density and is polarized: the almost stationary end has negative local charge density roughly equal to that of DNA whereas the growing end has lower surface charge density. One manner to control the charge of the tubulin dimer is in terms of the charge states of GDP and GTP by ionization of the phosphates. Maximal negative charge for tubulin dimer would be 5 units.

Microtubules are highly dynamical objects with inherent instability and have varying length: one might say that microtubules are quantum critical objects. Quantum criticality and thus instability might relate to the fact that the metabolic energy quantum is very near to thermal energy at room temperature.

The dynamics for the length of microtubule could be induced from the dynamics of EZ involving the flow of protons between microtubule and its magnetic body defined by dark DNA. The gradient in charge density would make possible positive net charge density at the growing end of the microtubule.

In ZEO it looks reasonable to argue that the dynamical patterns are coded by a generalization of genetic code just as computer programs code for deterministic dynamical patterns.

5. What could the dark code behind the dynamics be? The α - and β tubulins of tubulin dimer involve GTP (see http://tinyurl.com/ybtjluaf) resp. GDP (see http://tinyurl. com/y8uok7kq). In the case of DNA one has XMP, X = A, T, C, G. The analogs of dark RNA sequences would contain mere G and the information coded by the tubulin would be determined by the conformation of the tubulin dimer giving 1-bit code. This looks somewhat disappointing.

If the charge states of the phosphates of GDP and GTP can vary and all charge combinations for phosphates are possible, one has 2^3 charge states for GTP and 2^2 charge states for GDP. Together with the bit associated with the tubulin conformation this would give 2^6 states and realize 6 bits of the ordinary genetic code! One would have 2-D realization of the genetic code analogous to that proposed for the lipid layer with the state of tubulin analogous to RNA codon.

This coding together with thermal criticality would make microtubule a dynamical object since the deviation of the tubulin charge from -1 units would spoil charge local charge neutrality of tubulin-dark RNA pair.

I have proposed that flux tubes connecting tubulins to the lipids of the axonal lipid layer could give rise to topological quantum computation [K7, K7]. The size scale of lipid is about $L_e(141)$ and that of tubulin about $L_e(151) = 32L_e(141)$, and the radius of axonal membrane is by two orders of magnitude larger than microtubular surface. Hence this proposal does not look realistic unless one assumes that sub-structures of cell membrane with size scale of order $L_e(167)/L_e(151) = 2^8$ larger than tubulin size represented as space-time sheets with cell nucleus size L(167) have flux tube connections to tubulins.

This kind of map would give rise to a kind of abstraction about what happens at the level of axonal membrane integrating out un-necessary details. This abstraction is natural since microtubules would indeed correspond to a higher level of cognitive hierarchy. Roughly $N = 2^{16}$ lipids would contribute to the information received by single tubulin. Could nerve pulse patterns can induce braiding of the flux tubes in this scale?

3.5 Freaky DNA

The popular article "Freaky Eight-Letter DNA Could Be the Stuff Aliens Are Made Of" (see http: //tinyurl.com/y5wb7cm8) tells about very interesting discovery related to astrobiology, where the possible existence of variants of DNA and other bio-molecules are of considerable interest. The article "Hachimojii DNA and RNA: A genetic system with eight building blocks" (see http: //tinyurl.com/y2mcjb4r) published in Science tells about a discovery of a variant of DNA with 8 letters instead of 4 made by Hoshika *et al* [I43]. By using an engineered T7 RNA polymerase this expanded DNA alphabet could be transcribed into Hachimoji variant of RNA. The double strand structure of hachimoji DNA is similar to that of ordinary DNA and it is thermodynamically stable. No amino-acid (AA) counterparts assigned to the hachimoji RNA were engineered: this would require the existence of translation machinery. The possible existence of also additional AAs leads to the speculation is that both alien life forms utilizing this kind of extended code could have evolved. One can also ask whether mere synthetic hachimoji RNA could be enough for synthetic life.

The abstract of the article gives a more technical description about what has been achieved.

We report DNA- and RNA-like systems built from eight nucleotide "letters" (hence the name "hachimoji") that form four orthogonal pairs. These synthetic systems meet the structural requirements needed to support Darwinian evolution, including a polyelectrolyte backbone, predictable thermodynamic stability, and stereoregular building blocks that fit a Schrödinger aperiodic crystal. Measured thermodynamic parameters predict the stability of hachimoji duplexes, allowing hachimoji DNA to increase the information density of natural terran DNA. Three crystal structures show that the synthetic building blocks do not perturb the aperiodic crystal seen in the DNA double helix. Hachimoji DNA was then transcribed to give hachimojii RNA in the form of a functioning fluorescent hachimoji aptamer. These results expand the scope of molecular structures that might support life, including life throughout the cosmos.

If the additional code letters for DNA (8 code letters instead of 4) really carry information, the number of codewords is extended by factor $2^3 = 8$ giving $2^9 = 512$ code words. What the number of AAs would be, can be only guessed: the simplest guess is that also now the number is scaled up by factor 8 but this is only a guess.

In the sequel I consider hachimoji code from TGD perspective. The natural guess is that the hachimoji code corresponds to 8 copies of the ordinary genetic code in some sense. TGD predicts two basic realizations of the genetic code corresponding to dark genetic code and bio-harmony.

- 1. In the case of the dark code it is possible to imagine an extension of the code based on the notion of dark nucleus and the number codons is multiplied by 8. In the case of bio-harmony fusion of 8 copies of bio-harmony allows to realize hachimoji code.
- 2. I have considered two basic realizations of bio-harmony [L16, L92] giving also realization of genetic code. The first realization is as a fusion of 3 icosahedral harmonies and tetrahedral harmony. Second realization is as a fusion of 2 icosahedral harmonies and 1 toric harmony. These constructions do not however allow any elegant geometric interpretation since two different geometries are involved in both cases.

During writing I was forced to reconsider this problem and realized that a fusion of 2 icosahedral harmonies with 20 chords and 2 dodecahedral harmonies with 12 chords produces genetic code with 20+20+12+12=64 codons. Icosahedral and docecadedral harmonies correspond to dual tessellations of sphere so that bio-harmony can be represented as a bundle over sphere with two notes represented as points of the fiber. Hachimoji harmony is obtained by replacing 2-point fiber with 8×2 -point fiber. The presence of the dual tessellations conforms with the fact that Eastern music uses micro-intervals, which rather naturally correspond to 20-note dodecahedral scale.

- 3. The reason why for the hachimoji code could the basic problem of the music scale realized in terms of rational frequency ratios. Already Pythagoras was aware of this problem. The construction of the scale as powers of quint (3/2-fold scalings of the basic frequency) using octave equivalence produces with 12 iterations 7 octaves but only approximately: the 12th iterate does not quite correspond to the basic note in the octave equivalence. Performing the 12-fold iteration 8 times gives therefore a refined scale with each note replaced with 8 almost copies identifiable as hachimoji scale.
- 4. A further discovery was that the quint scaling appearing in the earlier model can be replaced with a unique scaling, which is same for icosahedral and dodecahedral codes. One must however generalize the notion of Hamiltonian cycle by introducing the analog of gauge symmetry in a discrete bundle over sphere and allowing to generate new Hamiltonian cycles from given cycle by gauge transformations. In this manner one obtains extremely rich harmony from single basic chord transposable to $CEG\sharp$.

3.5.1 Icosa-tetrahedral and icosa-dodecahedral bioharmonies as candidates for genetic code

Both the icosa-tetrahedral [L16] and icosa-dodecahedral harmony to be discussed below can be considered as candidates for bio-harmony as also the harmony involving fusion of 2 icosahedral harmonies and toric harmony [L79]. The basic reason is that the third harmony corresponds to doublets. One cannot exclude the possibility of several equivalent representations of the code.

Icosa-tetrahedral harmony

Icosahedral harmonies can be characterized by a subgroup of icosahedral isometries A_5 having 60 elements. If reflections are included the isometry group, oneas $A_5 \times Z_2$ with 120 elements. The group of symmetries is Z_6, Z_4 , or Z_2 . There are two choices for Z_2 and the interpretation has been that Z_2 correspond to either reflection or rotation by π . A_5 however allows also $Z_2 \times Z_2$ as subgroup. AAs correspond to orbits of the symmetry group and DNA codons coding for the AA correspond to triangles (3-chords) at the orbit. In purely icosahedral model on obtains 20+20+20 codons. A fusion with tetrahedral harmony gives 64 codons.

- 1. Z_6 gives rise to 3 AAs coded by 6 codons each (leu,se,arg) and 2 AAs coded by 2 codons: the choice of the doublet would require additional conditions. One option is ile doublet.
- 2. Depending on whether one includes reflection or not, one can have either $Z_4 \subset A_5$ (60 = 4×15) or $Z_4 = Z_{2,rot} \times Z_2 \subset A_5 \times Z_2$. I have assumed that $Z_4 = Z_{2,rot} \times Z_2$ but the recent argument suggests the first option. This does not have any implications for the earlier model. Icosahedral Z_4 gives rise to 5 AAs coded by 4 codons each (5 × 4 = 20). This leaves 11 AAs and 3 "empty" AA formally coded by stop codons.
- 3. Icosahedral Z_2 gives rise to 10 dublets. These 4-plets would correspond to (phe, tyr, his, gln, asn, lys, asp, glu, cys, stop-doublet) This leaves (stop,trp) double and (ile,met) doublet with broken Z_2 symmetry.

The fusion with tetrahedral code with 4- codons and 4 AAs should explain these 4 AAs. Tetrahedral isometries form group S_3 and reduce to group Z_3 for tetrahedral cycle.

- (a) One could argue that ile-triplet and met correspond to 3-element orbits with 1-element orbit. (stop,trp) would be formed by Z_2 symmetry breaking from trp doublet and there is no obvious mechanism for this.
- (b) If one tetrahedral face is fixed as a face shared with icosahedron, the symmetry group of tetrahedral cycle reduces to Z_1 . This would give 4 singlets identifiable as (ile,met) and (stop,trp) symmetry broken doubles. Since ile appears also in doublet, tetrahedral 1-orbit and icosahedral 2-orbit must have a common doubled triangle identifiable as the common face of icosahedron and tetrahedron. The doubling of the common triangle replaces ile-doublet with ile-triplet. This option looks rather reasonable.

Dodecadedral harmony

Dodecahedral harmony correspond to the unique Hamilton cycle at dodecahedron. Dodecahedral harmony as 20 notes and 12 5-chords. If one assumes that the octave divides to 20 notes, this brings in mind "eastern" view about harmony.

The obvious objection against dodecahedral harmony is that dodecahedral faces are pentagons so that dodecahedral chords would be 5- rather than 3-chords so that the correspondence between chords and DNA codons would be lost. The situation changes if 3 notes - 3-chord - determine the 5-chord completely and one can assign a unique 3-chord to each pentagon. This is indeed the case!

1. 3-edges meet in every dodecahedral vertex (this makes the dodecahedral cycle unique apart from rotations) and each edge pair in the vertex belongs to same pentagon (in the case of icosahedron there are 5 edges per vertex so that this is not true). Therefore each pentagon must contain at least 2 edges of Hamilton's cycle.

The cycle must visit all vertices of pentagon, and the visit to the vertex means that the cycle shares at least one edge with pentagon. Since all vertices of the pentagon must be visited, there are two options. For option a) given pentagon shares with the cycle disjoint 2-edge with 3 vertices and 1-edge with two vertices. For option b) the pentagon shares with the cycle 4-edge with 5 vertices.

2. The numbers n_a of pentagons with 4-edges and $n_b = 12 - n_a$ 2-edge+ 1-edge (making 3 edges) can be deduced easily. Cycle has 20 edges. Pentagon of type a) shares 3 edges with the cycle and the edge is shared by 2 pentagons. This gives $3n_a/2$ edges. Pentagon of type b) shares 4 edges with the cycle. This gives $2n_b = 2(12 - n_a)$ edges. The total number of edges is $3n_a/2 + 2n_b = 20$, which gives $n_a = 8$ and $n_b = 4$. Dodecahedral Hamilton's cycle can be found from web (see http://tinyurl.com/y5woajcb). The structure is as deduced here.

For case a) the 3-chords correspond naturally to the 3 vertices of the 2-edge shared with the cycle. Therefore it is possible to assign unique 3-chords to the dodecahedral harmony and to obtain connection with codons in this case. One however obtains also 12 2-chords: could they have some genetic counterpart?

What about 5-chords for pentagons of type b)? Hamiltonian cycle can be oriented and this is induces orientation of the pentagons. One can say that the first vertex in the 4-edge is the vertex at which cycle arrives to the pentagon and identify the 3-chord as the first three vertices. It turns out that for the replacement of quint cycle this is not actually necessary.

Is icosa-dodecahedral harmony consistent with the genetic code?

One must check whether icosa-dodecahedral harmony is consistent with the degeneracies of the genetic code.

- 1. A fusion of 2 icosahedral harmonies and 2 copies of dodecahedral harmony would be in question. As in the case of icosahedral harmony already discussed, the two icosahedral harmonies would have symmetry groups Z_6 and Z_4 and give the codons coding for 3 6-plets and 1 doublet + 5 4-plets + two copies of dodecahedral harmony.
- 2. Can the model predict correctly the numbers of codons coding for AAs? It is known that dodecahedral Hamilton cycle divides dodecahedron to two congruent pieces related by Z_2 symmetry (see http://tinyurl.com/yy6pcogt). Also the Hamiltonian cycle defining the common boundary has Z_2 symmetry. A good guess is that these Z_2 :s corresponds to reflection symmetry and rotation by π but I am not able to exclude $Z_4 \subset G_0$, where G_0 consists of 60 orientation preserving isometries. In this case some orbits - presumably all 3 of them could contain 4 pentagons. This is not consistent with the condition that one has doublets and singlets.

If the second symmetry corresponds to reflection, it can be excluded by simply assuming that reflections change the orientation of the cycle.

3. Rotation by π has two fixed points corresponding to opposite poles so that one has 5 2-orbits and 2 1-orbits giving 12 triangles for each copy. Two copies of dodecahedral harmony would give 5+5=10 doublets and 2+2=4 singlets. A possible interpretation would be as (ile,met) and (stop,trp).

Consider now objections against dodecahedral harmony.

- 1. Why two copies of dodecahedral code? What distinguishes between them? If imirror symmetry leaves the cycle invariant apart from orientation the copies could be mirror images and consist of same faces. The second option is that they related by a rotation?
- 2. The number of dodecahedral AAs is 24 rather than 20. Could the additional 4 AAs as orbits have interpretation as AAs in some sense. Could the "empty" AAs coded by stop codons be counted as AAs exceptional in some sense. In TGD framework one can consider the possibility that although AA is "empty", there is analog of AA as physical signature for the

end of protein telling what stopping codon it corresponds. The magnetic body of protein is a good candidate.

Genetic code has several slightly differing variants. Could the 2 additional exotic AAs Pyl and Sec correspond in some situations to the additional AAs?

3. Essential for the bio-harmony as a fusion of harmonies is that one can select from each orbit single face as a representative of the AA it codes - kind of gauge choice is in question - and that the orbits corresponding to different AAs can be chosen to be disjoint. Otherwise codons belonging to the orbits of different Hamilton cycles can code for the same AA if the AA can be chosen to be in intersection. If not, the same codon can code for 2 different AAs - this can indeed occur in reality [L87]!

The condition that orbits of different cycles do not interesect seems quite stringent but has not been proven. But what if it is actually broken? Indeed, in the case of icosahedral harmony with Z_1 symmetry tetrahedron and icosahedron could have common a doubled face the breaking of this condition would geometrically explain why ile belongs to both icosahedral and tetrahedral orbit.

Ile is the problem also in the case if icosa-dodecahedral harmony. Dodecahedral singlet codes for ile as also icosahedral doublet. Could one talk about doubling of ile face so that it corresponds to a pair of triangle and pentagon (in 1-1 correspondence with triangle as chord).

4. The two copies of the dodecahedral code should correspond to 5 doublets and 2 singlets each. One expects that together they give rise to 10+2+10+2=24 faces. Do they? Mirror symmetry and rotation by π act as symmetries of the cycle so that neither can map the two cycles to each other. Dodecahedral (equivalently icosahedral) rotations give rise to new equivalent cycles. The action on pentagons corresponds to the action on vertices of icosahedron so that it easy to understand what happens.

Each symmetry corresponds to a rotation around some axis and has opposite icosahedral vertices at this axis as fixed points. Hence any two cycles obtained in this manner have 2 common pentagons. This means reduction $24 \rightarrow 22$ unless one interprets the situation in terms doubled faces? Could the disappearing doublet correspond to stop-doublet? What about the remaining stop of the vertebrate code pairing with trp? Why does second singlet correspond to empty AA and not something else such as exotic AA.

5. There is also further problem. Suppose that an intersection of orbits takes place at single triangle. Suppose that one cannot choose this triangle to be "AA" triangle for both orbits. In this case it is not clear to which AA the codon codes. This kind of phenomenon actually takes place in some cases and is known as homonymy [L87]. It is associated with the deviations of the code from the vertebrate code and involves exotic AAs Pyl and Sec. Codons can serve as a stop codon or code for an exotic AA.

Clearly, the notion of bio-harmony involves many unclear aspects but my strong feeling is that there is very beautiful mathematics involved.

3.5.2 Hachimoji code and realizations of genetic code suggested by TGD inspired quantum biology

The discovery of Hachimoji code relates interestingly to two realizations of the genetic code inspired by TGD based quantum biology.

- 1. The first realization is dark genetic code with codons realized as 64 3-proton states made of dark protons having non-standard value $h_{eff} = n \times h_0$ of Planck constant [L77]. The hierarchy of Planck constants is predicted by adelic physics providing physical correlates for correlation in terms of p-adic physics [L67]. Dark genetic code would be fundamental in TGD and bio-chemical realization would be kind of shadow or mimicry of it and not even complete in some cases. One cannot talk about letter decomposition for dark proton triplets since the 3-proton states are entangled.
- 2. Second realization relies on the notion bio-harmony [L16, L92]: the realization of the genetic in terms of 3-chords of bio-harmony emerged as a by-product from a model of harmony.

Does dark realization of genetic code allow hachimoji code?

Could one realize hachimoji codons as dark codons?

- 1. If the proposed dark proton triplets [L77, L76] is the only fundamental realization of genetic codons, the real information storage capacity should not increase but the correspondence between dark codons and chemically realized codons would not be 1-to-1 but 1-to-8. Furthermore, the transcription of dark DNA to ordinary one would not be possible in 1-to-1 manner so that hachimoji code could not have evolved.
- 2. One can however imagine of having also neutrons rather than only protons in the dark nuclear string. If one can have both dark protons and neutrons, one could obtain effectively 8 letters. Also the number of dark RNA codons and perhaps also of ordinary AAs would increase presumably by factor 8. Since the dark nucleons would be located along magnetic flux tube, Fermi statistics, which does not allow protons to have the same position, would not affect the situation and one would indeed obtain just the factor 8.

There is however an objection. Dark proton sequences would be generated by the formation of exclusion zones in Pollack effect [L20] [L20], and would be stable against transformation to those containing neutrons since the energy needed to transform proton to neutron is about MeV and huge in the scale of biochemistry.

Is it possible to overcome this objection?

1. TGD inspired nuclear physics relies on nuclear string model [L1] for which unexpected correlations between nucleons (EMC effect) provide support. Nucleons would be connected bo nuclear string by color bonds having quark and antiquark at their ends. Bonds could be color neutral and color confinement would make the bonds stable.

The bonds connecting nucleons to nuclear string would have u/d type quark and antiquark at their ends and could have total charges +, -1, and 0. This would predict new exotic states of nuclei with binding energy differences of order keV (small scale compared to MeV scale of nuclear binding energies). There is evidence for keV energy scale.

In fact, several scaled variants of dark nuclear physics are predicted [L77], and the nuclear binding energy scale would behave like 1/L, where L is the size scale of dark nuclei identifiable as p-adic length scale in TGD framework. Even dark nuclear binding energy scale of order metabolic energy quantum of order .5 eV can be considered.

2. Same would apply to dark nuclei formed from dark protons. The bonds connecting dark protons to nuclear string could also have total charge +1,-1, and there could exist two states with charge 0. Only 3 spin states analogous to those of (neural) ρ_0 meson are accepted in the original model whereas neural pion-like state is not allowed. Now the states analogous to both ρ_0 and ρ_{-1} are accepted. One can denote the bond as B(q), q = 0, +1, -1.

The pair p + B(-1) would behave like neutron effectively. The pair p + B(1) would have charge +2 and could be be unstable due to repulsion whereas neutron like state could be stable by attraction. This could give rise to an effective doubling of letters.

Remark: A possible objection is that the neutral ρ meson like color bond is expected to have energy higher than neutral pion by spin-spin splitting as in the case of ordinary mesons. A good argument for throwing out the pion-like bond is needed.

Is the realization of hachimoji code in terms of bio-harmony possible?

What about the realization of hachimoji code as a bio-harmony [L16, L92]? Bio-harmony makes it possible to transfer the genetic information at the level of dark variants of basic bio-molecules (also RNA, AAs, and tRNA) in terms of 3-chords of dark photons coupling via frequency resonance. The coupling to ordinary variants of DNA would take place via energy resonance and involve the transformation of dark photon to ordinary photon or vice versa coupling. Music expresses and induces emotions and the music of dark photons would provide fundamental expression of emotions realized at the bio-molecular level [L84].

Can one scale the number chords of bio-harmony by factor 8 by using icosa-dodecahedral bio-harmony?

The number 64 of 3-chords defining the bio-harmony should be scaled up by 8. As far as chords are considered, each note appearing in the chord should be doubled.

1. There are two variants for bio-harmony. 12-note scale is represented as a Hamiltonian cycle defined as a closed path (by octave equivalence) going through all vertices of as tessellation of sphere or torus and not intersecting itself. Both icosahedron and tetrahedron can be regarded as tessellations of sphere by triangles.

The first realization [L16, L92] involves fusion of 3 Hamiltonian cycles at icosahedron defining 20 chord harmony H_{20} each and 1 cycle at tetrahedron defining 4-chord harmony H_4 . This gives 20+20+20+4=64 3-chords defining the codons.

Second realization [L79] is a fusion of 2 20-chord harmonies H_{20} defined by Hamiltonian cycles at icosahedron and 24-chord harmony H_{24} by cycle associated with torus tessellation. The fusion of two icosahedral cycles gives 20+20 3-chords and torus cycle gives 24 chords: 64 altogether. There are large number of Hamiltonian cycles and their fusions would correspond to different emotional states.

- 2. Can one imagine any modification of the model giving rise to 8-fold increase of the basic chords? One can consider doubling of the 4 basic frequencies to 8. For instance, splitting of each frequency could correspond to the doubling of the code letters. One can also imagine that each triplet of dark nucleons (dark neutron would be now dark proton+the bond with varying charge) corresponds to its own cyclotron frequency triplet so that 8-fold increase of 3-chords would become possible.
- 3. Could one have a geometric interpretation for the 8-fold increase of 3-chords realized as faces of Platonic solid or toric triangular tessellation. Could summand in the sum of 3 icosahedral harmonies and one tetrahedral harmony (of 2 icosahedral and toric harmonies) be replaced with an analog of tessellation having 8-fold number of triangles? The splitting of each triangle to 8 smaller equilateral triangles so that the 12-note scale would have now $8 \times 12 = 96$ notes, is not possible since the side of the smaller triangle should be $2^{-3/2}$ times smaller than that of the original triangle: inverse integer scaling would be required.
- 4. The simplest manner to get 8-fold scaling for the number of chords is some kind of fusion of 8 octaves of bio-harmony. By octave equivalence the 8-letter code would bring new information at the level of bio-harmony perceived in an improved resolution only. New information would require that the fused scales differ slightly. A natural interpretation for the fusion would be as formation of a discrete bundle structure in which 8-fold increase of notes of the scale corresponds to 8-point fiber.

The fusion of fundamental harmonies with 20, 4 or 24 3-chords is used in the proposed models of bio-harmonies. The geometric interpretation of the fusion is not quite clear. For a fusion of 3 icosahedral code one could imagine a discrete bundle structure in which 3 copies of note as points of icosahedron form a 3-point fiber. The addition of tetrahedron could be seen as a union of icosahedron and tetrahedron with gluing along common face. This does not however fit with the bundle interpretation.

Same applies to the union of 2 icosahedral codes with (V, F) = (12, 20) and 1 toric code with (V, F) = (20, 24). One could ask whether the latter option could allow interpretation as singular bundle structure such that in the fiber space two tori collapse to spheres. This would correspond to a disappearance of 4 faces so that one has 20 faces instead of 24. This does not look like an attractive option.

5. Could one find a realization of the code consistent with the bundle interpretation? Could one have 64 codons by using fusion of 2 icosahedral and 2 dodecahedral codes (forget for a moment that the faces of dodecahedron are pentagons!)? Dodecahedron has 20 vertices (maybe 20-note scale might relate to micro-intervals used in Eastern music) and 12 faces. The fusion would give 20+20+12+12= 64 chords. Dodecahedral harmony is unique since there is only single Hamilton's cycle.

One would have only single topology and the interpretation as fiber space with 2 points in the fiber would make sense if the dodecahedral tessellation is constructed as a dual of icosahedral one with new vertices as centers of icosahedral triangles. Music, even the music of light realized as triplets of dark photons with frequencies equal to those of the chords of bioharmony, expresses emotions and this leads to the suggestion that emotions are expressed even at the level of bio-molecules [?] Therefore I cannot avoid the temptation to ask whether the uniqueness of the dodecahedral harmony could relate to the eastern notion of empty mind empty of any emotions and thoughts.

6. For this realization of bio-harmony the fusion of 8 bio-harmonies could be seen as a transition to a higher hierarchy level considering structures made of structures and would produce the required number 96 of notes. These bio-harmonies would have slightly different 12-note scales. Octave equivalence would suggests that 12-note scale is effectively replaced with $8 \times 12 = 96$ note scale. The interpretation in terms of fiber space structure with 2×8 points in the fiber would make sense.

The problem of Pythagoras a motivation for the fusion 8 copies of bio-harmonies

Could one imagine any justification for the fusion of 8 copies bio-harmonies possibly with slightly differing scales? A problem that teased already Pythagoras suggests this kind of justification!

1. The basic problem of Pythagorean scale based on rational frequencies realized as quints of the basic frequency modulo octave equivalence is that octave equivalence is not quite exact. The octave projections by scaling by a power of 2 of the scale in higher octaves to the lowest octave do not quite quite co-incide with the 12-note scale assigned with it: the reason is that no power of x = 3/2 can exactly co-incide with power of 2 so that $x^{12} = 2^7$ is true only with 1 per cent accuracy.

Pythagoras who firmly believed that Nature relies on the arithmetics of rationals was even ready to believe that Nature is imperfect! In TGD framework one could say that only the cognition based on rationals is imperfect (also cognition using algebraic numbers is predicted to be possible and evolution would mean increase of the complexity for the extension of rationals). Tempered scale would require the powers of algebraic number $x = 2^{1/2}$ to belong to the extension.

The problem is that Pythagorean scale seems however to have a deeper meaning (people with absolute ear love it) [L32]. Could some number of octaves - say 8 - give a more precise mathematical model of music experience in the case of people having absolute ear? Could it be that people with absolute ear have a better pitch resolution and are able to distinguish between notes of 96-note scale?

Remark : The realization of 12-note scale using irrational frequency ratios coming as $2^{1/12}$ -powers of the fundamental frequency does not have problem with octave equivalence.

- 2. The 8 × 12-note would be obtained as follows. One performs first 12-fold iteration to get 12-note scale. The 12th iterate is very near to the basic note by octave equivalence. After that one repeats 12-iteration 7 times so that each note in the original 12-note scale is mapped to 8 notes. These notes must be within interval corresponding to half-note (say E-F), which corresponds to the scaling $r = 2^{1/12}$ in good approximation. This gives the condition $(x^{12\times8}/2^8)^8 < r$ giving the condition $x < 2 \times r^{1/(8\times12)} = 2 \times 2^{1/96} \simeq 2.0145$ satisfied for $x_8 = 27/17$.
- 3. The construction of bio-harmony was based on the assumption that the subsequent vertices along Hamiltonian cycle (neighboring points of tessellation) are related by the scaling of frequency by $x_7 = 3/2$ (Hamiltonian cycle would correspond to quint cycle especially familiar for jazz musicians) and projecting to the basic octave. 12 scalings of this kind give slightly more than 7 octaves $((3/2)^{12} \simeq 129.746...$ rather than $2^7 = 128$): there relative error is about 1 per cent. $x_7 = 3/2$ would suggest 7 rather than 8 copies of the basic bio-harmony.

Quint rule is consistent with 8-fold repetition of the basic 12-iteration but one can imagine also alternative rules for generating the notes of the scale using powers of some number x reduced to basic octave. Could a simple choice for $x = x_8$ give $x_8^{12} = 2^8$ in a better approximation than $x_7 = 3/2$ gives $x_7^{12} = 2^7$? The replacement $x_7 = 3/2 \rightarrow x_8 = (3/2) \times y$, where y is rational approximation for $2^{1/12}$, gives a natural guess for x_8 . For y = 18/17giving $x_8 = 27/17$ (to be compared with $x_7 = 27/18$ one obtains $x_8^{12}/2^8 = 1.006...$, so that the error is .6 per cent whereas for $x_7 = 3/2$ the corresponding error is around 1 per cent. Note that p = 17 is Fermat prime of form $F_n = 2^{2^n} + 1$ near to power of 2. Primes near power of two are in fundamental role in TGD.

4. It will be found that the recent proposals for bio-harmony have drawbacks, and that a more elegant identification of bio-harmony as a fusion of icosahedral and dodecahedral harmonies leads to a replacement of powers of quints (C - G) with powers of slightly larger interval $(C - G\sharp)$ and a generalization of Hamiltonian cycle by introducing the analogy of gauge symmetry.

Details of the icosa-dodecahedral harmony

Consider now the details of the icosa-dodecahedral harmony.

1. Dodecahedral harmony involves $n_{20} = 20$ notes. The generalization of the quint cycle means that the frequencies in the basic octave are obtained from the base frequency as scalings by octave equivalence: $f/f_0 = x_{20}^k/2^{r(k)}$, k = 0, 1, ..., 19 with r(k) fixed by the condition that $1 \leq f/f_0 \leq 2$. x_{20} is a rational number determined by the condition that x_{20}^{20} is as near as possible to power $2^{k_{20}}$, where k_{20} can have several values.

 $k_{20} = 12$ gives $x_{20} = 127/40$ as optimal choice. $x_{20}^{20}/2^{12} = 1.0007$, so that the error is very small. What puts bells ringing that Mersenne prime 127 appears in the numerator of x_{20} : it appears also in the model of genetic code based on Combinatorial Hierarchy [K60].

2. One can argue that the values of x should be such that 20-note scale shares the notes of 12-note scale under octave equivalence. This requires that x_{12} and x_{20} differ by a power of 2. For $n_{12} = 12, k_{12} = 8 x_{12} = 127/80 = x_{20}/2$ gives $x_{12}^{12}/2^8 = 1.0007$, which is an excellent accuracy. Note that x_{12} is not very far from quint x = 3/2. 20-note scale shares under octave equivalence the notes of 12-note scale in the sense that one has $x_{12}^r 2^{-r} = x_{20}^r$.

8 icosahedral octaves emerges a as a prediction of icosa-dodecahedral codes and this is the number of octaves required by hachimoji DNA. Presumably there is a connection between these two identical numbers.

- 3. To get some idea about dodecahedral harmony one can use the fact that $x_{12} = 1.5875...$ is near to $2^{8/12} = 1.5874...$, which corresponds to the interval $C - G^{\sharp}$ rather than quint C - G. For case b) the notes of 4 pentagons containing 4-edge would can be transposed to $CG^{\sharp}ECG^{\sharp}$ so that the notes begin to repeat themselves approximately and one would indeed obtain only 3-chords modulo octave equivalence! If the notes of 3-chord correspond to same power of x, all 3-chords would be of the same type: the melancholic 3-chord with which so many finnish tangos end! Since the repetition is not exact the notes of dodecahedral scale cover the entire octave. The basic CEG^{\sharp} chord transponated by the powers of x_{20} covers entire octave.
- 4. For 8 pentagons of type a) one would obtain 3-chord transposable to $CG \sharp E$ and 2-chord transposable to $CG \sharp$.
- 5. Should one allow also for the icosahedral harmonies only chords for which the notes belong to the cycle and triangle? This would allow 3-chords for triangles containing two edges of the cycle: these chords would be of type CGD involving two quints. Triangles containing single edge would correspond to 2-chords with separation by quint. The triangles containing no edges would correspond to notes. The choice of the note would not be unique. The model of icosahedral harmony indeed predicts this kind of 3-chords. For instance, dissonant chords involving 3 subsequent notes are possible [L16] and more natural interpretation would be as possible notes of melody.

Is gauging of sphere needed to make icosa-dodecahedral harmony non-trivial?

There is also a second objection. If the notes of the chord correspond to same power of $x_{20} = 127/40$, only the notes $C, EC, G \sharp$ would appear in the 3-chords the approximation that $x^{20}/2^{12} = 1$ as is obvious from the fact that one $x_{20} \simeq 2^{4/12}$. Both icosahedral and dodecahedral harmonies based on $x_{20} = 127/40$ would be trivial. As noticed, one obtains the 20 transposes of this chord but having only chords with same structure looks still trivial.

1. One could solve the problem by allowing combinations of notes of 3-chord with different values of k in x_{20}^k (or x_{12}^k). The division of octave to 20 (12) notes guarantees that the chords obtained in this manner allow to realize very rich repertoire of harmonies. Essentially $20^3 = 8000$ chords become possible. What looks like a weakness of Pythagorean view about music based on rationals would become a strength.

The analogy with the non-uniqueness of gauge choice in gauge theories is obvious. Gauge transformations changing the value of k in local manner give new Hamiltonian cycles from given cycle. Mathematically this solution looks elegant since one can also choose $x_{20} = 127/40 = 2x_{12}$. This also gives 8 octaves for icosahedral harmony as hachimoji code requires.

2. Although the proposed solution is mathematically elegant, it is interesting to look also for the case $x_{12} = 3/2$. The first problem is that x_{12}^{20} deviates 20 per cent from base note, and would correspond to $E\flat$ rather than C. What is however nice is that the notes for a pentagon containing 4-edge would correspond to C, G, D, A, E, H. From these one can select major chords CEG, GHD, and minor chords ACE, EGH. One could obtain the basic harmonies from the dodecahedral part by allowing all possible choices.

Could one assume a slightly modified quint scale and different scales for icosahedron and dodecahedron? Icosahedral and dodecahedral scales are roughly consistent if k_{20} corresponds to an integer multiple of k_{12} . For $k_{12} = 7$ and $k_{20} = 2k_{12} = 14$ one has $x_{12} = 3/2$ and $x_{20} = 13/8$. One has $x_{20}^2/2^{14} = 1.006$. One has $x_{20}/x_{12} = 13/12 = 1.08$. to be compared with $2^{1/12} = 1.059$... The difference is more than half-note that x_{20} corresponds roughly to $C - G\sharp$ interval as for $x_{20} = 127/40$ as above. Therefore this option does not look attractive.

Summarizing

Some concluding remarks are in order.

- 1. Hachimoji DNA turned out to be extremely inspiring discovery also from TGD point of view and led to a more refined vision about bio-harmony with elegant mathematical interpretation.
- 2. If the above arguments make sense, one cannot avoid the question whether the fact that some people have absolute ear mean that genetic code with 8-fold number of codons is realized at the level of dark codons and bio-harmony? Chemical realization would have been probably discovered.
- 3. 8×12-note scale would allow discretized glissandos and also discretized blue notes appearing in popular music. Purely electronic production of this kind of music using computer programs is possible using Garage Band or some other similar program, and it would be interesting to test how the discretized glissando is heard.

One can imagine also instruments producing this kind of music. A hybrid of piano and violin comes first in mind. The keys of piano would be replaced by keys sensitive to touch - the technology used in smartphones would allow to realize this. The 8 1/16 notes associated with a given ordinary half-note would correspond in an increasing order to linearly ordered regions along the key, and one could change the note or chord by shifting the fingers along the key. The strength of touch could code for the volume. The chords of the harmony do not consist of arbitrary notes of the 8×12 note scale but are obtained by transposing the chords of the basic bio-harmony. This would help enormously in playing since one can shift all fingers along the keys defining the chord.

Chapter 4

Geometric Theory of Bio-harmony

4.1 Introduction

The model for bio-harmony predicted vertebrate genetic code correctly has evolved to its recent form during 4 years. The recent progress in the understanding of the model motivated writing of a separate chapter summarizing the earlier results and adding the new results achieved during 2018.

Remark: In the sequel I will use the shorthand AA for amino-acids and shorthands DDNA, DRNA, DtRNA, DAA for the dark analogs of DNA, RNA, tRNA, and AA realizes as dark proton sequences with codon represented as dark proton triplet.

4.1.1 Some background

For some years ago I introduced the notion of Hamiltonian cycle as a mathematical model for musical harmony and also proposed a connection with biology: motivations came from two observations [L21]. The number of icosahedral vertices is 12 and corresponds to the number of notes in 12-note system and the number of triangular faces of icosahedron is 20, the number of aminoacids (AAs) and the number of basic chords for the proposed notion of harmony. This led to a group theoretical model of genetic code and replacement of icosahedron with tetra-icosahedron to explain also the 21st and 22nd AA and solve the problem of simplest model due to the fact that the required Hamilton's cycle does not exist.

The article [L16] was meant to be a continuation to the mentioned article providing a proposal for a theory of harmony and detailed calculations. It however turned out that the proposed notion of bio-harmony was too restricted: all isosahedral Hamilton cycles with symmetries turned out to be possible rather than only the 3 cycles forced by the assumption that the polarity characteristics of the AAs correlate with the properties of the Hamiltonian cycle. This working hypothesis had to be given up. The fuel of the minirevolution was the observation the symmetries of the Hamiltonian cycles (Z_6, Z_4, Z_2) are nothing but the icosahedral symmetries needed to predict the basic numbers of the genetic code and its extension to include also 12st and 22nd AAs. Thus icosahedral Hamiltonian cycles predict genetic code without further assumptions.

One also ends up with a proposal for what harmony is leading to non-trivial predictions both at DNA and AA level.

- 1. 3-adicity and also 2-adicity are essential concepts allowing to understand the basic facts about harmony. The notion of harmony at the level of chords is suggested to reduce to the notion of closeness in the 3-adic metric using as distance the distance between notes measures as the minimal number of quints allowing to connect them along the Hamilton's cycle. In ideal case, harmonic progressions correspond to paths connecting vertex or edge neighbors of the triangular faces of icosahedron.
- 2. An extension of icosahedral harmony to tetra-icosahedral harmony was proposed as an extension of harmony allowing to solve some issues of icosahedral harmony relying on quint identified as rational frequency scaling by factor 3/2.

This extension is kept also now. One must however give up the idea about correlation between polarity characteristics of proteins and properties of Hamilton cycles. One must allow *all* 11 icosahedral harmonies with symmetries as bio-harmonies: their symmetry groups Z_6 , Z_4 , Z_2 can be identified as the symmetry groups defined the decomposition of 60 DNA codons to 20+20+20 codons in the model of the genetic code. The 4 remaining DNAs and AAs can be assigned to both tetra-icosahedron and tetrahedron and icosahedron regarded as defining separate genetic codes. This explains why stopping codons can code for the 21st and 22nd AA under some circumstances.

Tetrahedral code is second member in the hierarchy of genetic codes [K60] inspired by the notion of Combinatorial Hierarchy $M(n + 1) = M_{M(n)} = 2^{M(n)} - 1$ giving the numbers 2, 4, 7, 64, 2^{126} , ... as numbers of DNA codons. The fourth member would correspond to what I called "memetic code" allowing representation of codons as sequences of 21 DNAs. It is not known whether the Combinatorial Hierarchy of Mersenne primes continues as Hilbert conjectured.

- 3. The notion of bio-harmony is partially characterized by the triplet $n = (n_0, n_1, n_2)$, characterizing the numbers of 0-, 1-, and 2-quint chords which in turn correspond to DNA codons in consistency with the observation that codons indeed correspond to triplets of nucleotides. *n*-quint chord corresponds to a triangle (face of icosahedron) containing *n* edges of the Hamiltonian. Particular bio-harmony requires a selection of a specific Hamiltonian cycle from each class of cycles (1 Z_6 symmetric cycle having $n = (2, 12, 6), 2 Z_4$ symmetric cycles $n \in \{(0, 16, 4), (4, 8, 8)\}, 3 Z_2 = Z_2^{rot}$ with $n \in \{(0, 16, 4), 1(2, 12, 6), (4, 8, 8))\}$ and 5 $Z_2 = Z_2^{refl}$ symmetric cycles with $(n \in \{(2, 12, 6), (4, 8, 8)\})$. Note that the are only three different triplets *n*.
- 4. The original idea was that the rules of bio-harmony could be applied to AA sequences interpreted as sequences of basic 3-chords. DNA would have represented the notes of the music. For *given choice of harmony* as Hamiltonian cycle meaning selection of of 4, 5 or 10 AAs coded by the 20 DNAs in question, the hypothesis had to be modified by replacing AA sequences with DNA sequences.

These DNA sequences however define also AA sequences identifiable as specific triangle at the orbit of Z_n defining the DNA codons assigned to that AA (there is a singular fiber space structure). Together the three 20-plets of DNAs define an AA harmony with (4+5+10 =19 chords with tetrahedral extension defining a harmony with 22 chords/AAs). Hence both DNA sequences and AA sequences define "bio-music".

- 5. The assumption that harmonic transitions between chords (DNA codons) minimize the distance between chords defined by quint-metric leads to highly non-trivial and testable predictions about both DNA sequences and AA sequences. Negentropy Maximization Principle (NMP) [K73] suggests that evolution favors the generation of harmony which should thus increase in the proposed sense for DNA sequences defining particular genes or other functional units of DNA during evolution. Large quint-distances between subsequent codons/chords would tend to polished out under evolutionary pressures.
- 6. Could icosahedron, tetrahedron, and tetra-icosahedron have direct physical counterparts in living matter? For instance, water molecules form icosahedral clusters and the chlathrates associated with synaptic contacts have icosahedral symmetries. Tetra-icosahedron has 13 vertices with the added vertex representing one note- say E- in C-key as note with slightly different frequency to resolve the basic problem of rational number based 12-note scale (12 quints give slightly more that 7 octaves). Intriguingly, microtubules consist of basic structures consisting of 13 tubulins with 2 states defining bit: could these bit sequences define representation for the 3-chords and thus representation of sequence of DNA codons and realization of genetic code.
- 7. Music is language of emotions and peptides are molecules of emotion as Candace Pert [J6] expressed it. Could bio-harmonies serve as direct correlates for emotions? What is biomusic? A natural TGD inspired guess is that sounds can be replaced with $h_{eff} = n \times h$ dark photons with low frequencies and having energies in the range of bio-photons (visible and

UV range maximally effective biologically) as proposed on basis of some physical facts and theoretical ideas [K91]. The frequency spectrum of dark cyclotron photons along magnetic flux tubes would define bio-music as "music of dark light" and bio-harmonies would correlate with emotions and moods.

If one can find various icosahedral Hamilton's cycles one can immediately deduce corresponding harmonies. This would require computer program and a considerable amount of analysis. My luck was that the all this has been done. One can find material about icosahedral Hamilton's cycles (see http://tinyurl.com/pmghcwd) in web, in particular the list of all 1024 Hamilton's cycles with one edge fixed [A7, A16] (this has no relevance since only shape matters). If one identifies cycles with opposite internal orientations, there are only 512 cycles. If the cycle is identified as a representation of quint cycle giving representation of 12 note scale, one cannot make this identification since quint is mapped to fourth when orientation is reversed. The earlier article about icosahedral Hamiltonian cycles as representations of different notions of harmony is helpful [L21].

The tables listing the 20 3-chords of associated with a given Hamilton's cycle make it possible for anyone with needed computer facilities and music generator to test whether the proposed rules produce aesthetically appealing harmonies for the icosahedral Hamiltonian cycles. Biologist with access to DNA sequences could experiment with DNA codons to see whether their are harmonious in the sense that the distance between subsequent chords assignable to DNA codons tend to be small in quint metric. Note that DNA decomposes to pieces corresponding to different Hamiltonian cycles (harmonies) so that the comparison is not quite straightforward.

This summarizes the original article about geometric model of harmony [L16] and contributions in online books [K122, K91]. This chapter contains besides this article also some new results and considerations related to music harmony. Most of them have emerged during 2018.

4.1.2 Questions emerged during 2018

The model of music harmony is separate from the model of genetic code based on dark proton triplets [L36] and one of the challenges has been to demonstrate that they are equivalent. One can raise several questions.

- 1. Could the number of harmonies be actually larger than 256 as the original model predicts? One could rotate the 3 fused Hamilton's cycles with respect to each by icosahedral rotations other leaving the face shared by icosahedron and tetrahedron invariant. There are however conditions to be satisfied.
 - (a) There is purely mathematical restriction. If the fused 3 harmonies have no common 3-chords the number of coded AAs is 20. Can one give up the condition of having no common 3-chords and only require that the number of coded AAs is 20?
 - (b) There is also the question about the chemical realizability of the harmony. Is it possible to have DNA and RNA molecules to which the 3-chords of several harmonies couple resonantly? This could leave only very few realizable harmonies.
- 2. The model predicts the representation of DNA and RNA codons as 3-chords. Melody is also an important aspect of music. Could AAs couple resonantly to the sums of the frequencies (modulo octave equivalence) of the 3-chords for codons coding for given AA? Could coding by the sum of frequencies appear in the coupling of tRNA with mRNA by codewords and coding by separate frequencies to the letterwise coupling of DNA and RNA nucleotides to DNA during replication and transcription? Could the emergence of DNA be interpreted as an evolutionary step from a holistic picture using codons as basic units (dark codons cannot be decomposed to letters) to more analytic picture in which letters are treated separately?
- 3. As I developed the model of bio-harmony [L16] (see http://tinyurl.com/yad4tqwl) it did not occur to me that also the tRNA part of the dark code should have counterpart in the icosahedral model. Could tRNA correspond to pairs of harmonies with 20+20+4=44 codons? What about single 20+4=24 codon representation as kind of pre-tRNA? Could tRNA correspond to a union of 2 20-codon codes? Combining only 2 20-codon codes with 40 codons and tetrahedral code with 4 codons would give maximally 44-letter code and

the upper bound for tRNAs is according to Wikipedia 45! Dark proton model predicts 40 DtRNAs suggesting that only the 40 isosahedral codons contribute to DtRNA code. The additional tRNAs could result from homonymy. The code sequences could be seen as a hierarchical sequence $3 \rightarrow 2 \rightarrow 1$ in this framework.

An important implication is that there are many realizations of DtRNA and tRNA harmony: (Z_6, Z_4) , (Z_6, Z_2) , (Z_4, Z_2) and Z_2 could be either $Z_{2,rot}$ or $Z_{2,refl}$. This could explain the homonymy of mRNA-tRNA pairing via difference in the chords in turn affecting biochemical counterparts. Note however that the chords for tRNA must be a subset of chords for mRNA so that RNA harmony determines tRNA harmony apart from the three choices (Z_6, Z_4) , (Z_6, Z_2) or (Z_4, Z_2) giving rise to 3 different contexts. If DAAs code by 3-chords the AAs then this choice does not affect AAs.

4. What is the origin of 12-note scale? Does genetic code force it? The affirmative answer to this question relies on the observation that 1-1 correspondence between codons and triplets of photons requires that the frequency assignable to the letter must depend on its position. This gives just 12 notes altogether. Simple symmetry arguments fix the correspondence between codons and 3-chords highly uniquely: only 4 alternatives are possible.

Hence it would be possible to listen what DNA sequences sounds in given mood characterized by the bio-harmony: the allowed 3-chords of harmonies with symmetries are given in [L16] and I can provide the basic Python modules allowing to transform DNA sequences for given harmony to audible form using Garage Band program.

5. What disharmony could mean? A possible answer comes from 6 Hamiltonian cycles having no symmetries. These disharmonies could express "negative" emotions.

Remark: I proposed the theory of bio-harmony in the article [L16]. I have discussed the model of bio-harmony also in the chapter "Quantum Model of Hearing" [K91] of book "TGD and EEG" and in the chapter "Three new physics realizations of the genetic code and the role of dark matter in bio-systems" [K122] of book "Genes and Memes". The recent findings motivated writing a chapter including the previous results plus new results emerged during 2018.

4.2 What could be the basic principles of harmony?

It indeed seems that the idea about definition of notion of harmony in terms of Hamiltonian cycles makes sense.

4.2.1 Icosahedral harmonies

1. Chords (major and minor) are labeled by their basic tones and comes either as major or minor. Harmony in classical sense requires that the transitions from key to another take place by a small number of quints and that the piece does not wander too far from the major key, say C.

If quint corresponds to a step along the edge of the cycle in the direction of its orientation, the notion of tonal closeness corresponds to the closeness in the metric of icosahedron. For instance C, F, and G are commonly used keys in same piece and correspond to 3 subsequent points along Hamiltonian cycle. Note that the number of \sharp s of the key increases by one unit in standard direction and the number of \flat s by one unit in opposite direction.

2. It turns out that major and minor 3-chords and are mapped to each other in the orientation reversal for icosahedral path so that basic moods "happy" and "sad" in music have this orientation as a geometric correlate. The effect of orientation reversal does not actually depend on the icosahedral representation but is implied by quint cycle representation alone. C and half-octave $F\sharp$ defining the tritonus interval are the fixed points of the orientation reversal. Orientation reversal induces pairings ($C \leftrightarrow C$, $F\sharp \leftrightarrow F\sharp$, $G \leftrightarrow F$, $D \leftrightarrow B\flat$, $A \leftrightarrow D\sharp$, $E \leftrightarrow G\sharp$, $H \leftrightarrow C\sharp$. Quints of cycle correspond to the fourths of oppositely oriented cycle so that majors and minors are mapped to each other and one can say that the moods "happy" and "sad" have geometric correlates in the sense that majors and minors are transformed to each other in the reversal of orientation of the cycle.

The notion of harmony can be characterized in terms of numbers of basic 3-chords identified as faces of the icosahedron and their neighborhood relationship telling when corresponding chords are near to each other or vertex or face neighbours. The wall neighbours assignable to given edge are expected to be in very special relationship harmonically since they possess a common quint.

The basic classification is according to the number n = 0, 1, 2 of edges of cycle contained by them and the triplet $n = (n_0, n_1, n_2)$ for the numbers of faces of various kinds gives the first rough classification. 2-quint chords have common edge and thus two common notes with two 1-quint chords and are therefore natural intermediates in transitions between them. 0-quint chords are tonal loners having no edge neighbours turns out that they involve dissonances since they consists of three notes spanning length of 1 or 3/2 steps (say EFG, $EF \ G$ or $D \ EF$). Maximally symmetric harmony is an exception: 0-quint chords correspond to augmented chords of type $CEG \ with$ two major thirds.

The numbers of three different kinds of face neighbor pairs for the 12 edges of the path serve as an additional classification criterion in terms of the $p = (p_{1,1}, p_{1,2}, p_{2,2})$ for the numbers $p_{i,j}$ of different kind of edges. Note that the neighbor faces of an edge correspond to 3-chords, which possess two common notes and are in this sense close to each other. These numbers characterize the most natural transitions between the chords of the harmony. A further criterion is the distribution of these neighbor pairs along the cycle.

4.2.2 Why quints are near to each other harmonically?

The naïve expectation would be that frequencies near to each other (using half-note as unit) are close to each other. This is not true. Their simultaneous presence is experienced as dissonance. This probably has a neurophysiological correlate: in ear the hair cell groups detecting notes which are near to each other in frequency space are overlapping. This explanation does not however tell why the conscious experience is dissonance.

The distance measure for notes could be formulated in terms of distance defined as the number of quints connecting them. For quint the distance would be minimal. This measure applies also to chords and allows to understand the basic rule of classical harmony stating that harmonic transitions take place the chords related by quint shift of the basic note (adding either one \sharp or one \flat to the scale). Also the key changes can be understood using the same rule: consider the changes $C \rightarrow G$ and $C \rightarrow F$ as examples. Note that in this case the chords have common note.

One could of course question the assumption that it is possible to choose the shortest route. The notes obtained by quint scaling are not quite same in the two directions and means that \sharp is the inverse of \flat in well tempered scale only. Could it be that people with absolute ear are able to distinguish between the two slightly differing scales and experience notes of quint C-G as harmonically close when 1 quint connects them but as harmonically distant 11 quints in opposite direction connects them?

If cognition is p-adic, one can ask whether the notion of harmony can be formulated in terms of p-adic distance concept.

- 1. By octave equivalence the scaling by power of two means nothing so that the scalings by 3/2 are equivalent with scalings by 3 and the distance defined by 3-adic norm having values 3^k , where k is the number of quints makes sense. The distance defined as quints could be identified the absolute value of k along the quint cycle in the direction in which the distance is shorter. If so, the maximal distance is 6 units.
- 2. 3-adic measure of distance seems to be rather realistic. Quint corresponds to 1 unit distance. Half step corresponds to a distance of 5 units and 6 units defines the largest distance and corresponds to the tritonus interval which was forbidden by catholic church. Fourth (C-F) corresponds to 1- step in opposite direction and 11 steps in standard direction.
- 3. There is also a problem. Second (C-D) corresponds to 3 quints but third (C-E) corresponds to 4 quints and small third to 3 quints in opposite direction. Major third would thus correspond to a longer harmonic distance than second. This is a genuine problem, whose solution might

be provided by the extension of icosahedral scale to icosatetrahedral one bringing in one additional note which is very near to one of the icosahedral notes and is major or minor third of icosahedral note.

4. Could one use the number of icosahedral edges as distance between notes but not as a minimal distance along the Hamiltonian cycle but along a minimal edge path along icosahedron? The icosahedral measure of distance would be analogous to a distance between points of object along shortest route in space that it inhabits and depends on harmony characterized by the shape of icosahedral cycle. C and E (and also C and $F\sharp$) could be close to each other in some harmony and distant from each other in some other harmony. Icosahedral geometry would become an active determinant of the harmony.

To sum up, music seems to have both 2-adic (octave equivalence) and 3-adic (12-note scale by quint scalings) characters. The principle of tonal unity for classical music stating that modulations of key should not lead too many quints away from the basic chord would have 3-adic interpretation.

4.2.3 What could be the rules for building a harmony?

What guarantees good harmony when one has fixed the key/harmony/representation of particular Hamilton cycle?

1. One should pose conditions on the allowed transitions between chords. Are there principles would imply harmonic smoothness in geometric sense? Could the transitions occur only between chords with a common note? Or can one require a common pair of notes? Or can one require even a common quint. If so, 0-quint chords would become tonal hermits and could not be used at all. In practice their dissonant character has eliminated them in popular music and much of classical music too.

The standard quint and fourth transitions (say C to G and C to F) are basic examples in which there is only one common note between chords, and it seems that one cannot require more than this in the general case. Playing with the chords of bio-harmony however suggests that smooth bossa nova/jazz emotionally ambivalent mood is created if common pair of notes or even quint connects the neighboring chords. The rule is that only transitions between chords with same basic note are allowed. Obviously this is too stringent a condition.

- 2. Could 2-quint chords act as bridges between two 1-quint chords? For instance, for the maximally symmetric harmony consisting of disjoint groups of chords related by half-octave scaling the augmented chords ($F^{aug} = FAC^{\sharp}$ and G^{aug} mapped to each other both by half-octave scaling and reversal of orientation could serve as mediating bridges.
- 3. Could harmonic transitions take place only between neighboring faces of icosahedron (see http://tinyurl.com/ns9aa) or should it only tend to minimize the quint distance between subsequent chords (this distance vanishes if they have a common note)? For the 0-quint distance harmony, the harmonic movement could be seen as a path in dodecahedron which is dual of icosahedron. In the most general case the transition can take place to both wall and vertex neighbors, whose total number is 3+3=6. In this geometric picture harmony and melody could be seen as duals of each other.

Dodecahedron is dual of icosahedron and one can ask whether the harmonic motion could correspond to a path at dodecahedron. The vertex of dodecahedron is pentagon and has 3 neighbours (see http://tinyurl.com/mp5d8). The above argument gives 3 + 3 > 3 neighbors for the triangle of icosahedron. Are the wall neighbors of icosahedral triangle mapped to nearest neighbor vertices? If so then transitions between vertex neighbor triangles should correspond to longer steps at dodecahedron. By the duality triangles of icosahedron correspond to three pentagons associated with the vertex of dodecahedron. The rule that comes in mind is that steps can occur between vertices for which the 3-pentagons have one or 2 common pentagons.

Note that if the dodecahedral path is Hamiltonian cycle, it is unique apart from isometries of dodecahedron and would define a unique chord progression. One can - and of course must

- allow self-intersecting harmonic paths. The condition that there exists a basic chord from which everything begins and to which everything ends implies that closed but in general self-intersecting path is in question.

- 4. An interesting test for the idea would a computerized generation of random chord sequences satisfying at least one common vertex rule and finding whether they are aesthetically appealing. Incidence matrix (see Appendix) for the icosahedral (and tetra-icosahedral) triangles wholes element tells how many common vertices two chords have have allows computational construction of the allowed chord sequences as random sequences.
- 5. For most harmonies 0-quint chords involve dissonances induced by three nearby notes (such as $CC \ddagger D$) and spanning large number of quints (maximally symmetric harmony has 2 0-quint chords, which do not have dissonances and second harmony with 2 reflection symmetries has no 0-quint chords). Also maj7_, $sus4_+$, and 6_ 1-quint chords have half-note dissonances. Dissonances as such are however not un-sesthetical. For instance, Bach used them to create a deeply melacholic feeling.

4.2.4 More general notion of harmony

The notion of harmony discussed in previous section is rather conservative and certainly too stringent.

- 1. 0-quint rule is too restrictive already in chord based music. For instance, the downwards progression Am, G, F, E appearing in Spanish music and music forms like Passacaglia would have chords with 1-quint distance. Hence one must consider also a weaker notion of harmonic chord progression according to which this distance is minimized and below some maximum value k_{max} . One quint would define the smallest non-vanishing maximal distance. One can define incidence matrices for chords with *n*-quint distance. The incidence matrices with different values of k_{max} have disjoint sets of non-vanishing elements and the total incidence matrix is their sum.
- 2. Even this is not enough. The direction of step matters for scales (major-minor difference) and it seems to matter also for chord harmonies. The inverse E, F, G, Am of the above mentioned progression does not sound harmonic in the same Am key. The impression of achieving the goal/ending down to something dictated by fate is lost.

Instead of EFGA one often has $EF \sharp G \sharp A$ as a melodic progression and with E, B7, E7, Am as a chord progression having only 0-quint steps. The rule seems to be that 1-quint steps are possible only downwards in minor harmony, whereas upwards steps are 0-quint steps. Climbing slowly upwards by 0-quint steps and falling down by 1-quint steps! Could this "gravitational analogy" serve as a metaphor?

Also the number of n-quint steps between chords matters. The larger this number, the closer the chords are. Two 0-quint steps means that chords have two common notes, 1 0-quint stet that they have single common note. The two 1-quint steps for downwards step Am - G are between 3rd and 1st $(C \to G)$ and 5th and 3rd $(E \to H)$. For upwards 0-quint steps E - H71-quint steps are between 5th and 5th $(H \to F \sharp)$ and 1st and 1st $(E \to H)$. For $H7 \to E$ the reversals of these steps occur. For $E7 \to Am$ one has 3 1-quint steps: (the reversals 1-quint steps $E \to A$ and $H \to E$ steps and 1 quint step $D \to A$. The laste step seems to be the smallest one in a well-defined sense.

For G-F step the number of 1-quint steps is one $(C \to C)$: same is true for F-E step (A and E).

Using geometry language, for chords connected by 1-quint step(s) the mutual orientation of corresponding triangles with shape defined by the intervals involved matters since the number of 1-quint steps depends on the orientation.

The notion of chord harmony does not apply as such to polyphonic music with several simultaneous melodies unless on can say that it involves definite chord sequence. One could try to apply the concept of harmony for melody also in this case. The challenge is to guess what harmony for melodies could mean.

- 1. A conjecture inspired by the genetic code is that the codons defining the allowed melody notes associated with a given chord are in one-one correspondence with the triangles at the orbit of the triangle associated with the chord under the group Z_6, Z_4 , or Z_2 characterizing the chord as a counterpart of amino-acid. In table 11.2 the Z_6 orbits are represented as groups of 6 similar chords (2 for 1-quint chords and 1 for 2-quint chords). In table 11.3 for Z_4 chords the groups consist of 4 similar chords and in the tables 11.4 and 11.5 for Z_2 harmony the chord groups consist of 2 similar chords.
- 2. The first guess is that the union of the notes of these chords could define the chords, whose notes are compatible with chord in the time scale shorter than the duration of the chord. Note that same triangle can appear at orbits of several chords since the orbits of each group span entire icosahedron.

If the note lasts for a duration of several chords, the notes must be consistent with all the chords involved. The rule would explain why fast chromatic sequences (in the scale of chord duration) sound harmonic but slow chromatic sequences do not.

For melodies in Am key EFGA is rare and does sound harmonic being often replaced with $E, F\sharp, G\sharp, A$. As far as intervals are considered, this is the inversion $D\sharp, F, G, G\sharp$ of AGFE shifted upwards by 5 quints. Could one regard progressions (say Am, G, F, E) breaking the strongest rule for chord harmony as polyphonic progressions satisfying the rules for polyphonic progressions.

To conclude whether the DNA inspired notion of harmonic is realistic, one should understand how the sub-groups Z_n , n = 6, 4, 2 of the isometries of the icosahedron and defining the genetic code act on the Hamiltonian cycles.

- 1. The simplest guess is that these groups are represented as subgroups of Z_{12} (also a subgroup of icosahedral group) representing quint cycle. Z_n generator would shift the basic note of the chord by 12/n that is 2, 3, 6 quints.
- 2. Z_n maps chords of same type to chords of same type only if it is a rotational symmetry of the harmony. For instance, the action of Z_6 (see Fig. ??) on icosahedron allows doublet orbit consisting of X aug type chords, since Z_3 maps 2 0-quint triangles in the middle of the figure to themselves and reflection group Z_2 permutes them. 6-element orbits consist of either minor or major chords. More generally, the inspection of the cycles shows that the cyclic orbits of triangle under Z_n correspond to the orbits of corresponding subgroups of icosahedral group.
- 3. $Z_2 refl$ maps the shape of the chord to its mirror images and so that the character of the chord can vary along Z_4 orbits. The rules are $(M \leftrightarrow m)$, $(6 \leftrightarrow 7)$). For other chords the character is unaffected.
- 4. Any subgroup of icosahedral isometry group $A_5 \times Z_2^{refl}$ having 120 elements must map chords to chords (faces to faces). In particular any Z_n) even if it is not a symmetry of a particular harmony. The character of the chord is not preserved and the number of quints can change. Whether these maps have interpretation in terms of music remains unclear.

These considerations forced me to finally realize that the 3 groups Z_6 , Z_4 , and Z_2 that I had assigned to 20+20+20 DNA codons in the model of the genetic code are nothing but Z_6 -, Z_4 -, and Z_2 -symmetric Hamilton cycles! The numbers of amino-acids associated with various types would be 3+1=4, 5, and 10 (with empty amino-acid included). Tetrahedral extension based on gluing of tetrahedron at triangle corresponding to X6 type chord possessed by all Z_2^{refl} type harmonies would give 3 additional real amino-acids giving altogether real 22 amino-acids as required. This has implications.

1. All 11 Hamilton cycles are realized separately as DNA level harmonies. Amino-acid level harmonies would correspond to selection of three Hamiltonian cycles, one for each Z_n .

2. To get something one must give something away. Now one must give up the idea that (4, 8, 8) is special via the corresponding of n-quint property with polarity properties. This is a pity, since just taking this correspondence seriously led to the extension of the icosahedral cycles to tetra-icosahedral ones. Fortunately, the extension itself makes sense for all Hamiltonian cycles.

To understand the action of symmetries one must look how the groups Z_n act on C major chord.

- 1. Z_2 would induce half-octave shift and map C = (C, E, G) to $F \sharp m = F \sharp, B\flat, D\sharp$). The assignment of $F\sharp$ -tritonus with C note sounds strange in the ears of harmonic conservatives.
- 2. Z_4 would map C = (C, E, G) to $A = (A, C\sharp, E), F\sharp = (F\sharp, B\flat, C\sharp)$ and $D\sharp = D\sharp = (D\sharp, G, B\flat)$. These would span 8 notes since $E, G, B\flat, C\sharp$, appear twice. Note that C, E, G, A are the notes assignable to the tetrahedron in the extension of the scale and pentatonic scale corresponds to C, D, E, G, A. Z^4 orbit does not contain the notes $DFG\sharp H$ but the orbit of G chord does so. The orbit of C chord plus G7 chord alone define the notes of C major key.
- 3. Z_6 would map C and E to the same "impressionistic" 6-note scale consisting of 6 whole notes. Together with the Z_6 image of G one obtains all 12 notes of the scale.

4.3 Harmony and biology

4.3.1 Could harmonic principles be realized in biology?

The basic idea behind icosahedral harmony is the connection with biology suggested by the fact that the number of icosahedral basic chords is 20 which is also the number of amino-acids. Actually there are two additional amino-acids and one ends up to an extension of genetic code by attaching to icosahedron a tetrahedron and thus adding one vertex more. The number of DNA codons increases from 60 for icosahedral code to 64 for the real code. The triangle along which icosahedral and tetrahedral amino-acids are attached together corresponds to punct coded by stopping codons.

Could the application of harmonic principles to biology make sense? The triangles of the icosa-tetrahedron correspond to amino-acids or DNA codons for the amino-acids coded by 20 codons in question.

- 1. The strictest rule stating that there must be common edge of Hamiltonian cycle between the amino-acids/DNAs cannot be satisfied since 0-quint amino-acids/DNA codons would be total loners and effectively eliminated from biology.
- 2. The weaker "common edge or vertex" rule could however make sense. A given codon in the group of 20 codons/amino-acid could be followed only by 3+3 different nearest neighbor similar codons/amino-acids. If the first amino-acid is fixed there would be only 6^N N-amino-acid sequences instead of 20^N sequences. This kind of symmetry would have been probably observed if exact but one can ask whether harmonic pairs could more probable than completely random pairs.
- 3. A more plausible formulation is obtained by restricting the rule to the level of DNA sequences and generalizing it so that it applies also to transitions between harmonies with different symmetries so that a transition between corresponding amino-acids is induces.
- 4. An even weaker formulations states that the transitions occur with highest probabilities between codons/amino-acids having shortest quint distance.

A natural conjecture is that evolution favors the generation of harmony even in the very concrete sense that proteins defined by harmonious chord sequences for bio-harmony are emerge as what Darwinist would call the fittest ones.

Icosahedral water clusters made from tetrahedra

The obvious questions concern the concrete realization of the icosahedron - or more generally icosahedral symmetries. One should also understood what the attachment of tetrahedron to icosahedron means (note that tetra-icosahedron is not the same thing as icosi-tetrahedron, which is Archimedean (not Platonic) solid (http://tinyurl.com/6onvry)). What comes in mind is attachment of an information molecule to the receptor of cell membrane.

Water molecules form icosahedral structures and - what is amazing to me - Plato regarded icosahedron as a symbol of water (http://tinyurl.com/y7bo9omm4a3378c13bcad793a52213a325db7db0-30. html)! The page "Water structure and science" of Martin Chaplin gives illustrations about the rather complex icosahedral structures. Icosahedral structures of size 3 nm can be formed from 20 14-molecule tetrahedral water molecule clusters containing 280 water molecules altogether. They can also consists of cyclic pentamers and tricyclo-decamers and also from bi-cyclo-octomers. The 20 tetrahedrons correspond to the faces of the icosahedron and tetra-icosahedron would be formed as tetrahedron is glued to the icosahedron along one of the faces.

The bioharmonies could manifest themselves already in the structure of water molecules. Second - more plausible - option is that they differ only at the level of the magnetic body of the biomolecule. Bio-harmony suggests that 3 radial magnetic flux tubes or flux tube pairs emerge from each water tetrahedron. Hamilton's cycle could be realized as a flux tube connecting the vertices of the icosahedron and assigning the quint cycle to the cyclotron frequencies (magnetic field strengths).

This scenario raises several questions related to the pairings between ordinary DNA/aminoacids, their icosahedral representations, and their representations as dark proton sequences.

Suppose that one takes seriously the idea that genetic code is represented as dark proton sequences with the states of dark protons formed from 3 quarks representing DNA and RNA codons, amino-acids, and even tRNA.

- 1. How dark proton sequences are realized? Could one regard them as icosahedral bound states of 20 dark protons? Or with a Hamiltonian cycle consisting of penta-quarks and representing dark nuclear string? Could the icosahedral representation as dark nucleus consisting of 20 dark protons and dodecahedral representation as dark nucleus consisting of 12 dark 5-proton states be dual ways to interpret the state or are they different states related duality. Equivalence of the two pictures would require that dark protons are color excited and in an entangled state.
- 2. Could dark proton sequences correspond to sequences of icosahedrons connected by flux tubes connecting the dark protons assignable to the dark proton states assignable to the faces of the icosahedrons? These dark nuclei would be definitely different from those possibly associated with the Hamiltonian cycle.
- 3. What about the tetrahedral part of the genetic code in relation to dark protons sequences? What dark proton states could tetrahedral codons and amino-acids correspond? Are they associated with water tetrahedrons representing the faces of the water icosahedron? Note the amusing numerological co-incidence that the vertices of tetrahedron have 3 quarks associated with them and those of icosahedron 5 and that the quint for icosahedral edge is replaced with third for tetrahedral edge.
- 4. Could the chords correspond to triplets of cyclotron frequencies for quarks associated with the three flux tubes emanating from the each face of the icosahedron? Could the breaking of the rotational symmetry from SO(3) to SO(2) now actually $Z_3 \subset SO(2)$ assumed to occur for dark proton states correspond to the reduction forced by the triangular geometry?
- 5. How DNA -amino-acid correspondence is represented at the level of dark DNA? The correspondence should be realized in terms of magnetic flux tube triplets connecting dark DNA and dark amino-acid and resonance condition would be essential. When the chords at the orbits of Z_n are of same type, different DNAs correspond to the same chord but with different key. When Z_2^{refl} is involved, the two chords at the orbit are not of same type (note the analogy with left and right-handed biomolecules). The only manner to circumvent the problem is to assume that the chord associated with amino-acids magnetic body is that of

DNA. Information is not actually lost in translation, it is only transformed to different kind of information perhaps representing correlates of emotions.

6. Could the non-representability of one of the Z_6 codons as amino-acid have an analog?

The fiber space having icosahedron as a base and 3 copies of icosahedron assigned with 3 regions of icosahedron corresponding to Z_n , n = 6, 4, 2, defines a formal geometric representation of genetic code. Could this space represented in terms of water icosahedra?

- 1. Perhaps one should first try to identify the function of water icosahedrons. The first guess is that they serve as local bridges between dark DNA/amino-acid sequences and ordinary DNA/amino-acid sequences. This would suggest that dark proton of dark DNA forms a flux tube connection with the face of water icosahedron dictated by the state of the dark proton: this would take place by flux tube reconnection and cyclotron resonance. Water icosahedron in turn couples with the DNA/amino-acid like DNA conjugate codon with codon so that kind of double helix is formed.
- 2. What about the pairing of ordinary DNA/amino-acids and water icosahedrons? Water icosahedron has size of about 3 nm. The size of single DNA codon is about 1 nm. Single codon corresponds to a twist of $3\pi/5=36$ degrees, an angle closely related to Golden Mean. If the radius of the helix consisting of water icosahedrons is above some minimal radius which is easy to estimate from an equation for the helix. There are 10 DNAs per L(151) = 10 nm and they correspond to a total twist of $3 \times 2\pi$. Therefore the twist angle is $\Delta \Phi = \pi/5 = 36$ degrees for single codon and corresponds to a distance of L(151)/10 = 1 nm). From this one has equation for DNA and icosahedron helices as $z = k\Phi$, $k = h/(6\pi)$, h = L(151) = 10 nm (radii are constant). Single codon corresponds to a distance $s = \sqrt{dz^2 + R^2 d\phi^2} \Delta \Phi$ along the water icosahedron helix of radius R accompanying DNA helix. One must have $s \ge L = 3$ nm defining the size of water icosahedron in order to avoid overlap. $\Delta s \ge L = 3$ nm gives the condition $R \ge 10 \times \sqrt{2}/(3\pi)$ nm $\simeq 1.5$ nm.
- 3. If the representation of genetic code is possible, do the fiber icosahedrons correspond to subsets of faces of the icosahedron itself? Or do they correspond to faces the of icosahedrons in some manner associated with the amino-acid icosahedron. Direct attachment is not possible but association could be achieved by connecting the icosahedrons by flux tubes with the tetrahedron at the ends of flux tubes identified as representation of the same amino-acid. This kind of structure with three icosahedra emanating from a given icosahedron could be iterated and one would obtain a fractal structure representing a binary tree. Could the water icosahedrons organize in this manner to form larger clusters?

What could be the physical correlates of Hamilton cycles representing harmonies?

- 1. Could Z_6 , Z_4 and Z_2 orbits associated with the Hamiltonian cycles be realized even in the structure of water icosahedrons? Could they be realized as structures formed by the water tetrahedra and correspond to three separate regions of these icosahedral structures? Could one assign to each of the three regions of icosahedron icosahedron such that the attached icosahedron decomposes to the orbits associated with that particular region? Could the hierarchy of the icosahedral symmetry breakings have a direct counterpart at the level of the icosahedral structures formed by water molecules? My intuitive feeling is that the answer to these questions is negative.
- 2. Could Hamiltonian cycles be realized only at the level of dark photons as quint cycles defined by closed flux tube giving rise to dark nucleus, that is in terms of 3-chords formed by dark photons propagating along flux tubes emanating from the icosahedron? If cyclotron frequencies of dark quarks are in question then the magnetic fields associated with the flux tubes would define the notes.
- 3. The breaking of Z_2^{refl} symmetry is of special interest since it could serve as a prebiotic analog of chiral selection and could relate to dark variant of weak physics with effectively massless weak bosons in nano-scales. This would require dark magnetic body. Half-octave scaling

is second broken symmetry and would have also an analog in Z_2^{refl} variant of icosahedron. Note that 256 variants of the bio-harmony are predicted and could be realized for magnetic body naturally. The presence of electric fields at flux tubes is possible and if the electric and magnetic fields are non-orthogonal, U(1) instanton density is non-vanishing and induces parity breaking. Is this breaking associated with Z_2^{refl} only?

Clathrin molecules as icosahedral structures

Clathrin (http://tinyurl.com/y8ho23zf is a structure appearing at the ends of microtubules and necessary for the transmission of signals between the presynaptic and post-synaptic neurons. Clathrin consists of triskelions - kind of triangular structures with three spiral like legs and having as symmetries the rotational symmetry group Z_3 of equilateral triangle. Clathrins can form hexagonal planar lattices and pentagonal icosahedral lattices consisting of 12 pentagonal faces - the number of vertices of icosahedron. One can associate 3 triskelions with each pentagonal face: this makes $12 \times 3 = 36$ triskelions altogether. One can regard the centers of the 12 faces as vertices of icosahedron and assign to this structure 20 faces, which are triangles formed by 3 pentagons.

If proteins and other molecules attach to the faces of clathrin, one can ask whether each icosahedral triangle of this kind has an address formed by the three notes associated with it and serving as a password: only those molecules, which "know" this password can attach to the face. The realization would be in terms of three U-shaped magnetic flux tubes emerging from the 3 pentagonal faces representing the three notes as frequencies of dark $h_{eff} = n \times h$ cyclotron photons with ELF frequencies but energies of bio-photons (in visible and UV range). The binding of the molecule to the face triangle would be preceded by reconnection of U-shaped flux tubes of the clathrin and molecule, by a resonant interaction by dark cyclotron photons, and by an h_{eff} reducing phase transition bringing the molecule to the face.

Microtubules as music instruments?

It has become clear that microtubules have a central role in biology, neuroscience and perhaps also in consciousness theory and the evidence that they are quantum coherent systems is accumulating. Could music metaphor could help to understand microtubules?

- 1. Tetra-icosahedron has 13 vertices with the added vertex representing one note- say E- in C-key as note with slightly different frequency to resolve the basic problem of rational number based 12-note scale (12 quints give slightly more that 7 octaves). Intriguingly, microtubules consist of basic structures consisting of 13 tubulins with 2 states defining bit: could these bit sequences define representation for the 3-chords and thus representation of sequence of DNA codons and realization of genetic code.
- 2. The recent TGD inspired model of microtubules [L19], [K88] was inspired by the findings of the group of Bandyopadhyay (see http://tinyurl.com/ze366ny) [J1], [J24] relies on the general vision about bio-communications and control as being based on dark cyclotron photon radiation travelling along magnetic flux tubes.

These dark photons have a universal energy spectrum in the range of bio-photons (visible and UV) to which they transform as the value of $h_{eff} = n \times h$ reduces to its standard value. Frequencies would span a wide energy range but EEG frequencies would be of special importance since they would also couple to acoustic vibrations. The precise value of the energy scale of cyclotron photons would be determined by the strength of the magnetic field at flux tube.

- 3. Frequency modulation would be the general manner to code information in living matter: "whale's song" would be a good metaphor for it. This is assumed in the model for cell membrane as generalized Josephson junction: the modulation would be now induced by the variations of generalized Josephson frequency by variations of the membrane potential. Also microtubules have been proposed to base their communications on frequency modulation.
- 4. The first possibility coming in mind is that the continually varying microtubule length codes for the frequency [L19]. The change of the frequency by say octave would however require

quite fast and large variations of microtubule length. Neither does this realization conform with the idea that the state of single tubulin corresponds to frequency. Microtubule length could also code for the length of the music piece represented by the microtubule serving as a music instrument or musician at the bio-molecular level. It would also the number of microtubular units and thus the size of the orchestra consisting of 13-units.

- 5. Another possibility inspired by the proposal is that magnetic flux tubes form an analog of 3-D grid ideal for communication purposes using 12-note (or actually 13-note) system as a code equivalent with genetic code. Also microtubules would involve three kinds of flux tubes [L19] defining coordinate grid of cylindrical coordinates: longitudinal, radial and those which rotate along the microtubule. Radial flux tubes would be ideal for communication using 13-note system as a realization of genetic code.
- 6. 13-note system as cyclotron frequency spectrum for given value of h_{eff} would be determined by the spectrum of the magnetic field strengths going transversally through the microtubule and each tubulin would correspond to one particular note represented as magnetic field strength. The system would be highly analogous to the system formed by hair cells in cochlear. Note would indeed characterize single tubulin molecule rather than entire microtubule as required if one wants to code chords using the two tubulin conformations as a bit. Tubulin conformation would determine whether the tubulin serves as a sending/receiving antenna or not.
- 7. Melody in 12-note system can be interpreted as a discretized version of frequency modulation with frequency being piece-wise constant in time. Obviously the 13 bit sequences defined by tubulin conformations code for the chords of rational 12-note scale involving a representation of one particular note (the third note of the Pythagorean scale) with two slightly different frequencies in order to avoid problems caused by the rational number ratios of frequencies. 13th bit could also serve as a kind of period. Also chords could be coded up to a chord with 13 notes so that microtubules would have quite a high representative power.

The is an objection against the model.

- 1. One could argue that a unit consisting of 13 tubulins allows only one octave to be represented. One can of course assume that the magnetic field strengths for subsequent units differ by octave. What makes this interesting is that microtubules allow two variants, called A and B. B type microtubules appear as 13-units since microtubular surface has a gap so that the helical symmetry is broken. For variant A, which is not found in vivo or in vitro, 13-units integrate to form longer helical units. This is assumed in Penrose-Hameroff model and the experimental absence of A type microtubules is one of the basic objections against Penrose-Hameroff hypothesis.
- 2. The TGD inspired proposal is that A type microtubules corresponds to a critical state having therefore an enhanced symmetry and long range correlations: criticality would explain their experimental absence. The experiments of the group of Bandyopadhyay support that the critical state is induced by a resonant excitation at specific AC frequencies [L19]. Long range correlations would mean enchance helical symmetry - that is fusion of several 13-units to form a longer helical structure. This structure would allow an interpretation as a structure with frequency spectrum of several octaves represented coherently in terms of magnetic field strength: the 10 octave span for hearing would mean the integration of 10 microtubule units meaning length scale of order micrometer assuming that tubulin size is of order 10 nm.
- 3. If the field strength for subsequent units differ by octave, one can argue that for variant B various octaves play their own music without knowing of each other and thus without coherence. In state A they would play together forming something analogous to orchestra or choir.

If the octave is same for all 13-units, the phase transition would involve octave scaling of the magnetic field strength at the flux tubes. The flux tube radius should suffer p-adic scaling by an integer number of half-octaves, which makes sense if one accepts p-adic length scale hypothesis. This kind of phase transition have been proposed as candidate for a basic step of energy metabolism since they can store or liberate cyclotron energy as metabolic energy.

4. Microtubules could directly couple with both DNA and clathrin molecules if they represent 12 note system as a resonant system able to receive the radiation with corresponding frequencies. 12-note system and the 3-chord system associated with it could define universal communication code allowing communications between DNA, proteins, and microtubules.

To sum up, 13-note extension of 12-note system could be seen as a realization of the genetic code in terms of frequencies. The existence of kind of realization was obvious from the beginning and I proposed it in the model of microtubules as quantum antennas during the first years of TGD inspired theory of consciousness [K83]. Discovering the precise realization of the proposal has however required time.

4.3.2 Could biology help in the understanding of musical harmony?

One can also ask whether biology could provide ideas about the notion of harmony. Could icosatetrahedral harmony possessing additional 13th note very near to the fourth of basic major chord provide a better view about harmony?

- 1. The extension of the ideas about harmony to the case of isosatetrahedron is a non-trivial task. If one assumes that the extended Hamiltonian cycle is obtained by deforming tetrahedral Hamiltonian cycle according to the proposal made earlier, one ends up with a problem since the cycle makes a wedge while making a side track of two steps via the new vertex. The two steps must give one quint so that the new vertex must correspond to either minor or major third of note where it started from (and ended to). This would add to the scale a chord of type CGD a chord of type CEG or $CE \flat G$ (plus two other chords containing major or minor third. Depending on the orientation of the cycle one would obtain major or minor key. The remarkable feature of icosahedral harmonies is that they often lack a unique basic chord. Could it be that the addition of tetrahedron breaks the symmetry and fixes the key?
- 2. The added third could be slightly different from the icosahedral third and this could allow to resolve the problems due to the fact that quint cycle does not quite close $((3/2)^{12} = 2^{7} \text{ does not hold true exactly.}$ The problems can be of course solved by introducing well-tempered scale defined in terms of powers of $2^{1/12}$: for this choices the topologically induced by these scalings is same as that induced by real topology in frequency space. Algebraically this means introduction of an algebraic extension of rationals. The problem is that persons with absolute ear prefer rational number based scale and experience tempered scale as unaesthetic.

The problem with 3-adic distance of notes was already described: the distance is 4 quints for major third (C-E) and 3 quints for minor third (C - Eb). A smaller distance is suggestive for major third.

- 1. The proposed extension of the scale would break symmetry by bringing a third which is indeed nearest neighbor of the basic note plus two other notes, which are in corners of a *1-quint* triangle in the biological realization. Thus chord CEGandchord containing EG and third note would be introduced.
- 2. Using the general results one can readily find the possible extensions of harmony if one assumes that both major and parallel minor with same number of \sharp s or bs are obtained. The chord chosen for extension must be CGA, which an be seen as part of C6 or Am7. If the added vertex corresponds to E one obtains C = CEG, Am = CEA, and the GEA which is part of C6/Am7 as also the lost chord. In amino-acid analog CGA would become "empty" amino-acid, punct, and would be replaced with GEA contained also in C6. One can perform this kind of realization for all 11 harmonies and/or their mirror images. The modification induces symmetry breaking and defines a key which is otherwise not obvious for the icosahedral harmonies. Also half-octave symmetry is broken.
- 3. One can perform the modification also for the inverted harmony. The transformation to reverted harmony $X \to Y$ corresponds to $X7 \leftrightarrow Y6$ and vice versa so that the presence of X7 type chords in harmony guarantees the existence of the required type extension in the reverted harmony. One can of course define extension also using X^7 type chords. This would generate besides CEG two dissonant chords of type $GEE\flat$ and $CEE\flat$.

- 4. In maximally symmetric harmony (2, 12, 6) with 6-fold rotation symmetry, there are as many as 6 ways to perform this modification so that any note of the 6-note scale spanning "impressionistic" octave can define the key. The key is either F, G, A or $Dm, E, F \ddagger m$. The harmony contains however no X7 type chords and since the transition to the reverted harmony acts as $X6 \leftrightarrow Y7$, it does not allow a modification generating both major and parallel minor. There are also other harmonies possessing no X6 type chords such as (2, 12, 6) and bio-harmony (4, 8, 8) with 2-fold rotational symmetry so that the extension in the simplest form can be performed only for their reversals.
- 5. For the two harmonies with 4-fold reflection symmetry there are 2 ways to perform the modification and modified chords are related by half-octave shift. With the conventions of Table ?? the modification introduces key which is either A ($F \ddagger m$) or $D \ddagger$ (Cm) for both harmonies (second one is bio-harmony (4, 8, 8)).

4.3.3 About the interpretation of bioharmonies

1. How ideas about harmony evolved?

A brief summary about the evolution of the notion of bio-harmony is in order.

- 1. The first guess [L21] was that amino-acids could be understood as chords of icosahedral bio-harmony characterized by 3-tuples (3, 10, 7), where the integers tell the numbers of icosahedral triangles with 0, 1, or 2 edges of the Hamiltonian cycle and identifiable as 3-chords with 0, 1, or 2 quints. The interpretation was that 3 0-quint chords correspond to 3 basic polar amino-acids, 10 1-quint chords to the 10 non-polar amino-acids, and 7 2-quint triangles to the 7 polar and acidic polar amino-acids. It turned out however that (3, 10, 7) does not appear as Hamiltonian cycle although it satisfies the necessary conditions.
- 2. I introduced also a model of genetic code motivated by the properties of the code table suggesting that 60 DNA codons are grouped into 3 groups of 20 codons. The idea that DNA codons coding for a given amino-acid form an orbit of a subgroup of icosahedral group with order which is not smaller than the number of these DNAs and has the aminocid at it. Three subgroups Z_6, Z_4 , and Z_2 would predict 3 amino-acids coded by 6 codons and two amino-acids coded by 1 codon, 5 amino-acids coded by 4 codons, and 10 amino-acids coded by 2 codons. The total number of codons would be $3 \times 6 + 2 + 4 \times 5 + 10 \times 2 = 20 + 20 + 20 = 60$ rather than 64. The number of doublets is 10 instead of 9. Could one Z_2 orbit corresponds to punct coded by two stopping codons? But what about the codon triplet associated with Ile? Something is clearly missing.

There is also second problem: a really realistic model of genetic code should include also 21st and 22nd amino-acids (Pyl and Sec). Pyl or pyrrolysine is modification of Lys and is basic polar amino-acid so that the number 3 of basic polar amino-acids increases to 4. Contrary to the original naïve extrapolation Sec (selenocystein) is acidic polar rather than non-polar so that the number 2-quint triangles increases from 7 to 8. For the properties of amino-acids see http://tinyurl.com/y8b7fumq. The notion of hydrophobicity is discussed at http://tinyurl.com/9qr8e7q).

3. The solution of the problems came from the extension of icosahedral code with tetrahedral code bringing 4 additional codons and 3 amino-acids assigned with the external faces of the tetrahedron (Ile, Pyl, and some standard non-polar amino-acid), and increasing the number of stopping codons from 2 to 3. This gives 60+3+1=64 codons but one should code also Pyl and Sec. The solution of the problem would be that stopping codons code also these under some conditions. Are DNA codons or their mRNA counterparts pairing with tRNAs - perhaps their magnetic body - modified somehow?

For instance, Pyl and Sec could correspond to icosahedral codons before fusion. After fusion they cease to be coded - most naturally because the group orbits containing punct are replaced with those associated with tetrahedron. The 3 ordinary amino-acids represented by tetrahedron are Ile, 1-quint amino-acid and 2-quint amino-acid. As fusion is broken temporarily Pyl and Sec are coded.

- 4. The geometric correlate for the fusion of the codes is gluing of tetrahedron to icosahedron along one face which corresponds to "empty" face identifiable as punct coded by stopping codons. The icosahedral Hamiltonian cycle (4, 8, 8), which exists as two variants, is extended to (4, 10, 8) with two new amino-acids.
- 5. The music analogy for the fusion of tetrahedron is symmetry breaking bringing in a definite key by introducing the major and minor chords as 1-quint chord (but with 2-edges since tetrahedral edges correspond to major and minor thirds).

2. Understanding the misunderstanding

This was the picture as I started to work again with the notion of bio-harmony. Just when I thought that I understand the notion, I realized that something very essential is missing and even wrong.

- 1. One could argue that the assumption about the correlation of forms of amino-acid polarity with character of Hamiltonian cycle leading to (4, 4, 8) identification is ad-hoc: why not allow all harmonies? One can also wonder whether the group structure behind the genetic code leading to the identification of sets of DNA codons coding for a given amino-acid as orbit of the corresponding triangle can be totally dependent on the group structure emerging from the construction of the Hamiltonian cycles.
- 2. The question whether the group structures associated with genetic code and with the Hamiltonian cycles might have something to do with each other leads to the realization of the obvious: the groups involved are the same: Z_6 , Z_4 , and Z_2 ! The symmetries of DNA are the symmetries of cycles. DNA code would be inherent to the Hamiltonian cycles, and the triangles of the icosahedron representing the harmony would correspond to DNA codons! 20+20+20 icosahedral triangles to 60 genetic codons and 4 icosahedral triangles the remaining 4! The three 20-plets corresponds to 3+1 amino-acids coded by 6 (resp 2) codons, to 5 amino-acids coded by 4 codons, and to 10 amino-acids coded by two codons.

By direct inspection of the illustrations of the appendix one can indeed convince oneself that the groups in question map chords to chords of same type and one obtains appropriate number of orbits. This of course follows from group theory alone.

3. One must give up the assumption that the integers $n = (n_0, n_1, n_2)$ correspond to the numbers of the basic polar, non-polar, and polar and acidic polar implying that only n = (4, 4, 8)would define bio-harmony. All Hamiltonian cycles with symmetries define bio-harmonies and both Z_2^{rot} and Z_2^{refl} define Z_2 type bio-harmonies assignable to 10 amino-acids coded by 2 codons. This is somewhat frustrating outcome, since just this correspondence served as guideline leading to the extension of the icosahedral code. The extension as such is however independent of this identification and needed in order to get the 4 missing DNA codons and to understand the coding of 21st and 22nd amino-acids Pyl and Sec.

What do the Hamiltonian triplets n then correspond? Harmonies correlate with moods in music: maybe the serve as mathematical correlates for emotions and moods.

- 4. Harmonies are not for amino-acids but for DNAs coding them. One can however identify amino-acids as specific triangles the orbits and the chords associated with the amino-acids define much more restricted notion of harmony involving one representative of each basic type of chord. Perhaps the additional chords correspond to modulations of the harmony.
- 5. The rules of harmony generalize as such to transitions between DNA codons regarded as chords. If chords are near to each other with respect to the distance measured as quints, the transition between the chords respects harmony. One must think that DNA codons form a singular fiber space such that the union of fibers for type n gives the space of 20 amino-acids. The "gauge group" Z_n acting in the fiber is different in the 3 regions of the amino-acid space and the number of elements in the fiber is factor of n actually equal to n for $n \neq 6$ and having values 6 and 2 for n = 6. Each choice for the 3 Hamilton cycles of type Z_n , n = 6, 4, 2 defines a variant of this fiber space. The distance along the fiber isomorphic to the space of amino-acids is measured as minimal quint distance.

Note that the DNA codons for two different variants of the fiber space need not define same kind of chord so that also given amino-acid can correspond to several different chords. It is enough that the notes of the chords are specified - as they indeed are. The Z_n , n = 6, 4, 2 in turn can correspond to any Hamilton cycle with symmetry Z_n so that for n = 1, 4, 2 one can have 1, 2, 3 + 5 = 8 different fiber spaces. The hierarchy of Fibonacci numbers is involved. A hierarchy of symmetry breakings is highly suggestive and leads to increasingly richer harmonies.

 Z_6 has maximal symmetry but Z_4 is not a subgroup of Z_6 so that only the symmetry breakings $Z_4 \rightarrow Z_2^{rot}$ and $Z_4 \rightarrow Z_2^{refl}$ can be said to occur. Note that transition between different realizations of the covering space has interpretation as a phase transition and that it could occur at RNA rather than DNA level. These phase transitions need not relate to the biochemistry but to serve as correlates for emotions and moods. Also the degeneracy due to the existence of several DNAs coding given amino-acid could have similar interpretation.

One can of course play with more stringent scenarios for the transitions between DNAs or RNAs). For instance, the assumption that transitions can occur between chords of same type, leads to contradiction since the Xaug chords of Z_6 harmony do not appear in any other harmony.

In any case, the quint-rule in its various forms is readily testable for DNA sequences.

6. An open question concerns the change of the key. The convention of the illustrations is that 1-2 edge corresponds to C-G quint. Should one allow the DNAs at various sheets of covering space to be in different keys? Change of the key could be identified as a rotation by some number of quints. It would change the graph representing icosahedron and change the chords. Z_{12} would allow to realize all keys. Z_{12} is not however a subgroup of the icosahedral isometries (whereas $Z_6 = Z_3 \times Z_2^{rot}$ is) so that the transformation should be interpreted as a translation in quint space acting as coordinate transformation.

The active transformations induced by isometries of icosahedron do not change the graph and would map chords to new ones. The action of Z_6 is well-defined also for other harmonies than Z_6 symmetric ones. Could the modulations of the basic key correspond to Z_6 transformations. If so, one would have 6 keys. Unfortunately, the most common modulation by quint $(G \to G)$ would be missing.

The change of key could correspond also the change of the chords defined by the extension to tetra-icosahedral harmony. One can choose the chord for extension in several ways for Z_2^{rot} and Z_2^{refl} and these choices could define the allowed modulations of the key.

7. What would be the correlates of different keys the level of DNA? An attractive assumption is that notes are realized in terms of dark photons, which could also transform to ordinary sound since living matter is piezo-electric system. The general hypothesis is that dark photons have universal energy spectrum, which is that of bio-photons. Change of key corresponds to a change of frequency scale and would correspond the change of either Planck constant or of magnetic field strength the flux tubes of the magnetic body associated with DNA codon (or amino-acid perhaps). This would mean that 12-note scale would correspond to 12-note scale for the magnetic fields strength to which cyclotron frequency is proportional or equivalently for the thickness of the flux tube since magnetic flux is quantized if monopole fluxes are in question. 12-note scale could mean in biology a standardization of frequencies used.

One must modify the extension of the icosahedral Hamiltonian cycles to tetra-icosahedral ones appropriately.

1. The Z_6 symmetric 20-plet contains 3 6-plets and 1 doublet and the Z_2 symmetric code contains 10 doublets so that here is one 11 DNA doublets in the icosahedral code. "Ordinary" amino-acids have only 9 doublets. The interpretation is that the Z_6 doublet corresponds to ile and the additional ile is coded by tetrahedral codon. The second surplus doublet can be identified as 2 codons coding for punct, "punct". This gives 4+5+10=19 amino-acid if "punct" is counted.

- 2. What is lacking is one ile, met, trp, plus Pyl and Sec. Also 4 DNA codons are needed. One of them must code ile, one met, one for punct, and one for trp. The tetrahedral codons would thus correspond to orbits of Z_1 . This is actually the only possible subgroup since for the choices $Z_n = 2, 3, 4$ the numbers of codons and amino-acids are not correct. This exhausts all DNA codons.
- 3. The only manner to proceed is to assume that icosahedral and tetrahedral codes can appear also as unfused versions. This would naturally occur for Z_2^{ref} for which all cycles contain X6 type chord but can occur also for Z_2^{rot} if the completion is done for the inverse harmony and then mapped to the harmony back. The icosahedral code would be as already described. The "free" tetrahedral codes would correspond to Z_1 and the faces coding punct in the two codes would code for Pyl and Sec. The fusion of the tetrahedral and icosahedral codes codes gives just the ordinary genetic code so that the proposal is consistent with the proposal that dark proton sequences realize genetic code [K62].
- 4. Note that geometrically this extension means only that the amino-acid sheet of the fiber space is extended by tetrahedral sheet.

The challenge is to construct the covering space of the icosahedron representing amino-acids.

- 1. The has as a local fiber the orbit under Z_n associated with the amino-acid defining base point. The space of amino-acids decomposes to disjoint regions corresponding to the 20+20-20 DNA codons. Z_n is the analog of gauge group and by symmetry breaking is different from three different regions of amino-acid space. There are $1 \times 2 \times 8 = 16$ variants of this space due to existence of several harmonies for given symmetries. There are actually only three different options for n given by n = (0, 16, 4), (2, 12, 6, and (4, 8, 8).
- 2. The Z_n orbits of the three disjoint amino-acid regions (containing 3+1=4, 5, resp. 10 aminoacids) intersect each other. The challenge is to choose the representative amino-acids from the orbits of Z_n in such a way that the chosen amino-acids belong to the three disjoint regions. It remains to be proven that this is possible. One must also understand how uniquely this can be done.
- 3. One could think of choosing a set P_2 of 10 representatives from the 10 orbits of Z_2 related by 6-quint scaling along Hamiltonian cycle. The 3+1+5=9 amino-acids associated with Z_6 and Z_4 would belong to the mirror images P(S) of this 10-element set. P(S) decomposes into set P_6 of 3+1 triangles and set P_4 of 5 triangles and there are 2-element, 4-element and 6-element orbits connecting the elements of the sets P_2, P_4 , and P_6 .

The following observations lead to a rather detailed and surprisingly simple picture.

- 1. The key observation is that the construction of the covering space that is identifications of amino-acids at the orbits of the groups involved depends only on whether the choice of Z_2 as Z_2^{rot} or Z_2^{refl} ! Thus the two codes (ordinary one and code with Pyl and Sec coded by stop codons) are distinguished by different DNA-amino-acid covering spaces. The details of the Hamiltonian cycle do not matter. Only the structures and mutual relationships of the groups $Z_6 = Z_3 \times Z_2^{refl}$, $Z_4 = Z_2^{rot} \times Z_z^{refl}$ and Z_2^{rot} and Z_2^{refl} matter. Furthermore, the actions of the groups Z_{20}^{rot} , Z_3 and Z_{20}^{refl} determine also the actions of Z_6 and Z_4 . Only Z_{20}^{rot} and Z_3 are non-commuting actions.
- 2. One can decompose amino-acids to 10 pairs of Z_2^{ref} orbits and visualize the 20 codons involved as two layers on top of each other such that two on top of each other correspond to the same 2-orbit - 2 boxes on top of each other. The choice of the two layers is not unique since one can permute the members of any vertical box pair.
- 3. By a suitable choice of the members of vertical box pairs one can arrange that Z_3 and Z_2^{rot} act along the two layers horizontally. Z_2^{rot} orbits divide each layer to 5 pairs of horizontal boxes. One can also permute the vertical pairs horizontally in such a way that the 5+5 Z_2^{rot} orbits correspond to neighboring horizontal boxes along upper and lower layer giving

4	6	4	6	4		4	6	4	6(2)
2	2	2	2	2	2	2	2	2	2
2	6	2	6	2		2	6	2	6(2)
4	2	4	2	4	2	4	2	4	2

Table 4.1: The representations of the associations of amino-acids to the orbits of of Z_n , n = 6, 4, 2 for $Z_2 = Z_2^{refl}$ (upper two rows) and $Z_2 = Z_2^{rof}$ (lower two rows). The integer n in box tells that the amino-acid associated with that box corresponds to Z_n type amino-acid. "(2)" tells that the Z_6 orbit in question consists of 2 codons.

2+2+2+2+2 decomposition. This still leaves the possibility to permute these 5+5 horizontal pairs defining 4-orbits of Z_4 horizontally with each other.

Simply by drawing one find that Z_3 orbits divide each layer to 3 triplets and 1 singlet and by a suitable choice Z_3 singlets correspond to the 10th box on the right for both layer. The Z_3 orbits and Z_2^{rot} orbits overlap in such a way that the middle Z_3 orbit contains entire Z_2^{rot} orbit.

- 4. It is clear how to choose amino-acids from the orbits.
 - (a) Consider first the $Z_2 = Z_2^{refl}$ case. The lower layer corresponds to the 10 Z_2^{refl} aminoacids (punct included) coded by 2 codons. One must choose from each Z_4 orbit consisting of a square of 4 boxes one upper box to represent Z_4 amino-acid (ala, val, gly, pro, thr). Each 4-unit contains one free upper box to which one can assign 1 Z_6 amino-acid. One cannot however put two amino-acids on 3-orbit. There are 3+1 Z_6 amino-acids and 5 boxes so that one box remains unused. This must be the case. The used box must belong to either second or third horizontal Z_2^{rot} 2-box: if it were filled, the middle Z_3 3-orbit would contain 2 Z_6 amino-acids and the fiber space-structure would fail. Contrary to the original intuition, the unfilled box is *not* at the 2-orbit of Z_6 containing as Ile but at the middle upper 3-orbit, which would contain 2 amino-acids if filled. It is associated with one of the 10 amino-acids coded by two codons and is same for both Z_2^{rot} and Z_2^{refl} . One expects that this amino-acid is somehow special: maybe it is punct. Also the corresponding 6-amino-acid (Ser, Arg, or Leu) might be somehow special.
 - (b) $Z_2 = Z_2^{rot}$ can be treated similarly. The upper row of boxes is filled in the same manner as in the previous case. The horizontal box pairs in the lower row contain one $Z_2 rot$ box and one Z_4 box. The difference to the previous case is that Z_2 boxes are now shared by the both rows: in the previous case they belonged to the lower row.
- 5. The assignment of amino-acids to the orbits is not unique: for n similar orbits there are n! different assignments. Inside orbit there is also some non-uniqueness.

Table 4.1 represent the two situations graphically.

3. Music and physical correlates of emotions

Peptides are regarded as molecules of emotion and also information and positive/negative coloring of emotions would naturally correlate with the increase/reduction of negentropic resources of the system as negentropy is transferred to or from it away or increases as a whole. Music induces and expresses emotions. Therefore the idea that music in generalized form - say represented by dark photons with ELF frequencies and having energy spectrum in visible and UV energy range of bio-photons- could be the fundamental correlate of emotions and whether tetra-icosahedral music could be in special role (note that one can associated Hamilton's cycles and "music" with any graph).

There are 11 candidates for the icosahedral harmony and its extensions. The candidates have either Z_6 (**Fig.** ??, Z_4 reflection symmetry (**Figs.** ??, ??), or Z_2 rotation symmetry (**Figs.** ??, ??, ??), and Z_2 reflection symmetry (**Figs.** ??, ??, ??, ??). For the first case Z^2 reflection

symmetry and for the second case Z_2 rotation symmetry are represented as as half-octave shift. Second reflection symmetry corresponds geometrically to reflection in horizontal direction. The extension assigns to them definite key and adds to 1-quint chords minor and major chords absent for the icosahedral bio-harmonies. The question is whether one of these harmonies is selected in biology or whether all three can appear and are perhaps realized at the level of magnetic bodies of amino-acids.

The reversal of the harmony differs from the original one and major-minor transformation takes place. Could it be that both "moods" are realized at the level of magnetic body and even serve as the physical correlates of moods and emotions? Could emotions be realized at the level of amino-acid magnetic bodies as phase transitions affecting parts of organism or even entire organisms and in this manner changing the mood. Peptides are regarded as molecules of emotion: could these phase transitions occur only for peptides and other information molecules involving proteins? Could peptides also serve as seeds of these phase transitions? Could even the Hamiltonian cycle be changed for the magnetic body of the entire organism and correspond to some importance two-valued characteristic of emotional profile?

Could orientation reversal relate to time reversal, which in Zero Energy Ontology (ZEO) corresponds to state function at opposite boundary of causal diamond (CD)? This reversal would occur in volitional acts: the subsequent reduction would not affect the quantum state in positive energy but in TGD framework they affect the state at opposite boundary CD and in this manner give rise to the experience flow of time.

The simplest extension of the harmony in the proposed form requires that harmony possesses X_6 chord. It does not exist for for the candidate with Z_2^{rot} symmetry but for its reversal 4 of them are present as images of D7, E7 and $G\sharp7, B\flat7$ which are chords of type X^6 . One can however map the harmony to its reversal, perform the completion for it, and perform the reversal back to the original harmony. The reversal depends on what note remains invariant in the reversal. One can require that it is the basic note of the chord to itself: with this condition one would obtain $Dm, Em, G\sharpm, B\flatm$ and major keys $C\sharp, F, A, H$. 4 different harmonies would result. Without the restriction the number of harmonies is different and each has different emotional characteristics.

4. Religious myths, music, and biology

These symmetries define a hierarchy of symmetry breakings. This hierarchy has amazing connections with the myths, which I believe to reflect deep facts about consciousness and biology at fundamental level expected if also consciousness is fractal. The story of genesis is a good representative in this respect.

1. The hierarchy of symmetry breakings proceeding from Z_6 down to Z_2^{refl} brings strongly in mind evolution as loss of innocence. For Z_6 one as 4 orbits. One orbit contains 2 triangles (chords, DNA codons assignable to ile). The other orbits correspond to six codons assignable to amino-acids ser, arg, and leu. The chords at the orbits are major chords and 7-chords, and minor chords and 6-chords for the inverse of the harmony.

There are no dissonant chords in 0-quint sector: dissonances appear only for the remaining groups as 0-quint chords. This is musical representation of paradize. This harmony is based on 6-note scale for the basic notes of the chords and used by impressionistic composers. Amino-acids correspond to selections of preferred chord from each orbit and there are only four different chords: this sub-harmony is very simple. Life in paradize is simple!

2. Next comes an intriguing observation. The number of amino-acids obtained as projections of the icosahedral DNA orbits is 19, not 20. Could it be impossible to have 20 amino-acids as projections of the orbits and that 19 is the maximum number? The reason for 19 is that the number of amino-acid of type Z_6 is 3 + 1 = 4 rather than 5. Therefore there is one "non-playable" chord - located at some "paradize orbit" -, which does not correspond to any amino-acid.

The first guess for the non-playable chord is as one of the *aug* type chords (say $CEG\sharp$, which is the last breath in many finnish tangos telling about unhappy love end - it is something between happy CM and sad Am, "raueta" is finnish word for this manner to come to an end: "expire" might be the nearest english counterpart). This chord is located at the 2-chord orbit related to the other chord of the orbit by half-octave shift (chords could be $CEG\sharp$ and $F\sharp B\flat D$), the tritonus denied by church.

Unfortunately, this identification is not consistent with the argument identifying the aminoacid chords at Z_n orbits (see table 4.1) the non-playable chord must belong to an intersection of 6-orbit and 4-orbit and is not completely unique without further assumptions. It belongs to a 2-orbit of Z_2^{refl} : if it is somehow special, it could belong to the 2-orbit assignable to punct. If the chords at the 2-orbit have basic notes differing by tritonus, the inspection of the Table 11.5 shows that it is possible to find a unique chord pair having this property for all 5 Z_2^{refl} cycles.

One cannot avoid the associations between non-playable chord and the denied fruit hanging in the tree of good and bad knowledge in the story of Adam and Eve, and its analog in many fairy tales. The non-playable chord also brings in mind the hilarious story of Gödel-Escher-Bach about non-playable record (a truth unprovable in given axiom system).

- 3. The hierarchy of symmetry breakings leading from Z_6 to Z_2^{refl} encourages one to continue with the biblical analogies. Z^6 , Z_4 and Z_2^{rot} cycles have half-octave shift as a symmetry: good and evil do not exist in paradise, but dissonances are already there for Z_4 and Z_2 harmonies - the evil snake! These states correspond to the consciousness of animals, children, and saints. Note that bio-harmony corresponds to the presence of one sub-harmony of type Z_n , n = 6, 4, 2.
- 4. The banishing from the paradize takes place as Z_2^{refl} symmetric harmony replaces Z_2^{rot} harmony: half-octave shift is not a symmetry anymore, and one can tell between good and evil, and eventually church decides to deny tritonus as a symbol of evil! Paradise is left as icosahedral and tetrahedral code are fused to form the tetra-icosahedral code the ordinary genetic code leading to the breaking of Z_2^{refl} symmetry.
- 5. In banishment punct ("empty" amino-acid) as a counterpart of chord shared by tetrahedron and icosahedron emerges and means stopping of the music piece altogether. Death of the sinner! For unfused codes this chord is playable as Sec/Pyl and the music piece is never-ending: life is eternal in paradise! No notion of time, no sin, no death! Amusingly, impressionist music with 6-note scale is music of "now", attempt to catch this moment.
- 6. Also the holy trinity finds an analog as $Z_6 Z_4 Z_2$ trinity of the bio-harmony. Holy Spirit, Father, Son: perhaps in this order. Even more, Z_2^{rot} can be associated with Son in Heaven and $Z_2 refl$ with Son at Earth as ordinary mortal!

5. What do DNAs/amino-acids sound like?

If DNA/amino-acid sequences correspond to chord sequences of tetra-icosahedral harmony, one can ask what they sound like. The best manner to study this question is to build concrete simulations of the DNA/amino-acid sequences.

- 1. This requires specification of harmony by selecting one Hamiltonian cycle from the cycles belonging to the groups of cycles with Z_n , n = 6, 4, 2 symmetry and decomposing amino-acids to 3 groups correspondingly (those coded by 6, 4, and 2 codons). One must include tetrahedral codons and amino-acids.
- 2. The basic rule of harmony would be the minimization of quint distance between initial and final chords of the transition. One can consider probabilistic versions of this rule or pose strict form of the rules stating in the most stringent form that only transitions with vanishing quint distance (between neighboring triangles) are possible.
- 3. The transitions between different amino-acid regions would be governed by this rule. Aso the transitions between different variants of the DNA-amino-acid space defined by different choices of the Hamilton cycles would be governed by the same rule
- 4. The most plausible looking model considers only transitions between DNA codons since DNA sequences induce amino-acid sequences.

Appendix represents an example about randomly generated chord sequence assignable to bio-harmony defined as a composite of 3 harmonies - one from each symmetry type and $Z_2 = Z_2^{refl}$ involving tetra-icosahedral extension. Anyone having garage band skills in guitar playing can check what these chord sequences sound like and maybe try to build a melody on the background. One could also test the proposal that codons at the orbit of amino-acid define the melody by finding a concrete representation for the orbits and building random melodies defined by DNA sequences coding for the chord sequence.

Magnetic body, bio-harmonies, morphogenesis, and epigenetics

What TGD can possibly give to biology is the vision about magnetic body as an intentional agent using biological body as a sensory receptor and motor instrument and about various mechanism used by magnetic body for control and communication purposes. A new element is brought in by Zero Energy Ontology: magnetic body is 4-dimensional and thus correlate for a behavioral pattern rather than 3-D state for part of organism. Also the notion of bio-harmony suggests itself as a correlate for quantum coherence at the level of basic bio-molecules. The discussion below raises and tries to answer general questions.

The finding that behavioral patterns of planaria can be remembered also by the piece of split planaria without the brain is consistent with the idea that replication of magnetic body coding for behaviors is behind biochemical replication. That alleles of the same gene have different expression could be understood if the bio-harmony assignable to gene carries additional information besides the biochemical information. An alternative explanation is that emotional memories associated with conditioning are realized at the level of the body of planaria.

These notions might also provide a fresh approach to epigenetics. Histone modification and DNA methylation are believed to induce kind of geometric locking preventing transcription. They could also affect the frequency assignable to DNA codon or some key unit so that the resonance condition making possible reconnection of U-shaped flux tubes allowing biomolecules to get in contact fails and transcription cannot proceed. Epigenetic inheritance could reduce to the inheritance of bio-harmony: the magnetic bodies of cells of offspring get in tune with those of parent. To how high degree magnetic body and bio-harmony are inherited? This becomes the key question.

1. Basic ideas related to magnetic body

Recall first some key ideas of TGD inspired quantum biology.

1. In TGD framework magnetic body extends the pair formed by organism and environment to a kind of holy trinity. Magnetic flux tubes and the realization of genetic code in terms of dark proton sequences has been the key hypothesis. The model for cold fusion [L27] suggests that also more general dark nuclei must be allowed. Dark neutron sequences could correspond to genes separated by dark protons. Dark weak interactions with large value of h_{eff} effectively massless below neuron size scale would play central role and induce large parity breaking effects (chiral selection).

The chemistry would not be all that matters. DNA-nuclear/cell membrane as topological quantum computer with braided magnetic flux tubes would explain why organisms with virtually identical genomes are so different (we and our ancestors for instance). The hierarchy of magnetic bodies would be responsible for the development of intelligence and for cultural evolution. Flux tubes connecting DNA and mRNA as well as mRNA and tRNA molecules are present but it is difficult to say anything concrete.

2. Ontogeny could be seen as a kind of editing process for the text defined by the DNA. Control of control of... is involved so that situation is very complex. Who performs the editing? Does DNA edit itself and is the editing process defining evolution of genome coded by genome? Or is the editing performed by Darwinian selection at cell level (see http://tinyurl.com/nd9a9ks)? Or is the magnetic body the editor using genome also as its tool as TGD would suggest? What is important that in TGD framework self-organization in 4-D sense implied by Zero Energy Ontology replaces ordinary self organization leading to asymptotic spatial patterns and select spatiotemporal patterns as asymptotic behavioral

patterns defining various biological functions. The role of magnetic body is central in this process.

- 3. Magnetic body contains cyclotron Bose-Einstein condensates and cyclotron frequencies determined by the strength of magnetic field would give for DNA and other biomolecules additional characteristics. In TGD based model for musical harmony DNA codons would correspond quite concretely to 3-chords but played using dark photons (also ordinary music represented as sounds could be transformed to dark photon music). If one accepts the icosahedral model of bio-harmonies predicting genetic code correctly, there would be 256 fundamental harmonies characterised by the allowed collection of 3-chords and they would add to the information carried by DNA molecules. I have constructed a program building random sequences of the allowed chords using the additional harmonic rule that two subsequent chords contain at least one common note and this music sounds rather harmonic (albeit boring in absence of any other elements!)
- 4. Could one distinguish between different states/phases of DNAs, mRNAs, tRNAs, and amino acids in terms of harmony? Could their functioning depend on the harmony? With the inspiration coming from the connection of emotions and musical harmonies I have proposed that the harmony associated with a gene or organ could correlate with something analogous to an emotional state or mood maybe micro-mood or microemotion could be the proper notion. Could amino-acids be happy, hilarious, melancholic, sad, depressed? Could one distinguish between different phases of DNA, RNA, tRNA, aminoacid collections characterized by the harmony in turn characterizing the of a cell, organelle, organ, or even organism? tRNA defines the map of the harmony associated with DNA codons to amino-acid harmony. Is the information about DNA codon and about corresponding 3-chord represented at the level of magnetic body of amino-acid- that is as the 3-chord, which it represents, and realized as the rules telling with which tRNAs amino-acid can reconnect?

In contrast to DNA codons, which represent local information, harmony could represent holistic information and characterize entire genes or their intronic portions.

2. Problem

There is however a problem. DNA codons coding for the same amino-acid correspond to different 3-chords of harmony. One of these chords corresponds to amino-acid itself and the codons coding for amino-acid correspond to the orbit of this chord under subgroup of isometries of icosahedron moving the triangles of icosahedron along the orbit. This would apply also to mRNA and maybe also to tRNA. The chords at the orbit of amino-acid are isomorphic (intervals are same) and obtained as transposes of each other.

The chords are isomorphic but not identical and this leads to the problem with resonance paradigm unless one gives up the idea that amino-acid corresponds to a unique DNA codon and assumes that there is analog of gauge invariance allowing to choose the preferred codon freely.

1. The assumption about preferred DNA codon could be given up if one can choose the preferred DNA codon freely so that also the magnetic bodies of amino-acids are characterized by 3-chords and thus carry information about what DNA codon coded them. This is possible if one has the analog of fiber space structure with DNA codons coding for amino-acid defining the fiber and amino-acids defining the base. This fiber structure with discrete gauge invariance is strongly suggestive and I have proposed it for two decades ago but it seems that it poses strong conditions on the orbits of the subgroups of isometries of icosahedron.

This condition is very restrictive. Simplifying somewhat: one considers 60 codons decomposing into 20+20+20 codings and each group of 20 codons codes for amino-acids belonging to different groups. There are twenty of them. The 20 triangles of icosahedron correspond to 3 DNA codons each and each of them corresponds to one and only one amino-acid. One has 3 subgroups of isometries corresponding to 20+20+20 decomposition.

Can one perform a global gauge transformations realized as isometries and moving triangles along the orbits of one of the 3 subgroups involved - say isometry g_1 of G_1 ? These transformations would move the entire orbits of 2 subgroups involved - call them G_2 and G_3 . What happens to the chords of G_2 and G_3 : is their character changed completely so that these harmonies would be destroyed? It seems that this cannot work. Should one replace G_2 and G_3 with their automorphs $g_1G_2g_1^{-1}$ and $g_1G_3g_1^{-1}$. Does this make sense? 3-chords defining give orbit should be invariant under automorphisms of G_i ? This does not seem to be a realistic condition.

- 2. Could different automorphs correspond to different collections of chords physically just as global gauge transformations generate different physical situations? Isometries of groups G_i would therefore define physically different realizations of bio-harmonies such that for each of them only one of the DNA codons coding for given amino-acid could actually perform the coding. Ordinary genetic code with many-to-one correspondence would make sense in statistical sense only. If this is true, the cyclotron frequency 3-chord assignable to amino-acid depends on the DNA coding it and implies physical distinctions.
- 3. One can consider also a third alternative. DNA codon with same 3-chord as coding for amino-acid is in special role in that only it can resonate with the amino-acid! Could DNA codons codons correspond to same cyclotron frequency triplet (magnetic fields) but different value of h_{eff} so that one would have chord with respect to energy rather than frequency. Different values of h_{eff} for DNA codons coding for the same amino-acid would scale their cyclotron frequencies to the same amino-acid frequency while keeping cyclotron energies invariant? Cyclotron energy ratios for codons correspond to rational valued ratios $E_i/E_j =$ $h_{eff}(i)/h_{eff}(j) = n(i)/n(j)$. Amino-acid would correspond to fixed h_{eff} and this creates a problem: can DNA codon code for amino-acid with different value of h_{eff} . This option does not look attractive.

Second option looks most plausible. Of course, it is early to talk about a prediction: it might well be that I have mis-understood something.

3. Questions about bio-harmony

One can pose a lot of questions about bio-harmony.

- 1. It is not necessary to assign any interpretation on the harmony. Just the harmony could be enough if it is forced to be same for DNA, corresponding mRNA, tRNA, and aminoacids. One can however make questions. Is the harmony inherited invariant and could it distinguish between different personality types about which we learned in old books of psychology? Or could the harmonies correlate with our own moods?
- 2. Could differentiation selecting particular genes as expressed genes apply also to harmonies so that given gene would correspond only to a particular harmony and different copies of gene could correspond to different harmonies. Could this selection rely on the same mechanisms as ordinary differentiation realized in terms of epigenetic mechanisms and DNA editing? From the magnetic bodies of genes the harmony would be automatically transferred to the magnetic bodies of mRNA, tRNA and aminoacids since otherwise the transcription and translation do not work since magnetic bodies do not have common resonance frequencies and reconnection and resonant interaction is not possible.
- 3. Does given harmony characterize given gene or the entire cell? All basic biomolecules associated with a gene would naturally correspond to the same harmony. If the rRNAs associated with ribosomes are in harmony mutually cellular harmony seems to be the only option. If ribosomes have their own harmonies, only certain ribosomes can translate given gene. This would bring in additional control tool. The most plausible picture is that the situation depends on what happens in the self-organization process. Some organs/organisms are more harmonious, others not so harmonious. Harmony need not be given fixed to remain the same: magnetic body can have motor actions changing the cyclotron frequencies. Moods could reflect the character of harmony at gene level.
- 4. Does magnetic body control the differentiation by posing restrictions on gene expression or vice versa? The idea about magnetic body as intentional agent suggests that the first option is correct. There would be hierarchy of magnetic bodies with magnetic bodies at the

higher level controlling bodies at the lower level. The value of Planck constant would label the hierarchy levels and also DNA codons would be characterized by "intelligence quotient" defined by h_{eff}/h . This would be nothing but the analog for the hierarchy of program modules and I have earlier considered the realization of this hierarchy [L29].

5. The selection of harmony could take place and be analogous to cell differentiation. This would be a self-organization process in which magnetic bodies of genes, cells, etc.. tune themselves to resonance with each other by modifying their magnetic fields by controlling their thickness (for monopoles flux the flux is invariant). Something analogous to the development of social skills. This could pose resonance as a constraint on processes like replication, transcription, reverse transcription, silencing, enhancing, editing, etc.... It might induce the differentiation at gene level.

Editing processes for genome could be seen as being induced by the motor actions of the magnetic body involving reconnection and change of the value of h_{eff} changing the length of the flux tube and bringing biomolecules near to each other or separating them. This selection would also apply to the intronic part of DNA proposed to be responsible for topological quantum computation like processes. The copies of same fragment appearing in intronic portion and copies of genes could correspond to different harmonies.

4. Can the notions of magnetic body and bio-harmony explain something that ordinary genetic cannot?

It would be nice to identify some biological phenomenon difficult to understand in standard framework but having an elegant explanation in terms of magnetic body.

- 1. The notion of harmony could manifest itself at the level of genes as different expressions for the copies of same gene if they correspond to different notions of harmony. The copies of gene are known as alleles (see http://tinyurl.com/bpee49t). The alleles can indeed give rise to different phenotypic traits such as different pigmentation.
- 2. Morphogenesis provides examples of this kind of phenomena [I139, I140, I182]. The first key idea is that DNA and cell replication is induced by the replication of magnetic bodies serving as information carriers [K88]. The second key idea is that in zero energy ontology (ZEO) magnetic body is 4-dimensional and represents behavioral patterns rather than only 3-dimensional patterns. For instance, memory as behavioral patterns can be inherited by the piece of planaria worm not containing the brain. The explanation could be that the magnetic body carries behavioral patterns replicated in the splitting of the worm.
- 3. Epigenetics (see http://tinyurl.com/4xpwcm) studies changes of gene expression not caused by the change of DNA itself. Epigenome (see http://tinyurl.com/y9xkfb2u) is the highly dynamic part of DNA controlling expression of the rather stable part of genome. One might regard stable part of genome as hardware and epigenome as topological quantum computer programs assignable to magnetic body and modifying gene expression epigenetically. Comment sign in computer code serves as a computer scientific metaphor for epigenetic control by repression.

The modelling of epigenesis in terms of magnetic body and bio-harmonies deserves a separate discussion.

1. The modification of transcription rate is the basic tool of epigenetic regulation. There are two basic mechanisms involved. Histone modification (see http://tinyurl.com/y8ywse5v affects the histones of chromatin so that the transcription is repressed or activated. Histone modification takes place by several mechanisms. DNA methylation occurs for CpG pair and if it occurs for a promoter region it represses the transcription and serves as a kind of gene lock. The degree of methylation serves as a measure for the effectiveness of repression. I do not know whether the locking is absolute at the level of single gene or whether only the transcription rate is reduced. Two mechanisms are mentioned in the Wikipedia article (see http://tinyurl.com/y9kwrvwx). Methylation can impede geometrically some step in the transcription. Methylated site can be also accompanied by proteins affecting histones in chromatin and in this manner impede transcription.
2. The notions of magnetic body and bio-harmony suggest an alternative - one might even hope fundamental - mechanism of repression. Methylation (histone modification) could affect some cyclotron frequency associated with DNA codon (histone). In the optimal situation for transcription the DNA and protein catalyzing the transcription or mRNA are in resonance. When cyclotron resonance condition is not exactly satisfied, the reconnection rate for the U-shaped flux tubes associated with the molecules involved in the process is reduced and also transcription is repressed.

I have considered also the radical possibility that the dynamics at the level of magnetic body is fundamental for biology and that magnetic body defines templates for the bio-molecular selforganization making dark matter dynamics visible. This is probably too extremist view and it would seem that biochemistry affects the cyclotron frequencies assignable to the magnetic body by affecting the strengths of magnetic fields also at dark magnetic flux tubes.

3. The notions of epigenetic code (see http://tinyurl.com/y8ztzzza) and histone code (see http://tinyurl.com/y854w58p) have been proposed. Epigenetic code would consist of histone modifications and additional modifications such as DNA methylation. The codeword of the epigenetic code could code for some larger unit than protein: say gene or entire cell. The hypothesis is that the chromatin-DNA interactions are induced by histone tail modifications (such as methylation, acetylation, ADP-ribosylation, ubiquitination, citrullination, and phosphorylation). There are 4 histones and the position of modification varies as well as the modifier (the above modifications are not the only ones) so so that the number of modifications is very large.

The addition of bioharmonies to the genetic information could simplify the situation dramatically since the modifications could be seen as defining of of the 256 bio-harmonies with 64 chords each (this for fixed scale which varies if the value of magnetic field strength is varied: biophoton spectrum in visible is proposed to represent the range of values of magnetic field). The most plausible starting hypothesis is that given harmony characterizes the gene. Much simpler option would be that the harmony characterizes entire cell or even group of cells.

If the modification by kicking cyclotron frequency out of harmony is enough to repress transcription, almost endless number of bio-chemical ways to achieve would exist but the epigenetic code could be very simple at the basic level as TGD would predict. Each bioharmony [L16] [K91] would provide a representation of genetic code in terms of 3-chords predicting correctly the DNA-amino-acid correspondence (there are actually two slightly differing codes explaining the presence of 21st and 22nd amino-acid and deviations from the standard code). The states of dark protons (or neutrons) are also proposed to realize genetic code [L1, K62]: it is an open question whether these codes imply each other as they should.

- 4. The understanding of transgenerational epigenetic inheritance (see http://tinyurl.com/ h6qg64c) raises difficult challenges. One should understand how histone modification and DNA methylation are transferred to daughter cells in cellular division or inherited by the offspring. Transgenerational interaction of the genomes seems necessary. In TGD framework the interaction of magnetic bodies of via resonance mechanism could transfer the epigenetic programs to the offspring. Offspring could "learn" the epigenetic programs of the mother by tuning.
- 5. Gregory Carey (see http://tinyurl.com/ydyznsaq) gives nice real life examples about the complexities of epigenesis identified quite generally as gene regulation (see http://tinyurl.com/zb97cgs). He compares the gene regulation involved with the handling of a stressful situation to "nightmarish Rube Goldberg mousetrap" and sees the process as extremely ineffective from engineering point of view. For instance, the hormones secreted to blood circulation are distributed to the entire body. The whole thing could be carried out in brain! He also wonders why evolution is so inefficient. All cells have same genome although most of the genes are silenced. Second strand of DNA is totally un-used and most of DNA consists of introns. His explanation is that evolution does not make long term plans but finds just a solution to a particular without thinking it from a wider perspective: "If it ain't broke, don't fix it".

I tend to see this differently. If entire body is coherent quantum entity, engineering based thinking does not make sense. Entire body and also magnetic body must be informed from the stress situation since the reaction is holistic. The genes which are not used for gene expression might be used for other purposes. Topological quantum computation could be this purpose in TGD framework and repressed genes could be thus used for quantum information processing. Information processing could be actually the dominating function of the DNA of higher vertebrates.

To sum up, magnetic body could be seen as the "boss" controlling the gene expression and also the evolution of genome in longer scales. Magnetic body would use bio-molecular mechanisms for its purposes. This would bring in a new kind of inheritance: bio-harmony would be inherited. The most spectacular almost-prediction would be that genetic code is many-to-one only in statistical sense.

5. RNA is transferred between soma cells and germ cells

The basic question of epigenesis is how the information between soma cells and germ cells is transferred. In standard genetic the transfoer RNA or DNA molecules is necessary to achieve this. In TGD dark DNA, RNA, tRNA, and aminocids consisting of dark nucleons realized as nuclear strings and accompanied by the corresponding biomolecules is one possibility. The extremist view would be that the dynamics of the dark variants of basic bio-molecules induces the dynamics of their molecular shadows making them only visible. Also the transfer of information as cyclotron radiation can be considered in TGD framework and cyclotron resonance could serve as a fundamental mechanism of epigenetic control. The above model suggest that epigenetic control mechanisms rely on resonance mechanism for 3-chords associated with DNA codons and other biomolecules giving them "names" is also at work besides purely geometrical silencing.

The popular article "No Sex Required: Body Cells Transfer Genetic Info Directly Into Sperm Cells, Amazing Study Finds" (see http://tinyurl.com/hhdth5j) summarizing the findings discussed in the article [I70] (see "Soma-to-Germline Transmission of RNA in Mice Xenografted with Human Tumour Cells: Possible Transport by Exosomes" (see http://tinyurl.com/yde7wb55) as very interesting concerning this basic question.

The abstract of the article gives for a professional a readable summary.

Mendelian laws provide the universal founding paradigm for the mechanism of genetic inheritance through which characters are segregated and assorted. In recent years, however, parallel with the rapid growth of epigenetic studies, cases of inheritance deviating from Mendelian patterns have emerged. Growing studies underscore phenotypic variations and increased risk of pathologies that are transgenerationally inherited in a non-Mendelian fashion in the absence of any classically identifiable mutation or predisposing genetic lesion in the genome of individuals who develop the disease. Non-Mendelian inheritance is most often transmitted through the germline in consequence of primary events occurring in somatic cells, implying soma-to-germ line transmission of information. While studies of sperm cells suggest that epigenetic variations can potentially underlie phenotypic alterations across generations, no instance of transmission of DNA- or RNA-mediated information from somatic to germ cells has been reported as yet.

To address these issues, we have now generated a mouse model xenografted with human melanoma cells stably expressing EGFP-encoding plasmid. We find that EGFP RNA is released from the xenografted human cells into the bloodstream and eventually in spermatozoa of the mice. Tumor-released EGFP RNA is associated with an extracellular fraction processed for exosome purification and expressing exosomal markers, in all steps of the process, from the xenografted cancer cells to the spermatozoa of the recipient animals, strongly suggesting that exosomes are the carriers of a flow of information from somatic cells to gametes. Together, these results indicate that somatic RNA is transferred to sperm cells, which can therefore act as the final recipients of somatic cell-derived information.

Some background is needed to understand this rather technical summary.

1. Darwinism has dominated biology since Darwin. The rules of classical Mendelian inheritance conform with the Darwinian view and can be reduced to genetic level. Various traits are inherited genetically by sexual reproduction and genome would change during lifetime only through mutations. Genome changes exremely slowly by random changes for offspring from which selection pressures choose the survivors. Lamarckian view in turn assumed that the external circumstances experienced by organism leave a trace, which can be inherited but it could not be formulated in terms of modern molecular biology whereas the Darwinian dogma could be formulated in terms of Weissman's genetic barrier. Information flows from germ cells to soma but never in opposite direction. If it would do so, the soma interacting with environment could transfer information to germ cells and the experiences during lifetime could leave inheritable trace to germ cells.

An analogous dogma is that information is always transcribed from DNA to RNA to proteins but never in opposite direction. It is now known that this takes place in case of viruses and retroviruses: there are so called jumping genes which can also make copies of themselves. 5 per cent of human genome conists of endogenous retroviruses capable of doing the same. The huge genome of maize is due to this kind of proces.

2. The development epigenetics has started to shatter the belief on Wessimann's genetic barrier. Gene expression is not fixed by genome alone and can be change even when genes are unaffected. Silencing of genes by DNA methylation and histone modification allow to modify gene expression. Silencing is essentially a locking of gene preventing its expression by transcription followed by translation.

It is now known that epigenetic changes in the gene expression can be inherited. The mechanisms are still poorly understood. What seems however clear the genome is more like a slowly changing hardware and gene expression or whatever is behind it is the software and programs can change very rapidly by just adding or deleting comment signs in the code. A deeper understanding of this software is needed.

3. Epigenetic inheritance requires that genetic information is transferred from soma cells to germ cells. If only DNA or RNA are capable of representing genetic information, then DNA or RNA must be transferred from soma cells to germ cells. No instance of direct DNA or RNA mediated information from soma to germ cells had been observed before the above mentioned experiments. One can of course challenge the assumption about DNA and RNA as the only representations of genetic information.

The basic idea of the experiment was simple. Use a marker for RNA by using plasmids (DNA strands not belonging to chromosomes) genetically engineered to code for a marker protein making itself visible by fluorescence. Then one just follows the fate of these proteins generated in soma cells and looks whether they end up inside germ cells and how this happens.

More technically: mouse model was xenografted with human melanoma cells stably expessing EGFP-coding plasmid (expressed in a way possibly evoking emotions: human melanoma cancer tissue was implanted in mouse). EGFP-RNA is released from xenografted human cells to blood. One just looks whether it eventually ends up to the sperm cells of mice and tries to identify the transfer mechanism. Only transfer to sperm cells was studied. One might expect that the transfer of RNA can happen also to ovum. I guess that the sperm cells are easier to study.

What was observed?

- 1. The transfer of RNA from some cells to sperm cells was indeed found to occur. The transferred RNA can in turn induce epigenetic effects in germ cells known to be inherited by a mechanisms, which however remain poorly understood. Epigenetic mechanisms seem to be involved in the cases considered so that DNA is not changed, only its expression.
- 2. The transfer mechanism was identified. The transferred RNA is contained by exosomes analogous to synaptic vesicles transferring neurotransmitters from presynaptic to postsynaptic cell. Transfer of RNA takes place via fusion of the membranes just like transfer of neurotransmitters. Maybe genetic engineering using exosomes or analogous structures to transfer the needed material to cells has been tried.

The implications of the findings are dramatic but already implied by the earlier work in epigenetics. What is important that Lamarckian view can be now defended by a concrete genetic mechanism. Lamarckism implies that the time scale of inheritance becomes the time scale for the appearence of a new generation. Nutrition, environment, lifestyle and even meditation and similar practices, are already now known to affect gene expression on daily basis: we are not victims of genetic determinism and are epigenetically responsible for our own well-being. Epigenetic information can be transferred also to germ cells so that we responsible also for the well-being of our children. Our children suffer our sins and share our sufferings.

The precise mechanism of inheritance of epigenetic modifications remains still poorly understood although it seems that the transfer or RNA to germ cells occurs. There are also other hints: it is known that alleles (variants of game gene) can express themselves differently. One allele can also induce other allele to express in the same manner. Somekind of "social pressure" like interaction seems to be involved.

As explained, TGD suggests the notion of magnetic body and cyclotron resonance as this interaction. The DNA of offspring get tuned to the DNA of mother during pregnancy and this gives to epigenetic inheritance. Various epigenetic mechanisms such as methylation and histone modification could affect cyclotron frequencies besides purely geometric modifications of DNA and locking at the level of gene could be accompanied kicking out of tune at the level of magnetic body. In this framework the transfer of RNA to germ cells would be necessary to affect the cyclotron frequencies.

Epigenesis, inherited memories and moods lasting over several generations

Nikolina Benedikovic had an interesting comment concerning multiverse interpretation. This motivated to write a summary about the connection between epigenesis, inherited memories interpreted as behaviors and moods lastring for seveal generations. Nikolina's comment was following.

"One can imagine an intelligent amoeba with a good memory. As time progresses, the amoeba is constantly splitting, each time the resulting amoebas having the same memories as the parent. Our amoeba hence does not have a life line, but a life tree." - Huge Everett

Nikolina: Dear Mr. Everett! Before we find out what the true interpretation of quantum mechanics is, we will have to answer this question; why the amoeba possesses this "super power" of splitting and the electron and human being don't.

I agree with Nikolina. The following is my comment about what is involved. I proceed by questions.

1. What behaviors are?

The behavior of amoeba has nothing to do with parallel universes of Everett. The behavior as such is however highly interesting and challenges standard theories of biology and perhaps also of physics. Memories seem to replicate.

1. What do we mean with memories now: do we mean behaviors, skills, conditionings? Or episodal, sensory memories. I think it is memories in the first sense of the word. Suppose that essentially conditionings are in question.

In this respect a lot of progress happened as it was discovered that RNA somehow represents the memories: taking RNA of conditioned sea snail and scattering it over the neurons fo second snail in lab induces the conditions of the snail to these neurons.

2. Epigenetic approach would suggest that the behaviours essentially the same but now one does not have any convincing model for the model of the epigenesis.

2. What TGD inspired quantum biology and neuro-science can tell?

There are two key questions that one must answer.

1. What replication is?

In TGD Universe we are 4-D entities - quantum states are superpositions of space-time surfaces obeying deterministic dynamics. This solves the problem of free will and basic problem of quantum measurement theory. The superposition of space-time surface would be analogous to superposition of deterministic computer programs, behaviours, or biological functions in classical sense. Free will would select the program [L69, K77, L86, L18].

2. What memories as learned behaviours are? One can imagine several models, which need not exclude each other.

- (a) For instance, could it be that the replicas of ameba have geometric past that is partially shared: the part of the past as amoeba before the replication?
- (b) Second TGD explanation would be based on what conditionings are? They involve emotions in an essential manner. Emotions are induced and induce behaviors and conditionings involve long term moods. The mysterious epigenetic inheritance could be inheritance of moods affecting gene expression: moods could be inhereted and have time-span of several generations: this conforms with the first option.

3. What moods are?

Suppose that conditions are due to long term moods in turn correlating with behavior and at basic level with genetic expression. Consider a TGD based model for moods, second option.

- 1. Music its harmony defined by allowed chords represents emotions and generates them. The allowed 3-chords of bio-harmony, the set of which can vary, would define the mood.
- 2. Genes are associated with information. Codon contains 6 bits of information. Magnetic body with large $h_{eff} = nh_0$ is the boss, the "wise guy", controlling biological body and biochemistry so that genetic code must have primary representation at the level of flux tubes. Dark proton sequences at flux tubes interpreted as dark nuclei indeed represent codons as 3-proton units. The states of 3- proton units turn out to correspond to DNA, RNA, tRNA, amino-acids and vertebrate genetic code is predicted.

Chemical representation would be only a secondary representation only, mimicry, and often incomplete.

Dark proton sequences also realizing vertebrate genetic code would also have positive charge neutralizing the negative charge of nucleotides and make DNA stable. Pollack effect would generate the dark flux tube and this would require metabolic energy and in absence of it DNA would not be stable.

- 3. Dark proton sequences must also communicate by dark photons with large h_{eff} . The communications must rely on resonance, actually there must be resonance between similar 3proton units, dark codons. Therefore 3-chords consisting 3 dark photons must represent the codons represented by 3 protons [L77]. Only identical codons have resonant coupling. This makes possible remote replication of DNA reported by HIV nobelist Montagnier [L3] (see http://tinyurl.com/yygqen5g).
- 4. Allowed 3-chords define the harmony and emotional state mood. In TGD representations of emotions in terms of bio-harmony would provide the representation of genetic codons defined by RNA as 3-chords of light, triplets of 3 dark photons. The icosatetrahedral model for harmony realizing bioharmony [L16, L103]. gives also rise to vertebrate genetic code: the 6-bit units defined by codons correspond to ordinary temporarily local intellect, and the harmony to the holistic emotional intellect.
- 5. RNA and DNA, tRNA, amino-acids would naturally be represented by light 3-chords in communications. Given codon would only tell its name by the chord and resonate with codon having same name. The codons would couple by chords via triple resonance. Same DNA sequences could be in different mood defined by bioharmony and its expression would depend on this: this would give rise to epigenetics. Epigenetic inheritance would be emotions lasting for several generations.

The bioharmony associated with RNA could represent the mood infecting also DNA and generating DNA expression giving rise to the behavior related to conditioning.

6. If this were the case then the inheritance of memories (in this sense could be inheritatance of conditionings as long term moods. The replications of RNAs and DNAs and possible other biomolecules carrying the conditioning would give rise to replication of memories as behaviors induced by moods.

7. These moods can be very long term moods and extend over generations. This would fit with the model in which replicated amoebas have the 4-D magnetic body amoeba of the geometric past as part of their 4-D magnetic body.

To sum up, behaviors as conditionings could be caused by moods, which can last for several generations. This would bring in magnetic body as active agent. The representation genetic code in terms dark proton sequences and by 3-chords of dark photons would give a realization of both the "bitty" and emotional aspects of intelligence. Also the notions of 4-D brain and organism having temporal span of several generations as space-time surfaces would be essential for the understanding the inheritance of emotions. We should be very careful for what we do since also our children can feel themselves proud of or guilty for what we did.

E_8 symmetry, harmony, and genetic code

Bee gave in Facebook a link to an article about a connection between icosahedron and E_8 root system [B25] (see http://tinyurl.com/zotpm4b). The article (I have seen an article about the same idea earlier but forgotten it!) is very interesting.

The article talks about a connection between icosahedron and E_8 root system (see http://tinyurl.com/y7csb6uh). Icosahedral group has 120 elements and its double covering $2 \times 120 = 240$ elements. Remarkably, E_8 root system has 240 roots. E_8 Lie algebra is 248 complex-dimensional contains also the 8 commuting generators of Cartan algebra besides roots: it is essential that the fundamental representation of E_8 co-incides with its adjoint representation. The double covering group of icosahedral group acts as the Weyl group E_8 . A further crucial point is that the Clifford algebra in dimension D = 3 is 8-D.

One starts from the symmetries of 3-D icosahedron and ends up with 4-D root system F_4 assignable to Lie group and also to E_8 root system. E_8 defines a lattice in 8-D Euclidian space: what is intriguing that dimensions 3,4, 8 fundamental in TGD emerge. To me this looks fascinating - the reasons will be explained below.

1. What I might have understood

I try to explain what I have possibly understood.

- 1. The notion of root system is introduced. The negatives of roots are also roots but not other multiples. Root system is crystallographic if it allows a subset of roots (so called simple roots) such that all roots are expressible as combinations of these simple roots with coefficients having the same sign. Crystallographic root systems are special: they correspond to the fundamental weights of some Lie algebra. In this case the roots can be identified essentially as the quantum numbers of fundamental representations from which all other representations are obtained as tensor products. Root systems allow reflections as symmetries taking root system to itself. This symmetry group is known as Coxeter group and generalizes Weyl group. Both H_3 and H_4 are Coxeter groups but not Weyl groups.
- 2. 3-D root systems known as Platonic roots systems (A_3, B_3, H_3) assignable to the symmetries of tetrahedron, octahedron (or cube), and icosahedron (or dodecahedron) are constructed. The root systems consist of 3 suitably chosen unit vectors with square equal to 1 (square of reflection equals to one) and the Clifford algebra elements generated by them by standard Clifford algebra product. The resulting set has a structure of discrete group and is generated by reflections in hyper-planes defined by the roots just as Weyl group does. This group acts also on spinors and one obtains a double covering SU(2) of rotation group SO(3) and its discrete subgroups doubling the number of elements. Platonic symmetries correspond to the Coxeter groups for a "Platonic root system" generated by 3 unit vectors defining the basis of 3-D Clifford algebra. H_3 is not associated with any Lie algebra but A_3 and B_3 are.

Pinors (spinors) correspond to products of arbitrary/even number of Clifford algebra elements. Spinors induced orientation preserving transformations and pinos also orientation reversing ones. They mean something else than usually a bein identified as elements of the Clifford algebra acting and being acted on from left or right by multiplication so that they always behave like spin 1/2 objects since only the left(right)-most spin is counted. The automorphisms involve both right and left multiplication reducing to SO(3) action and see the entire spin of the Clifford algebra element.

- 3. The 3-D root systems (A_3, B_3, H_3) are shown to allow an extension to 4-D root systems known as (D_4, F_4, H_4) in terms of 3-D spinors. D_4 and F_4 are root systems of Lie algebras (see http://tinyurl.com/y97dzqc2). F_4 corresponds to non-simply-laced Lie group related to octonions. H_4 is not a root system of any Lie algebra.
- 4. The observation that the dimension of Clifford algebra of 3-D space is $2^3 = 8$ and thus allows embedding of at most 8-D root system must have inspired the idea that it might be possible to construct the root system of E_8 in 8-D Clifford algebra from 240 pinors of the double covering the 120 icosahedral reflections. Platonic solids would be behind all exceptional symmetry groups since E_6 and E_7 are subgroups of E_8 and the construction should give their root systems also as low-dimensional root systems.

2. McKay correspondence

The article explains also McKay correspondence stating that the finite subgroups of rotation group SU(2) correspond to simply laced affine algebras assignable with ADE Lie groups.

- 1. One considers the irreducible representations of a finite subgroup of the rotation group. Let the number of non-trivial representations be m so that by counting also the trivial representation one has m + 1 irreps altogether. In the Dynkin diagram of affine algebra of group with m-D Cartan algebra the trivial representation corresponds to the added node. One decomposes the tensor product of given irrep with the spin 2 representation into direct sum of irreps and constructs a diagram in which the node associated with the irrep is connected to those nodes for which corresponding representation appears in the direct sum. One can say that going between the connected nodes corresponds to forming a tensor product with the fundamental representation. It would be interesting to know what happens if one constructs analogous diagrams by considering finite subgroups of arbitrary Lie group and forming tensor products with the fundamental representation.
- 2. The surprising outcome is that the resulting diagram corresponds to a Dynkin diagram of affine (Kac-Moody) algebra of ADE group with Cartan algebra, whose dimension is m. Cartan algebra elements correspond to tensor powers of fundamental representation: can one build any physical picture from this? For m = 6, 7, 8 one obtains E_6 , E_7 , E_8 . The result of the article implies that these 3 Lie-groups correspond to basis of 3 3-D unit identified as units of Clifford algebra: could this identification have some concrete meaning as preferred non-orthogonal 3-basis?
- 3. McKay correspondence emerges also for inclusions of hyper-finite factors of type II_1 [K127] The integer m characterizing the index of inclusion corresponds to the dimensions of Cartan algebra for ADE type Lie group. The inclusions of hyperfinite factors (HFFs) are characterized by integer $m \ge 3$ giving the dimension of Cartan algebra of ADE Lie groups (there are also C, F and G type Lie groups). m = 6, 7, 8 corresponds to exceptional groups E_6 , E_7 , E_8 on one hand and to the discrete symmetry groups of tetrahedron, octahedron, icosahedron on the other hand acting as symmetries of corresponding 3-D non-crystallographic systems and not allowing interpretation as Weyl group of Lie group.

3. Connection with the TGD based model of harmony

These findings become really exciting from TGD point of view when one recalls that the model for bioharmony [K91] [L16] (see http://tinyurl.com/yad4tqwl) for 12-note harmonies central in classical music in general relies on icosahedral geometry. Bioharmonies would add something to the information content of the genetic code: DNA codons consisting of 3 letters A,T,C,G would correspond to 3-chords defining given harmony realized as dark photon 3-chords and maybe also in terms of ordinary audible 3-chords. This kind of harmonies would be roughly triplets of 3 basic harmonies and there would be 256 of them (the number depends on counting

criteria). The harmonies could serve as correlates for moods and emotional states in very general sense: even biomolecules could have "moods". This new information should be seen in biology. For instance, different alleles of same gene are known to have different phenotypes: could they correspond to different harmonies? In epigenetics the harmonies could serve as a central notion and allow to realize the conjectured epigenetic code and histone code. Magnetic body and dark matter at them would be of course the essential additional element.

The inspiring observations are that icosahedron has 12 vertices - the number of notes in 12-note harmony and 20 faces- the number of amino-acids and that DNA codons consist of three letters - the notes of 3-chord.

- 1. Given harmony would be defined by a particular representation of Pythagorean 12-note scale represented as self-non-intersecting path (Hamiltonian cycle) connecting the neighboring vertices of icosahedron and going through all 12 vertices. One assumes that neighboring vertices differ by one quint (frequency scaling by factor 3/2): quint scale indeed gives full octave when one projects to the basic octave. One obtains several realizations (in the sense of not being related by isometry of icosahedron) of 12-note scale. These realizations are characterized by symmetry groups mapping the chords of harmony to chords of the same harmony. These symmetry groups are subgroups of the icosahedral group: Z_6 , Z_4 , and two variants of Z_2 (generated by rotation of π and by reflection) appear. Each Hamiltonian cycle defines a particular notion of harmony with allowed 3-chords identified by the 20 triangles of icosahedron.
- 2. Pythagoras is trying to whisper me an unpleasant message: the quint cycle does not quite close! This is true. Musicologists have been suffering for two millenia of this problem. One must introduce 13th note differing only slightly from some note in the quint cycle. At geometrical level one must introduce tetrahedron besides icosahedron only four notes and four chords and gluing along one side to icosahedron gives only one note more. One can keep tetrahedron also as disjoint from icosahedron as it turns out: this would give 4-note harmony with 4 chords something much simpler that 12- note harmony.
- 3. The really astonishing discovery was that one can understand genetic code in this framework. First one takes three different types of 20-chord harmonies with group Z_6 , Z_4 , and Z_2 defined by Hamiltonian cycles: this can be done in many different maners (there are 256 of them). One has 20+20+20 chords and one finds that they correspond nicely to 20+20+20=60 DNA codons: DNA codons coding for a given amino-acid correspond to the orbit of the triangle assigned with the amino-acid under the symmetry group of harmony in question.

The problem is that there are 64 codons, not 60. The introduction of tetrahedron brings however 4 additional codons and gives 64 codons altogether. One can map the resulting 64 chord harmony to icosahedron with 20 triangles (aminoacids) and the degeneracies (number of DNA codons coding for given amino-acid in vertebrate code) come out correctly! Even the two additional troublesome amino-acids Pyl and Sec appearing in Nature and the presence of two variants of genetic code (relating to two kinds of Z_2 subgroups) can be understood.

4. What could the interpretation of the icosahedral symmetry?

An open problem is the proper interpretation of the icosahedral symmetry.

- 1. A reasonable looking guess would be that it quite concretely corresponds to a symmetry of some biomolecule: both icosahedral or dodecahedral geometry give rise to icosahedral symmetry. There are a lot of biomolecules with icosahedral symmetry, such as clathrate molecules at the axonal ends and viruses. Note that dodecahedral scale has 20 notes this might make sense for Eastern harmonies and 12 chords and there is only single dodecahedral Hamiltonian path found already by Hamilton and thus only single harmony. Duality between East and West might exist if there is mapping of icosahedral notes and to dodecahedral 5-chords and dodecahedral notes to icosahedral 3-chords and different notions of harmony are mapped to different notions of melody whatever the latter might mean!).
- 2. A more abstract approach tries to combine the above described pieces of wisdom together. The dynamical gauge group E_8 (or Kac-Moody group) emerging for m=8 inclusion of HFFs is

closely related to the inclusions for the fractal hierarchy of isomorphic sub-algebras of supersymplectic subalgebra. $h_{eff}/h = n$ could label the sub-algebras: the conformal weights of sub-algebra are be n-multiples of those of the entire algebra.

The integers n_i resp. n_f for included resp. including super conformal sub-algebra would be naturally related by $n_f = m \times n_i$. m = 8 would correspond to icosahedral inclusion and E_8 would be the dynamical gauge group characterizing dark gauge degrees of freedom. The inclusion hierarchy would allow to realize all ADE groups as dynamical gauge groups or more plausibly, as Kac-Moody type symmetry groups associated with dark matter and characterizing the degrees of freedom allowed by finite measurement resolution.

3. E_8 as dynamical gauge group or Kac-Moody group would result from the super-symplectic group by dividing it with its subgroup representing degrees of freedom below measurement resolution. E_8 could be the symmetry group of dark living matter. Bioharmonies as products of three fundamental harmonies could relate directly to the hierarchies of Planck constants and various generalized super-conformal symmetries of TGD! This convergence of totally different theory threads would be really nice!

5. Experimental indications for dynamical E_8 symmetry

Lubos (see http://tinyurl.com/htjp55h) (thanks to Ulla for the link to the posting of Lubos) has written posting about experimental finding of E_8 symmetry emerging near the quantum critical point of Ising chain at quantum criticality at zero temperature. Here is the abstract (see http://tinyurl.com/zulzk9y):

Quantum phase transitions take place between distinct phases of matter at zero temperature. Near the transition point, exotic quantum symmetries can emerge that govern the excitation spectrum of the system. A symmetry described by the E_8 Lie group with a spectrum of eight particles was long predicted to appear near the critical point of an Ising chain. We realize this system experimentally by using strong transverse magnetic fields to tune the quasi-one-dimensional Ising ferromagnet CoNb2O6 (cobalt niobate) through its critical point. Spin excitations are observed to change character from pairs of kinks in the ordered phase to spin-flips in the paramagnetic phase. Just below the critical field, the spin dynamics shows a fine structure with two sharp modes at low energies, in a ratio that approaches the golden mean predicted for the first two meson particles of the E8 spectrum. Our results demonstrate the power of symmetry to describe complex quantum behaviors.

Phase transition leads from ferromagnetic to paramagnetic phase and spin excitations as pairs of kinks are replaced with spin flips (shortest possible pair of kinks and loss of the ferromagnetic order). In attempts to interpret the situation in TGD context, one must however remember that dynamical E_8 is also predicted by standard physics so that one must be cautious in order to not draw too optimistic conclusions.

In TGD framework $h_{eff}/h \ge 1$ phases or phase transitions between them are associated with quantum criticality and it is encouraging that the system discussed is quantum critical and 1-dimensional.

- 1. The large value of h_{eff} would be associated with dark magnetic body assignable to the magnetic fields accompanying the E_8 "mesons". Zero temperature is not a prerequisite of quantum criticality in TGD framework.
- 2. One should clarify what quantum criticality exactly means in TGD framework. In positive energy ontology the notion of state becomes fuzzy at criticality. For instance, it is difficult to assign the above described "mesons" with either ferromagnetic or paramagnetic phase since they are most naturally associated with the phase change. Hence Zero Energy Ontology (ZEO) might show its power in the description of (quantum) critical phase transitions.

Quantum criticality could correspond to zero energy states for which the value of h_{eff} differs at the opposite boundaries of causal diamond (CD). Space-time surface between boundaries of CD would describe the transition classically. If so, then E_8 "mesons" would be genuinely 4-D objects - "transitons" - allowing proper description only in ZEO. This could apply quite generally to the excitations associated with quantum criticality. Living matter is key example of quantum criticality and here "transitons" could be seen as building bricks of behavioral patterns. Maybe it makes sense to speak even about Bose-Einstein condensates of "transitons".

The finding suggests that quantum criticality is associated with the transition increasing $n_{eff} = h_{eff}/h$ by factor m = 8 or its reversal - maybe the standard value $n_{eff}(i) = 1$. $n_{eff}(f) = 8$ could correspond to the ferromagnetic phase having long range correlations. Could one say that at the side of criticality (say the "lower" end of CD) the $n_{eff}(f) = 8$ excitations are pure gauge excitations and thus "below measurement resolution" but become real at the other side of criticality (the "upper" end of CD)?

3. The 8 "mesons" associated with spin excitations naturally correspond to the generators of the Cartan algebra of E_8 . If the "mesons" belong to the fundamental (= adjoint) representation of E_8 , one would expect 120+120 additional particles with non-vanishing E_8 charges. Why only Cartan algebra? Is the reasons that Cartan algebra is in preferred role in the representations of Kac-Moody algebras in that charged Kac-Moody generators can be constructed from Cartan algebra generators by standard construction used also in string models. Could this explain why one expects only 8 "mesons". Are charged "mesons" labelled by the elements of double covering of icosahedral group more difficult to excite?

4.4 Icosahedral harmonies

In the following the icosahedral harmonies are discussed in detail. This includes overall summary and tables giving the 20 3-chords of the harmonies and illustrations of the Hamiltonian cycles.

4.4.1 About symmetries of the icosahedral harmonies

Some words about the symmetries associated with the icosahedral harmonies and genetic code are in order.

There are 3 different kind of bio-harmonies characterized partially by the symmetry group which can be Z_6 , Z_4 or Z_2 which acts either as rotations or reflections.

- 1. The first variant as $Z_3^{rot} \times Z_2^{refl}$ subgroup of icosahedral group as symmetries and its orbits correspond to 3 6-plets and 1 2-plets for which Z_3 leaves the triangle invariant. The counterparts for the orbits are 3 DNA 6-plets and one 2-plet.
- 2. The second variant has Z_4 symmetry generated by two commuting reflection as symmetries as is obvious from figures ??, ??: the reflections act on vertical and horizontal coordinates. The orbits are five 4-plets of chords. Vertical reflection induces half-octave shift and horizontal one permutes the note sequences $B \triangleright CDG \ddagger F \ddagger E$ and $D \ddagger C \ddagger HFGA$.
- 3. Z_2^{rot} or Z_2^{refl} acts as symmetries of the remaining 3+5 cycles. The covering space of 10 amino-acids involved defined by 20 DNA codons decomposes to 10 2-plets.

The 2-fold rotation symmetry of the Hamiltonian cycles is obvious from the illustration ??: it corresponds to 6-quint rotation and the chord sets must be invariant under this rotation. This rotation corresponds to the 1/2 octave shift realized as rotation. These symmetries are realized as "coordinate transformations" for the cycle - a curve in the "embedding space" defined by icosahedron but induced from the "embedding space symmetries" acting as isometries of icosahedron.

DNA codons have also almost exact Z_2 symmetry discussed in [K122, K7, ?].

1. For the last codon the reflection A-T, C-G is an almost symmetry broken only for special cases. This approximate symmetry could be understood as following from the fact that the number of DNAs coding given amino-adic is even in most cases. The exceptions are ile, met, trp coded by odd number of DNA codons. By mapping DNAs to binary sequences one can order the situation so that the 6: th binary digit is the almost-symmetry digit.

2. What is trivial is that RNA has chosen the third bi-digit to be the almost symmetry digit with the ordering UCAG of the nucleotides so that a genuine physical symmetry is in question. An interesting question is how this symmetry relates to the model of genetic code based on tetra-icosahedral orbits.

The restriction of DNAs to 60 icosahedral DNAs demonstrates that this symmetry originates from the icosahedral Z_2 . The tetrahedral extension of the code breaks this symmetry by extending ile and punct multiples by one codon and introducing also 4 singlets met, trp, Pyl, and Sec.

The detailed correspondence between chords of the harmony and DNA codons is also a problem to be solved.

- 1. The correspondence matters in the proposed scenario since the chords at at the orbits are different and the gluing of tetrahedron breaks the symmetry in Z_2 sectors so that quint rule determining harmonic DNA sequences is different.
- 2. The common face of tetrahedron and icosahedron corresponds to punct so that the quint rule for different representations says something about the pairs of form codon-stop codon that is about the codon preceding the last codon of gene! This codon could allow to recognize what Hamiltonian cycle is in question. If C-major is one of the added chords, stop codons correspond to what was C6 = CGA chord and its Z_2 image, which is X7 type chord. By the strongest form of the quint rule only the chords having common notes with these chords would correspond to DNA codons of Z_6 and Z_4 cycles which can precede stopping codon.
- 3. There are some restrictions on the correspondence. Z_2^{refl} symmetry would correspond to the flipping of the 6th bit for the bit representation defined by nucleotides representing 2-bits in the case of $Z^3 = Z_3 \times Z_2^{refl}$. $Z_4 = Z_2^{rot} \times Z_2^{refl}$. For $Z_2 = Z_2^{rot}$ the role of Z_2^{refl} must be taken by Z_2^{rot} . One can of course ask whether Z_2^{rot} cycles are realized at all. For Z_4 cycles Z_2^{rot} would correspond to symmetry permuting the AT, CG doublets for the first nucleotide. For Z_6 subgroup Z_3 would cyclically permute the 3 doublets with respect to third nucleotide. These constraints do not fix the correspondence completely.

To sum up, there is a connection between genetic code and the groups acting along the Hamiltonian cycle. The simplest option fixes the orbits of the triangles and therefore also the representation of genetic code.

4.4.2 Summary of the basic results

One can find the list of Hamiltonian cycles at http://tinyurl.com/yacgzm9x. The edge $\{1,2\}$ is fixed and cycles are oriented so that there are 1024 of them. All of them are relevant from the point of music interpretation and the change of orientation corresponds to major-minor duality, albeit not in the simplest sense. Note that this duality does not affect the characteristics listed above.

The general following general results hold true as one can learn at http://tinyurl.com/ pmghcwd. One can classify the cycles using their symmetries which can correspond to isometries of icosahedron leaving them fixed or to a reflection taking the vertex n at the cycle to vertex 12 - n. This symmetry is not same as change of orientation which is purely internal operation and cannot change the cycle.

One can even find images of the cycles possessing symmetries at http://tinyurl.com/ y8ek7ak8 and deduce the triplets n and p characterizing them by visual inspection. Also one can write explicitly the 3-chords defined by the three kinds of faces. I have deduced the triplets nand the 3-chords defining the harmony by the inspection of the images. "Bio-harmony" (4, 8, 8) forced by the model of extended genetic code involving also the 21st and 22nd amino-acids is of special interest. The classes of cycles with symmetries 6-fold rotational symmetry and two distinct reflection symmetries realize it.

Before continuing some terminology and notation is in order. Take C as the major key. Submediant or relative minor corresponds to Am, subdominant (sharp or flat) to F major (F) or Fminor (Fm), dominant to G. The notation for chords is such that quints correspond to

$$\begin{array}{ll} CEG \equiv C &, & CD \sharp G \equiv Cm &, & CD \sharp F \sharp \equiv C^o &, & CEG \sharp \equiv Caug &, \\ CFG \equiv C4 &, & CF \sharp G \equiv C4_+ &, & CGG \sharp \equiv C6_- &, & CGA \equiv C6 &, \\ CGB\flat \equiv C7 &, & CGB \equiv Cmaj7 &, & CGC \sharp \equiv C9_- &, & CGD \equiv C9 &. \end{array}$$
(4.4.1)

Table 4.2: Notation of chords inspired by popular music notations.

subsequent notes in the chord. For 1-quint chords this means that first two notes define the quint. **Table 11.1** the notation inspired by the popular music notation. The basic different is that the third is in most cases excluded so that the emotional character of the chord is not fixed. Besides these notions it is convenient to introduce additional notations for various dissonant chords appearing as 0-quint chords.

$$CC\sharp D \equiv Cex1 , \quad CC\sharp D \sharp \equiv Cex2 , \quad CDD \sharp \equiv Cex3 , \quad CDE \equiv Cex4 , \\ CD\sharp E \equiv Cex5 , \quad CC\sharp E \equiv Cex6 , \quad CDF \sharp \equiv Cex7 , \quad CDG \sharp \equiv Cex8 .$$

$$(4.4.2)$$

Clearly, the sets $\{ex1\}$, $\{ex2, ex3\}$, $\{ex4, ex5, ex6\}$, $\{ex7\}$, $\{ex8\}$, corresponds to the span of 2, 3, 4, 6, 8 half notes for the chord. The following summarizes the results. Note that *Cex7* can be seen as part of *D*7 chord.

- 1. There are 6 collections of cycles without any symmetries containing 48 cycles each: these 48 cycle are mutually isometric so that one can say that there 6 different harmonies.
- 2. There is a collection with 6-fold rotational symmetry, 48/6=8 examples. n = (2, 12, 6). The chords of this scale define 6-note scale involving only total steps. CDF and its 6 translates by integer number of steps define 6 1-quint chords. $CE\flat G$ (Cm) and its 6 translates (they obviously correspond to the 6-fold rotational symmetry) define also 6 1-quint chords. The reflection transforms these series to those defined by $GB\flat G$ and its translate and by FAC (F major) and its translates. Impressionists like Debussy used 6-note scale of this kind. Half-octave shift is an exact symmetry. 1-chords lack the third so that one cannot assign to 3-chords any emotional quality. The extension to 4-chord can however bring either "happy" or "sad" quality. Clearly, these harmonies have "jazzy" character.

0-quint chords are $Faug \equiv FAC^{\sharp}$ and $Gaug \equiv GHD^{\sharp}$ are transformed to each other by both half-octave shift and inversion.

3. There are 2 collections with 2 distinct reflectional symmetries with 12=48/4 representatives in each. Half-octave scaling is a symmetry of both these scales as one might guess.

The first cycle (see Fig. ??) has n = (0, 16, 4) so that there are no 0-quint chords which in general are dissonant. Second cycle (see Fig. ??) realizes n = (4, 8, 8) bio-harmony and deserves some comments. It will be discussed in detail later.

- (a) The 8 2-quint chords consist of $B \flat FG \equiv B \flat 9$, C9, F9, G9 and their half-octave scalings. Clearly, the simple four-note scale appears here.
- (b) Using the popular notion introduced earlier 1-quint chords consist of two 4-plets Dmaj7, E9_, A7, A6 and G\$#maj7, B\$9_, D\$#7, D\$#6 related by half-octave shift. The harmony contains no "simple" major or minor chord and only the extension to tetrahedral harmony can provide them. The same is true for the second bio-harmony.
- (c) The 4 0-quint chords are $Cex3 \equiv CDD\sharp$ and $Eex2 \equiv EFG$ and their half-octave scalings $F\sharp ex3 \equiv F\sharp G\sharp A$ and $B\flat ex2 \equiv B\flat BC\sharp G$.
- 4. There are 3 collections with Z_2 rotational symmetry with 48/2 = 24 representatives in each. The triplets *n* are (0, 16, 4) (see **Fig.** ??), (2, 12, 6) (see **Fig.** ??), and (4, 8, 8) (see **Fig.** ??). All these harmonies are symmetric with respect to half-octave shift (tritonus), which obviously corresponds to the Z_2 rotation. Tritonus would not have been tolerated by catholic

church! This symmetry characterizes all 3 harmonies. Basic 3-chords do not contain pure minor and major chords. The reflection of the scale does not leave the collection of chords invariant but it is not clear whether this corresponds only to a change of scale, probably not.

Consider the (4, 8, 8) case (see Fig. ??).

- (a) The 8 2-quint chords appear as four-plet H9, C\$\$, D\$\$, F9 and its half octave shift (tritonus interval) acting as a symmetry of the harmony. 2-quint chords are always of type X⁹ (note that the third is missing) but also 1-quint chord can be of form X⁹ as explicit construction of chords demonstrates: I have denoted these 1-quint chords by symbol X4 (CDG is obviously equivalent with CDG).
- (b) Using the popular music notation introduced earlier, the 8 1-quint chords are D7, Amaj7, $A4_+$, E7 and their half-octave shifts $G\sharp7$, $D\sharp7$, $D\sharp4_+$, $B\flat7$.

No major and minor chords are included and only the extension to tetra-icosahedral harmony can provide them and also break the symmetry giving rise to well-defined key.

5. The four 0-quint chords appear in two types. $D \sharp ex2 \equiv D \sharp EF \sharp$ and its half-octave shift $Aex2 \equiv AB \flat C$ plus $Hex3 \equiv HC \sharp G$ and its half-octave shift $Fex3 \equiv FGC \sharp$. According to usual thinking these chords involve dissonances. This dissonance character is a rather general phenomenon for the harmonic loners and classical views about harmony would exclude them as asocial cases! In the case of maximally symmetric harmony the loners are diminished chords and thus not so dissonant. In some cases there are no 0-quint chords.

There are 5 collections with Z_2 reflection symmetry having 24 representatives in each (see **Figs.** ??, ??, ??, ??, ??, ??). The integer triplets *n* are (2, 12, 6), (2, 12, 6), (4, 10, 6), (2, 12, 6), (2, 12, 6). Bio-harmony has representative also in this class (see **Fig.** ??). The half-octave scaling symmetry is broken for these harmonies. I have not found simple characterization for the symmetry which corresponds to reflection in the direction of x-axis since it changes the interval structure of the chords.

Some comments (4, 8, 8) case are in order (see Fig. ??).

- 1. 2-quint chords appear as reflection related multiplets $C9, D9, H\sharp 9, D\sharp 9$ and $C\sharp 9, H9, F9, B\flat 9$.
- 2. 1-quint chords appear as symmetry related mutiplets G, D7, Amaj7, E7 and $C \sharp m, F \sharp 6, H6_-, E6$. Key G major and $C \sharp$ minor would be natural looking keys even without tetrahedral extension. For the mirror image $B\flat$ minor and E major would be the natural looking keys. For extension E major would be the key.

To sum up, half octave shift is a symmetry of all harmonies expected those having only Z_2 reflection symmetry, and fails thus also for the corresponding bio-harmonies.

4.4.3 Tables of basic 3-chords for the icosahedral harmonies with symmetries

The tables below give list for the three types of 3-chords for the 11 harmonies possessing symmetries. One must remember that the reversal of the orientation for the cycle induces the transformation $C \leftrightarrow C$, $F \sharp \leftrightarrow F \sharp$, $H \leftrightarrow C \sharp$, $F \leftrightarrow G$, $D \leftrightarrow B \flat$, $E \leftrightarrow G \sharp$, $A \leftrightarrow D \sharp$ and produces a new scale with minor type chords mapped to major type chords and vice versa. Also one must remember that all 3-chords except those which are simple majors or minors lack the third so that their emotional tone remains uncharacterized. For instance, C6 does could be replaced with Cm6 and G7 with Gm7. The reader can check the chords by direct inspection of the figures. The convention used is that vertex number one corresponds to C note.

$[\mathbf{(n_0,n_1,n_2)}]$	0-chords	1-chords	2-chords
(2, 12, 6)	(Faug, Gaug)	$(Cm, Dm, Em, F \sharp m, G \sharp m, B \flat m),$	$(C9, D9, E9, F\sharp 9, G\sharp 9, B\flat 9).$
		$(F6, G6, A6, B6, C \sharp 6, D \sharp 6).$	

Table 4.3: Table gives various types of 3-chords for harmonies with Z_6 rotational symmetry. Note that half-octave shift is an exat symmetry. Note that $G^{aug} = CEG\sharp$, F^{aug} act as bridges between the groups related by half octave shift. The chords have been arranged so that they form orbits of Z_6 . "Amino-acid chords" correspond to preferred chords at the orbits.

$(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})$	0-chords	1-chords	2-chords
(0, 16, 4)		$(D7, D6, G\sharp 7, G\sharp 6),$	$(B\flat 9, B9, E9, F9).$
		$(G4+, A9-, C\sharp 4+, D\sharp 9-),$	
		$(Emaj7, Gmaj7, Bbmaj7, C\sharp maj7),$	
		$(C9-, A9-, F\sharp 9-, D\sharp 9-).$	
(4, 8, 8)	$(Cex3, Eex2, F \sharp ex3, B \flat ex2).$	(Dmaj7, E9-, A7, A6),	$(B\flat 9, F9, C9, G9).$
		$(G \ddagger maj7, B \flat 9 -, D \ddagger 7, D \ddagger 6).$	$(E9, B9, F\sharp 9, C\sharp 9).$

Table 4.4: Table gives various types of 3-chords for the two harmonies with $Z_4 = Z_2^{rot} \times Z_2^{refl}$ symmetry. 4-plets represent the orbits. First cycle has no harmonic loners. Second cycle gives rise to bio-harmony (4, 8, 8) for which 0-quint chords are dissonant. Both cycles have Z_2 rotation symmetry acting as a vertical reflection symmetry in figures and realized also as half-octave shift so that 4-plets contains chords and their half-octave shifts. The genuine reflection symmetry acts as a horizontal reflection symmetry in figures. The cycles correspond to figures ??, ??

$\left \begin{array}{c} (n_0,n_1,n_2) \end{array} \right.$	0-chords	1-chords	2-chords
(0, 16, 4)		$(Em, B\flat m), (Cm, F\sharp m),$	$(D9, G\sharp 9),$
		$(G6, C\sharp 6), (A6, D\sharp 6),$	$(E9, B\flat 9).$
		$(D4+, G\sharp 4+), (B4+, F4+),$	
		$(Cmaj7, F \sharp maj7), (G6-, C \sharp 6-).$	
(2, 12, 6)	$(Aex4, D \sharp ex2).$	$(Am, D\sharp m), (G9-, C\sharp 9-),$	$(C9, F \sharp 9),$
		$(C4, F \sharp 4), (E4+, B\flat 4+),$	$(A9, D\sharp 9),$
		$(Dmaj7, G \sharp maj7),$	$(D9, G\sharp 9).$
		(Bmaj7, Fmaj7).	
(4, 8, 8)	(Aex2, Hex8, D # ex2, Fex8).	$(D7, G\sharp 7), (Amaj 7, D\sharp maj 7),$	$(G9, C\sharp 9), (A9, D\sharp 9),$
		$(A4+, D\sharp 4+), (E7, B\flat 7).$	$(B9, F9), (E9, B\flat 9).$

Table 4.5: Table gives various types of 3-chords for harmonies with Z_2 rotation symmetry acting as half-octave shift. The doublets represent 2-chord orbits. The cycles correspond to figures ??, ??, and ??.

$[(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})]$	0-chords	1-chords	2-chords
(2, 12, 6)	(F # ex3, Hex4),	$(Am, D\sharp), (A6, D\sharp7),$	$(C9, F9), (B9, F\sharp 9),$
		$(D7, B\flat 6), (G6-, Fmaj7),$	$(E9, C\sharp 9).$
		$(D4+, B\flat 9-), (E9-, G\sharp 4+),$	
(2, 12, 6)	(Dex4, Hex4).	(F, Fm), (C6-, Bbmaj7),	$(C9, D\sharp 9),$
		$(D7, G\sharp 6), (Gmaj7, D\sharp 6-).$	$(D\sharp 9, C\sharp 9),$
		$(C \sharp 4-, A4+), (E4+, F \sharp 6).$	(E9, B9).
(4, 8, 8)	(Fex1, D # ex3, G # ex1, A ex2).	(E7, E6), (Amaj7, B9-),	$(D9, B9), (C9, C\sharp 9),$
		$(G, C \sharp m), (D7, F \sharp 6).$	$(F9, G\sharp 9), (D\sharp 9, B\flat 9).$
(2, 12, 6)	(Hex3, Eex7).	$(D7, G\sharp 6), (G, D\sharp m),$	$(C9, D\sharp 9),$
		$(F, Fm), (C6-, B\flat maj7),$	$(D9, C\sharp 9),$
		$(A9-, C\sharp 4+), (E7, F\sharp 6).$	(E9, B9).
(2, 12, 6)	(F # ex2, Fex3).	$(F, B\flat m), (C7, G\sharp 6),$	$(B\flat 9, D\sharp 9),$
		(Amaj7, B9-), (E6, E7),	$(C9, C\sharp 9),$
		$(G, C \sharp m), (D7, B6).$	(D9, H9).

Table 4.6: Table gives various types of 3-chords for harmonies with single reflection symmetry. The cycles correspond to figures ??, ??, ??, ??, ??.

4.5 New results related to the notion of bio-harmony

This section contains some new results related to music harmony. During 2018 some new results related to the model of bio-harmony emerged. In the sequel they are collected together.

Remark :In the sequel I will use the shorthand AA for amino-acids and shorthands DDNA, DRNA, DtRNA, DAA for the dark analogs of DNA, RNA, tRNA, and AA realizes as dark proton sequences with codon represented as dark proton triplet.

4.5.1 Summary of the background

For some years ago I developed a model of music harmony [L16] (see http://tinyurl.com/ yad4tqwl), which should define map of dark codons to 3-chords represented as dark photon triplets and defining allowed 3-chords of music harmony (music of light and perhaps also of sound). The Appendix provides the tables describing the details of the harmonies.

1. The model relies on the geometries of icosahedron and tetrahedron and representation of 12-note scale as so called Hamiltonian cycle at icosahedron going through all 12 vertices of icosahedron [A19, A7, A16, A5, A12]. The 20 faces correspond to allowed 3-chords for harmony defined by given Hamiltonian cycle. This brings in mind 20 AAs.

Single step of Hamiltonian cycle connecting vertices of a face of icosahedron (triangle) is assume to correspond to a scaling of the frequency by factor 3/2. This leads to a problem since 12 scalings of this kind does not quite given 7 octaves which reduced octave equivalence to the basic octave would give 12-note scale. The solution is to add single note slightly differing from 7 octaves and represented as vertex P of a tetrahedron glued to icosahedron along face. The Hamilton cycles are deformed so that they begin and end from this vertex. This also gives the missing 4 DNA codons realized as 3-chords and also defines unique ground note for the scales.

2. One obtains 3 basic types of harmonies depending on whether the symmetries of icosahedron leaving the shape of the Hamiltonian cycle is Z_6 , Z_4 or Z_2 . For Z_2 there are two options: $Z_{2,rot}$ is generated by rotation of π and $Z_{2,refl}$ by reflection with respect to a median of equilateral triangle.

Combining together one harmony from each type one obtains union of 3 harmonies and if there are no common chords between the harmonies, one has 20+20+20 3-chords and a strong resemblance with the code table. To given AA one assigns the orbit of given face under icosahedral isometries so that codons correspond to the points of the orbit and orbit to the corresponding AA. 4 chords are however missing from 64. These one obtains by adding tetrahedron. One can glue it to icosahedron along chosen face or keep is disjoint. The model predicts a highly unique and realistic model for numbers of DNA codons coding for a given AA. The model in its original form predicts two codes and also explains the fact that there are two additional AAs Pyl and Sec that appear as end-products.

- 3. AAs correspond to single 20-codon code, DNA and RNA to a union of 3 20-codon codes with symmetries Z_6 , Z_4 or Z_2 : here Z_2 would correspond to $Z_{2,rot}$ or $Z_{2,refl}$ and this would give to two two different codes.
- 4. The model in its original form predicts 256 different harmonies with 64 3-chords defining the harmony. DNA codon sequences would be analogous to sequences of chords, pieces of music. Same applies to mRNA.

Music expresses and creates emotions and the natural proposal is that these bio-harmonies correlate with moods that would appear already at molecular level. They could be realized in terms of dark photon triplets realized in terms of light and perhaps even music (living matter is full of piezo-electrets). In fact, also the emotions generated by other art forms could be realized using music of dark light. [L84]. Dark photons in various wavelength ranges and correspond to various values of h_{eff} would correspond to various sensory qualia and are represented at pineal gland ("third eye") as imagined sensory percepts [L57]. They can be transformed to real sensory percepts at sensory organs by using DMT molecules as bridges allowing the propagation of dark photons (or the bio-photons resulting in their energy conserving transformation to ordinary photons) to sensory organs, where they generate genuine sensory experience identified as dream, psychedelic experience, hallucination, etc...

The model of music harmony is separate from the model of genetic code based on dark proton triplets [L36] and one of the challenges has been to demonstrate that they are equivalent. One can raise several questions.

- 1. Could the number of harmonies be actually larger than 256 as the original model predicts? One could rotate the 3 fused Hamilton's cycles with respect to each by icosahedral rotations other leaving the face shared by icosahedron and tetrahedron invariant. There are however conditions to be satisfied.
 - (a) There is purely mathematical restriction. If the fused 3 harmonies have no common 3-chords the number of coded AAs is 20. Can one give up the condition of having no common 3-chords and only require that the number of coded AAs is 20.
 - (b) There is also the question about the chemical realizability of the harmony. Is it possible to have DNA and RNA molecules to which the 3-chords of several harmonies couple resonantly? This could leave only very few realizable harmonies.
- 2. The model predicts the representation of DNA and RNA codons as 3-chords. Melody is also an important aspect of music. Could AAs couple resonantly to the sums of the frequencies (modulo octave equivalence) of the 3-chords for codons coding for given AA?
- 3. As I developed the model of bio-harmony [L16] (see http://tinyurl.com/yad4tqwl) it did not occur to me that also the tRNA part of the dark code should have counterpart in the icosahedral model. Could tRNA correspond to pairs of harmonies with 20+20+4=44codons? What about single 20+4=24 codon representation as kind of pre-tRNA? Could tRNA correspond to a union of 2 20-codon codes? Combining only 2 20-codon codes with 40 codons and tetrahedral code with 4 codons would give maximally 44-letter code and the upper bound for tRNAs is according to Wikipedia 45! Dark proton model predicts 40 DtRNAs suggesting that only the 40 isosahedral codons contribute to DtRNA code. The additional tRNAs could result from homonymy. The code sequences could be seen as a hierarchical sequence $3 \rightarrow 2 \rightarrow 1$ in this framework.

An important implication is that there are many realizations of DtRNA and tRNA harmony: (Z_6, Z_4) , (Z_6, Z_2) , (Z_4, Z_2) and Z_2 could be either $Z_{2,rot}$ or $Z_{2,refl}$. This could explain the homonymy of mRNA-tRNA pairing via difference in the chords in turn affecting biochemical

counterparts. Note however that the chords for tRNA must be a subset of chords for mRNA so that RNA harmony determines tRNA harmony apart from the three choices (Z_6, Z_4) , (Z_6, Z_2) or (Z_4, Z_2) giving rise to 3 different contexts. If DAAs code by 3-chords the AAs then this choice does not affect AAs.

- 4. What is the origin of 12-note scale? Does genetic code force it? The affirmative answer to this question relies on the observation that 1-1 correspondence between codons and triplets of photons requires that the frequency assignable to the letter must depend on its position. This gives just 12 notes altogether. Simple symmetry arguments fix the correspondence between codons and 3-chords highly uniquely: only 4 alternatives are possible so that it would be possible to listen what DNA sequences sounds in given mood characterized by the harmony.
- 5. What disharmony could mean? A possible answer comes from 6 Hamiltonian cycles having no symmetries. These disharmonies could express "negative" emotions.

4.5.2 Some questions about the realization of the bio-harmony

In the sequel by I will proceed by posing questions related to the relationship between the 3 representations of genetic code [K122] in terms of bio-molecules, their dark analogs represented as sequences dark proton triplets, and as 3-3-chords of bio-harmony.

What conditions pairings pose on the frequency triplets?

The realization of DDNA-DtRNA and DDNA-DAA pairings in terms of frequencies must involve a loss of information since the correspondence is many-to-one.

- 1. For DNA-mRNA pairing information is not lost and the pairing must be of form $(f_1, f_2, f_3) \rightarrow (f_1, f_2, f_3)$. Note that the frequencies cannot be associated with the letters. It is however possible to consider the assignment of (f_1, f_2) to the first letter pair XY as a whole and f_3 to the third letter Z.
- 2. For DDNA-DAA and DmRNA-DAA pairing the natural hypothesis is $(f_1, f_2, f_3) \rightarrow f_1 + f_2 + f_3$. AA couples to the sum of the frequencies of the triplet. The simplest possibility is that the $f_1 + f_2 + f_3$ is same for all codons codin for given AA. One might say that AA sequence defines melody and mRNA sequence the accompaniment. If the sums for codons coding given AA are different they must couple resonantly to it. If there are several harmonies the sum must same for all realizable 3-harmonies or all chords of 3-chord harmonies coding for same AA couple to it resonantly. Since one has linear 1-D structures one might ask whether frequency differences coming as multiples of lattice frequencies are allowed. Second natural possibility is octave equivalence. mRNA-AA pairing would take place directly rather than with the mediation of of tRNA.
- 3. In the case of DmRNA-DtRNA pairing one one does not lose so much information since the number of dark DNAs is 40 (as also the 3-chords if tetrahedron does not contribute). One must remember that tRNAs are pairs of RNA like codons - call them RNA_t, and AAs. Therefore there pairing involves also the pairing mRNA-AA give by $(f_1, f_2, f_3) \rightarrow f_1 + f_2 + f_3$ and guaranteeing that the code is realized by this pairing alone irrespective of mRNA-RNA_t pairing. At chemical level the first to mRNA codons pair with tRNA anticodons according to the standard rules. Could RNA_t have completely passive role in carrying the AA? This cannot be the case since the last two letters of RNA_t couple in standard manner to the first two letters of mRNA.

Remark: tRNA is analogous to melody + accompaniment using one of the 3 possible 2-harmonies for a given 3-harmony.

Suppose that mRNA-RNA_t pairing corresponds to 3 possible choices of 2-harmonies as subharmonies of 3-harmony. This would suggest these different sub-harmonies define maps $(f_1, f_2, f_3) \rightarrow (f_1, f_2, f_3)$ such that RNA_t pairs only with two sub-harmonies. For each choice RNA_t would correspond effectively to 40 sub-codons of the entire code (forgetting the tetrahedral part giving 4 additional codons). The three different realizations of the projection would give rise to the homonymy. Also the AA-trNA coupling would come out correctly. DAAs would be different in the sense that they couple only to the sum of the frequencies. This is in accordance with bio-harmony in which AAs correspond to orbits of 3-chords for DNA under isometries rather than single 20-chord harmony. The coupling to the sum of frequencies is in accordance with the quantal interpretation as 3-dark-photon state whose energy is $E = h_{eff}(f_1 + f_2 + f_3)$ and couples to AA chemically via the transition to ordinary photons with the same energy.

This leaves some questions.

- 1. Could one consider the possibility that the chords of one of the 20-chord harmonies corresponds to AAs? There would be 3 basic types of AAs. This does not look plausible and the association of AAs with the orbits of 20-note chords is more natural and fits nicely with $f = f_{XYZ}$ picture.
- 2. It would be nice to assign notes to the individual letters of codons. This is not possible since codons with 2 or 3 identical letters would reduce to 2-chords or 1-chords. It is also impossible to assign frequencies with letters at dark level since letter decomposition does not exist. Thus the 3-chord has resonant interaction with the entire codon.
- 3. The symmetries of the genetic code however suggest that it might make sense to treat the first two letters XY of the codon as a single unit and the third letter as separate single unit. Could one assign to XY a 2-chord not reducible to frequencies for the letters X and Y, and to letter Z its own frequency. The frequencies of A, G, T, C as third letter must be different. Four 32 codons of standard code the AA would not be sensitive to the frequency of Z: this is possible if these frequencies are resonance frequencies of the same AA. For the remaining 32 codons the AA would not distinguish between frequencies of T and C *resp.* A and G so that the two frequencies would be both resonance frequencies of the corresponding AA.

Probabilistic estimates for single 20-chord harmony

One can make first some naïve probabilistic estimates about single 20-chord harmony.

- 1. Given 20-chord harmony makes $20/220 = 1/11 \simeq 9$ per cent about al possible 3-chords. Three 20 chord harmonies would make $3 \times 9 = 27$ per cent about all possible 3-chords if there are no common chords so that the optimistic expectation might make sense. Of course, one cannot exclude the possibility that there are also triplets of 20-codon codes which gives smaller number of codons.
- 2. The total number of chords with different notes is $12 \times 11 \times /3! = 220$. Bio-harmony has 64 chords corresponding to faces of icosahedron: this is about 64/220 making 29 per cent of all possible 3-chords with different notes. Given bio-harmony thus throws out roughly 2/3 of all possible codons. This should be easy to test. For instance, does given gene correspond to a fixed bioharmony? Or does even entire genome do so. If bio-harmony is realized for non-nuclear genomes, it must satisfy rather strong constraints.
- 3. Given 20-chord harmony corresponds to 12 edges. Each edge is shared by two adjacent triangles. If all 20 triangles would contain just single face, there would be 24 triangles altogether. Therefore there must be triangles containing two subsequent edges of the cycle. Each triangle of this kind reduces the number of 24 neighbours by 2 units. Hence it seems that one must have at least 2 triangles with 2 edges at the cycle (two quints in the 3-chord).

If there are more than 2 triangles of this kind, there must be triangles having no edges along the path. Each vertex of icosahedron is shared by 5 triangles and there are 5 edges starting from it.

4. The notion of Hamilton cycle generalizes to any graph and magnetic flux tube networks define such graphs as tensor networks. Why only icosahedron? Could one consider the possibility that any tensor network is characterized by harmonies characterize by Hamiltonian cycles and that one could assign some kind of codes with the combinations of these cycles? In the general case symmetries would be absent so that the notion of code in the proposed sense would fail: one could not identified codons as points at orbits of symmetry group. Rather, one can imagine that the notion of code could be defined quite generally in terms of orbits as AAs and points at them as DNAs coding them. For regular polygons in any dimension the symmetries are present and one could define the notion of code and also fuse the codes.

For arbitrary tensor network the faces need not be symmetry related and one can also have faces that can be interpreted as higher-dimensional polytopes.

One can also ask whether the icosahedron is realized physically. Icosahedral geometry is indeed very common in biology. Could the fusion of icosahedral and tetrahedral geometries have some concrete realization at molecular level?

Is the maximal number of codons for the fusion of 3 20-codon codes possible?

It has not earlier occurred to me to wonder whether the chords associated with the 3-different icosahedral harmonies giving 20 codons each correspond to 20+20+20=60 different chords as assumed. Could there be common 3-chords? This question could be answered by studying the Hamiltonian cycles at icosahedron.

Remark: Perhaps more important constraint than absence of common chords is the chemical realizability of the codes. If same mRNAs and DNAs realized different bio-harmonies then they must be able to respond resonantly to several 3-chords.

One can make naïve probability estimates for a pair of codes to allow the maximal number of 60 codons. It seems natural to assume that the isometries of icosahedron (or their subgroup) can be applied separately and only the isometries acting on both in similar manner are symmetries. The situation would be the same as in the case of many-particle system: only the translations acting on all particles simultaneously remain symmetries and relative translations cease to be symmetries.

With this assumption the icosahedral group gives a large number of code pairs. For the fusion of 3 20-codon codes giving DNA/RNA the number is even higher. By choosing suitably the relative isometries it might be possible to obtain the maximal number of 60 different codons for the icosahedral genetic code. On the other hand, by a suitably choice of relative isometries one might have undesired common 3-chords. In any case, the earlier estimate 256 for the number of bio-harmonies [L16] suggested to correlate with "emotional" states of the basic biomolecules is expected to change.

Before going to estimates one must consider some delicacies related to the notion of 12-note scale as Hamiltonian cycle.

- 1. One can regard the cycles as purely geometric objects without orientation or assign to them orientation. For two different orientations the scales would run in opposite directions as scalings by 3/2 along single edge of the cycle. If two codes have common edge, the scaling must be same along it. If the orientation of the second cycle is changed, the common edge ceases to be common.
- 2. The basic note of the 12-note scale at cycle can be chosen arbitrarily: this corresponds to the choice of the key in music (one could of course argue that the key does not make sense in 12-note scale if one has tempered scale with notes comes as powers of $2^{1/2}$ scaling of ground note rather than Pythagorean scale with rational ratios of notes).

The fusion of tetrahedron to icosahedron selects one particular triangular face and brings in one additional vertex outside the icosahedron, call it P. It would be natural to assign the ground note as P. The isometries not affecting P would correspond to those of icosahedron leaving the common face invariant and isometries of tetrahedron leaving P un-affected and continuable to icosahedral isometries. One would have subgroup of icosahedral group as allowed isometries acting on the cycles to be fused.

- 3. If one assigns note sequences to the cycle by quint rule, cycles C_1 and C_2 can have common triangle in geometric sense but if the distances of the vertices A, B, C of the triangles from P measured as the number of edges of cycle portion connecting them are not same along C_1 and C_2 , the triangles correspond to different chords and are thus orthogonal in the proposed description as many-fermion states.
- 4. To sum up, the states associated with triangles would be characterize by the position of triangle (20 values), by the notes of the triangle characterized by the distances from P, and

the number 0, 1, 2 of the edges belonging to the cycle and should make easier to find ortogonal basis.

Again one can make probabilistic estimates: cycles are treated as purely geometric entities without orientation and without assignment of notes to the triangles.

- 1. Given cycles C_1 and C_2 what is the probability that they have at least one common edge as purely geometric entities without the sequence of notes? There are 30 edges so that given edge is shared with probability 1/30. If the edges of cycles were chosen randomly (certainly not true), the probability of having a common edge for two cycles would be P(1) = 12/30. The assumption of note sequence reduces this probability dramatically.
- 2. By the above estimate each cycle contains at least two triangles with 2 edges at the cycle with minimal angle between them. One can call these these edge pairs V-corners. Assume that for cycle C_1 one has V-corner ABC at vertex A, call it $V_{1,A}$. What is the probability that one one of the V-corners of C_2 is located at A co-incides with ABC. The probability of V-corner of C_2 to locate at A is 1/12 and the probability that the edge of C_2 from B is BC is is 1/4 so that the probability of having common V-corner is 1/48. If C_2 contains n V-edges the probability is naïvely n/48.

This estimate takes into account only geometry. The situation changes if one assumes that the cycles are oriented. In this case one can have common V-corner if the local orientations of C_1 and C_2 are opposite at the V-corner. If one assumes that the external vertex P of the tetrahedron defines the ground note then the number of edges connecting P to A defining distance d(P, A) must be same for C_1 and C_2 .

3. Given C_1 and C_2 (and vertices A with same distance d(P, A)) it might be possible to perform suitable isometry for C_2 that there is common V-corner. Therefore not all possible combinations of three code types allowing relative isometries need not maximal number of 3-chords.

Remark: An interesting question is whether these can be allowed meaning that some codons are missing in the chemical realization of the dark codons in terms of ordinary DNA codons. Also the 1-1 pairing between dark DNA and and dark RNA would not be 1-1 if mediated by 3-chord resonance and one would have homonymy. This suggests that only codes without common chords can be allowed.

- 4. What about chords having 1 edge at cycle for two cycles C_1 and C_2 ? Let the edge be AB. As found, the naïve probability for this is P(1) = 12/30. Both cycles must go through the third vertex C of the triangular face. The subsequent notes along cycle differ by a quint that is scaling of the frequency by factor 3/2. Notes are same if the numbers of the needed quints are same for C_1 and C_2 For C_1 the number $n_B > 1$ of quints is known. In the approximation that possible portions of C_1 represent *n*-step non-self-intersecting random walks from B to C, one must estimate the number of all non-self-intersecting *n*-step-paths from B to C and find what is the number of the paths leading to C. One can go from A to C with n_A steps and similar estimate applies.
- 5. The third possibility is that the one has 3 common vertices A, B, C forming a triangular face such that neither cycle contains any of its edges.

The cautious conclusion is that it is plausible that one can find 3 cycles having no common chords if one allows relative rotations of the cycles and that this condition is necessary for realizing the absence of homonymies at dark level. The automatic orthogonality of the Hamiltonian cycles cannot be excluded but would allow also codes with codons containing more than 3 letters so that one could have kind of super-DNA. Whether they can be realized chemically depends on whether there are biomolecules resonating with the the n frequency triplets involved. Octave equivalence for frequencies might give hopes about chemical realization of several harmonies. Therefore the evolution might be seen as gradual emergence of molecules able to pair with DDNA and one can even imagine artificial evolution by tailoring the frequencies involved (maybe cyclotron frequencies).

How the symmetries of the model of harmony could relate to those of the genetic code?

Genetic code has surprisingly strong symmetries. I have discussed a possible interpretation of these symmetries using analogies with particle physics and considered also a mechanism explaining their emergence earlier [K7, ?]. The proposal was that 3-letter code emerged as a fusion of 2-letter code with 16 codons and 1-letter coded with 4 codons. In the recent framework, a more natural option is that the third codon of 3-letter code was originally passive and became active via symmetry breaking distinguishing first between UC and AG pairs and later between U and C *resp.* A and G. Note that for the standard code the breaking is minimal and caused by odd number of Start and Stop codons.

- 1. For vertebrate code one half of codons has very high symmetry in the sense that the two first letters dictate the AA for 32 cases. Exception is UUU, which codes for Phe or Leu for some modifications of the standard code. UUU \rightarrow Leu means breaking of maximal symmetry.
- 2. There is also a second symmetry, which I have referred to as isospin symmetry. It is only slightly broken. For general codons XYU and XYC code for same AA as also XYA and ad XYG. For the standard code this symmetry is broken only in columns containing initiation codon or stop. The Start codon AUG codes also for met. UGA and UGG code for Stop and Trp. For the remaining codons one has slightly broken "isospin symmetry". The breaking of isospin symmetry is minimal for vertebrate code. The modifications of the code tend to break the isospin symmetry and even the maximal symmetry of 32 codons. This must be important.

If the model of genetic code based on music harmony [L16] is correct, the symmetries for the model of music harmony must relate to those of genetic code.

1. How the symmetries of the genetic code relate to the symmetries of icosahedron (60-element group) and tetrahedron (permutation group S_4 with 24 elements) in the model of bioharmony? Icosahedral symmetry group has 60 elements and has sub-groups $Z_2, Z_4, Z_5, Z_6 = Z_2Z_3$. Note that there are two Z_2 :s having rotation by π and reflection as generators.

The gluing of tetrahedron to icosahedral along single face reduces its group of symmetries to S_3 leaving the point P not belonging to icosahedron invariant. S_3 has as subgroups reflection group $Z_{2,refl}$ and Z_4 consisting of rotations.

2. What is the counterpart for maximal symmetry in icosahedral and tetrahedral groups? Do the 3-chords for codon XYZ decompose to two-chord characterizing XY and a note characterizing Z= A,U,C,G, which can depend on XY. The symmetry relating UC pair and AC pair could correspond to $Z_{2,refl}$ reflection symmetry, which is shared by icosahedral and tetrahedral groups. For 32 icosahedral codons the action of $Z_{2,refl} \times Z_{2,rot}$ would be trivial so that AA would not depend on the third letter at all. For most of the remaining codons the action of the symmetry group on icosahedral codons would reduce to $Z_{2,rot}$ permuting the third letters U and C resp. A and G. At the level of frequencies the sums of frequencies for codons coding for the same AA sould be same modulo octave equivalence.

The addition of tetrahedron brings in 4 tetrahedral codons with one of them shared with icosahedron. Icosahedral $Z_{2,rot}$ does not make sense for these codons. Intriguingly, there are 4 codons in vertebrate code which break isospin symmetry AUA and AUG coding for I and Met/start and UGA and UGG coding for Stop and Trp. If these codons correspond to the tetrahedral codons which cannot have $Z_{2,rot}$ as isospin symmetry, the breaking of $Z_{2,rot}$ would follow from the breaking of symmetry induced by the attachment of tetrahedron to icosahedron.

What is the origin of 12-note scale?

One fundamental question is why dark photon realization of genetic code should involve 12-note scale as icosahedral model requires.

Remark: The gluing of tetrahedral codons gives 4 additional codons but if tetrahedron is glued to icosahedron along one of its faces, the additional vertex gives only one additional note,

which should be very near to the 12:th one. This could relate to the basic problem observed already by Pythagoras that 12-note Pythagorean scale with rational valued frequency ratios does not quite close.

A popular article in Spacedaily with title "Scientists crack how primordial life on Earth might have replicated itself" (see http://tinyurl.com/y92ng5vd) led to a possible answer to the above question. The research paper [I83] is titled "Ribozyme-catalysed RNA synthesis using triplet building blocks" and published in eLife (see http://tinyurl.com/ya5qyjfn).

It is possible to replicate unfolded RNA strands in Lab by using enzymes known as ribozymes, which are RNA counterparts of enzymes, which are amino-adic sequences. In the presence of folding the replication is however impossible. Since ribozymes are in general folded, they cannot thus catalyze their own replication in this manner. The researchers however discovered that the replication using RNA triplets - genetic codons - as basic unit can be carried out in laboratory even for the folded RNA strands and with rather low error rate. Also the ribozyme involved can thus replicate in codon-wise manner. For units longer than 3 nucleotides the replication becomes prone to errors.

These findings are highly interesting in TGD framework. In TGD the chemical realization of genetic code is not fundamental. Rather, dark matter level would provide the fundamental realizations of analogs of DNA, RNA, tRNA, and amino-acids as dark proton sequences giving rise to dark nuclei at magnetic flux tubes [L77] (see http://tinyurl.com/yalny39x). Also ordinary nuclei correspond in TGD Universe to sequences of protons and neutrons forming string like entities assignable to magnetic flux tubes.

The basic unit representing DNA, RNA and tRNA codon and amino-acid would consist of 3 entangled dark protons. The essential aspect is that by entanglement the dark codons do not decompose to products of letters. This is like words of some languages, which do not allow decomposition to letters. This representation is holistic. As we learn to read and write, we learn the more analytic western view about words as letter sequences. Could the same hold true in evolution so that RNA triplets would have come first as entities pairing with dark RNA codons from from dark proton triplets as a whole? Later DNA codons would have emerged and paired with dark DNA codons. Now the coupling would have have been letter by letter in DNA replication and transcription to mRNA.

It is intriguing that tRNA consists of RNA triplets combined from amino-acids and analogs of mRNA triplets! The translation of mRNA to amino-acids having no 3-letter decomposition alone forces the holistic view but one can ask whether something deeper is involved. This might be the case. I have been wondering whether during RNA era RNA replicated using a prebiotic form of translational machinery, which replicated mRNA rather than translated RNA to protein formed from amino-acids (AAs) with AA serving as a catalyst.

- 1. During RNA era amino-acids associated with pre-tRNA molecules would served as catalysts for replication of RNA codons. The linguistic mode would have been "holistic" during RNA era in accordance with the findings of the above experiments. RNA codon would have been the basic unit.
- 2. This would have led to a smaller number of RNAs since RNA and RNA like molecules in tRNA are not in 1-1 correspondence. A more realistic option could have been replication of subset of RNA molecules appearing in tRNA in this manner.
- 3. Then a great evolutionary leap leading from RNA era to DNA era would have occurred. AA catalyzed replication of RNA would have transformed to a translation of RNA to proteins and the roles of RNA and AA in tRNA would have changed. [Perhaps the increase of h_{eff} in some relevant structure as quantum criticality was reached led to the revolution]
- 4. At this step also (subset of) DNA and its transcription to (a subset of) mRNA corresponding to tRNA had to emerge to produce mRNA in transcription. In the recent biology DNA replicates and is transcribed nucleotide by nucleotide rather than using codon as a unit so that helicases and DNA and RNA polymerases catalyzing replication and transcription should have emerged at this step. The ability of DNA to unwind with the help of helicase enzyme helping DNA to unwind is essential for the transcription and translation of DNA. Therefore helicase must have emerged together with the "analytic linguistic mode" as an analog of

written language (DNA) decomposing codons to triplets of letters. This would been a crucial step in evolution comparable to the emergence of written language based on letters. Also the counterpart of RNA polymerase and separate RNA nucleotides for transcription should have emerged if not already present.

An alternative option would involve "tDNA" as the analog of tRNA and the emergence of helicase and polymerases later as the transition from holistic to analytic mode took place.

The minimal picture would be emergence of a subset of DNA codons corresponding to RNAs associated with pre-tRNA and the emergence of the analogs of helicase and DNA and RNA polymerases as the roles of amino-acid and RNA codon in tRNA were changed.

5. How DNA could have emerged from RNA? The chemical change would have been essentially the replacement of ribose with de-oxiribose to get DNA from RNA and $U \rightarrow T$. Single O-H in ribose was replaced with H. O forms hydrogen bonds with water and this had to change the hydrogen bonding characteristics of RNA.

If the change of $h_{eff} = n \times h_0$ was involved, could it have led to stabilization of DNA? Did cell membrane emerge and allow to achieve this? I have proposed [L77] (see http: //tinyurl.com/yalny39x) that the emergence of cell membrane meant the emergence of new representation of dark genetic code based on dark nuclei with larger value of h_{eff} .

Remark: One has $h = 6 \times h_0$ in the most plausible scenario [L41, L83] (see http://tinyurl.com/goruuzm and http://tinyurl.com/y9jxyjns).

One can of course ask whether something simpler could be imagined by utilizing the potential provided by dark variants of bio-molecules present already from beginning and providing both genes and metabolism simultaneously.

1. Viruses are probable precedessors of cellular life. So called positive sense single stranded RNA (ssRNA) associated with viruses can form temporarily double strands and in this state replicate just like DNA (see http://tinyurl.com/yc5f8b3t). The resulting single stranded RNA can in turn be translated to proteins by using ribosomal machinery. RNA replication takes place in so called viral replication complexes associated with internal cell membranes, and is catalyzed by proteins produced by both virus and host cell.

Could ribozyme molecules have catalyzed RNA replication during RNA era? For this option AA translation would have emerged later and the storage of genetic information to DNA only after that. There is however the question about the emergence of AAs and of course, DNA and RNA. Which selected just them from enormous variety of options.

- 2. Lipid membranes are formed by self-organization process from lipids and emerge spontaneously without the help of genetic machinery. It would be surprising if prebiotic life would not have utilized this possibility. This idea leads to the notion of lipid life as a precedessor of RNA life. In this scenario metabolism would have preceded genes (see http://tinyurl.com/ y7ehv8cq and http://tinyurl.com/y8nltb9e). The basic objection against both genes-first and metabolism-first options is that they need each other!
- 3. In TGD framework the dark variants of DNA, RNA, AA, and tRNA would provide the analogs of genes and all basic biomolecules. They would also provide a mechanism of metabolism in which energy feed by (say) solar radiation creates so called exclusion zones (EZs) of Pollack [L20] in water bounded by a hydrophilic substance. EZs are negatively charged regions of water giving rise to a potential gradient (analog of battery) storing chemically the energy provided by sunlight and the formation of these regions gives rise to dark nuclei at magnetic flux tubes with scaled down binding energy.

When the p-adic length scale of these dark nuclei is liberated binding energy is liberated as metabolic energy so that metabolic energy feed giving basically rise to states with nonstandard value $h_{eff}/h = n$ of Planck constant is possible. For instance, processes like protein folding and muscle contraction could correspond to this kind of reduction of h_{eff} liberating energy and also a transformation of dark protons to ordinary protons and disappearance of EZs. The cell interiors are negatively charged and this is presumably true for the interiors of lipid membranes in general and they would therefore correspond to EZs with part of protons at magnetic flux tubes as dark nuclei representing dark variants of basic biomolecules. Already this could have made possible metabolism, the chemical storage of metabolic energy to a potential gradient over the lipid membrane, and also the storing of the genetic information to dark variants of biomolecules at the magnetic flux tubes formed in Pollack effect.

4. In TGD framework biochemistry would have gradually learned to mimic dark variants of basic processes as a kind of shadow dynamics. Lipid membranes could have formed spontaneously in water already during prebiotic phase when only dark variants of DNA, RNA, AAs and tRNA, water, and lipids and some simple bio-molecules could have been present. The dark variants of replication, transcription and translation would have been present from the beginning and would still provide the templates for these processes at the level of biochemistry.

Dark-dark pairing would rely on resonant frequency pairing by dark photons and darkordinary pairing to resonant energy pairing involving transformation of dark photon to ordinary photon. The direct pairing of basic biomolecules with their dark variants by resonance mechanism could have led to their selection explaining the puzzle of why so few biomolecules survived.

This is in contrast with the usual view in which the emergence of proteins would have required the emergence of translation machinery in turn requiring enzymes as catalyzers so that one ends up with hen-or-egg question: which came first, the translation machinery or proteins. In RNA life option similar problem emerges since RNA replication must be catalyzed by ribozymes.

5. Gradually DNA, RNA, tRNA, and AA would have emerged by pairing with their dark variants by resonance mechanism. The presence of lipid membranes could have been crucial in catalyzing this pairing. Later ribozymes could have catalyzed RNA replication by the above mentioned mechanism during RNA era: note however that the process could be only a shadow of much simpler replication for dark DNA. One can even imagine membrane RNAs as analogs of membrane proteins serving as receptors giving rise to ionic channels. Note however that in TGD framework membrane proteins could have emerged very early via their pairing with dark AA associated with the membrane. These membrane proteins and their RNA counterparts could have evolved into transcription and translation machineries.

DNA molecules would have emerged through pairing with dark DNA molecules. The difference between deoxi-ribose and ribose would correspond to the difference between dark RNA and dark DNA manifesting as different cyclotron frequencies and energies making possible the resonant pairing for frequencies and energies. Proteins would have emerged as those proteins able to pair resonantly with dark variants of amino-acid sequences without any pre-existing translational machinery. It is difficult to say in which order the basic biomolecules would have emerged. They could have emerged even simultaneously by resonant pairing with their dark variants.

The communication between dark ordinary variants of biomolecules involves resonance mechanism and would also involve genetic code represented as 3-chords, music of light, and it is interesting to see whether this model provides additional insights.

- 1. The proposal is that 3-chords assignable to nucleotides as music of light with allowed 64 chords defining what I have called bio-harmony is essential for the resonance [L84, L87, L83](see http://tinyurl.com/ydhxen4g, http://tinyurl.com/yd5t82gq, and http://tinyurl.com/y9jxyjns). The 3 frequencies must be identical in the resonance: this is like turning 3 knobs in radio. This 3-fold resonance would correspond to the analytic mode. The second mode could be holistic in the sense that it would involve only the sum only the sum of the 3 frequencies modulo octave equivalence assigning a melody to a sequence of 3-chords.
- 2. The proposal is that amino-acids having no triplet decomposition are holistic and couple to the sum of 3 frequencies assignable to tRNA and mRNA in this manner. Also the RNAs in

tRNA could couple to mRNA in this manner. One could perhaps say that tRNA, mRNA and amino-acids codons sing whereas DNA provides the accompaniment proceeding as 3-chords. The couplings of DNA nucleotides to RNA nucleotides would rely on the frequencies assignable to nucleotides.

- 3. If the sum of any 3 frequencies associated with mRNA codons is not the same except when the codons code for the same amino-acids, the representation of 3-chords with the sum of the notes is faithful. The frequencies to DNA and RNA nucleotides cannot be however independent of codons since the codons differing only by a permutation of letters would correspond to the same frequency and therefore code for the same amino-acid. Hence the information about the entire codon would be needed also in transcription and translation and could be provided either by dark DNA strand associated with DNA strand or by the interactions between the nucleotides of the DNA codon.
- 4. The DNA codon itself would know that it is associated with dark codon and the frequencies assignable to nucleotides could be determined by the dark DNA codon. It would be enough that the frequency of the letter depends on its position in the codon so that there would be 3 frequencies for every letter: 12 frequencies altogether.

What puts bells ringing is that this the number of notes in 12-note scale for which the model of bio-harmony [L16, L84] (see http://tinyurl.com/yad4tqwl and http://tinyurl.com/ydhxen4g) based on the fusion of icosahedral (12 vertices and 20 triangular faces) and tetrahedral geometries by gluing icosahedron and tetrahedron along one face, provides a model as Hamiltonian cycle and produces genetic code as a by-product. Different Hamiltonian cycles define different harmonies identified as correlates for molecular moods.

Does each DNA nucleotide respond to 3 different frequencies coding for its position in the codon and do the 4 nucleotides give rise to the 12 notes of 12-note scale? There are many choices for the triplets but a good guess is that the intervals between the notes of triplet are same and that fourth note added to the triplet would be the first one to realize octave equivalence. This gives uniquely $CEG\sharp, C\sharp FA, DF\sharp B\flat$, and $DG\sharp B$ as the triplets assignable to the nucleotides. The emergence of 12-note scale in this manner would be a new element in the model of bio-harmony.

There are 4!=24 options for the correspondence between $\{A, T, C, G\}$ as the first letter and $\{C, C\sharp, D, D\sharp\}$. One can reduce this number by a simple argument.

(a) Letters and their conjugates form pyrimidine-purine pairs T, A and C, G. The square of conjugation is identity transformation. The replacement of note with note defining at distance of half-octave satisfies this condition (half-octave - tritonus - was a cursed interval in ancient music and the sound of ambulance realizes it). Conjugation could correspond to a transformation of 3-chords defined as

$$CEG \ddagger \leftrightarrow DF \ddagger B \flat \ , \ C \ddagger FA \leftrightarrow D \ddagger GB \ .$$

(b) One could have

$$\begin{array}{ll} \{T,C\} \leftrightarrow \{CEG \sharp, C \sharp FA\} &, & \{A,G\} \leftrightarrow \{DF \sharp B \flat, D \sharp GB\} \\ & \text{or} \\ \{T,C\} \leftrightarrow \{DF \sharp B \flat, D \sharp GB\} &, & \{A,G\} \leftrightarrow \{CEG \sharp, C \sharp FA\} \end{array}.$$

(c) One can permute T and C and A and G in these correspondences. This leaves 8 alternative options. Fixing the order of the image of (T, C) to say $(C, C\sharp)$ fixes the order of the image of (A, G) to $(D, D\sharp)$ by the half-octave conjugation. This leaves 4 choices. Given the bio-harmony and having chosen one of these 4 options one could therefore check what given DNA sequence sounds as a sequence of 3-chords [L16].

That the position the frequency associated with the nucleotide depends on its position in the codon would also reflect the biochemistry of the codon and this kind of dependence would be natural. In particular, different frequencies associated with the first and third codon would reflect the parity breaking defining orientation for DNA.

What disharmony could mean?

Harmonies - also those, which are sad (consider only passions of Bach) - are usually thought of as something beautiful. Could negative emotions really correspond to any bio-harmonies characterized by symmetries. In a discussion with Sini Kunnas I realized that also the notion of disharmony could make sense. There are indeed 6 Hamiltonian cycles without any symmetries [A7, A12, A5]. I neglected them in the model of harmony because they would represent which one might call disharmony. Could one of the contributing 3 Hamiltonian cycles in bio-harmony correspond to this kind of dis-harmony and bring in 20 3-chords without any symmetries? If so the relationship between geometry and aesthetics would become very concrete. The alternative view would be that there are several harmonies realized simultaneously and thi creates disharmony.

The faces of the icosahedron belonging to the orbits of the symmetries of the harmony correspond to DNA codons coding for the same AA assignable to the orbit. The fact that there are no symmetries for these 6 bio-disharmonies, suggests one-to-one correspondence between DNA and AAs if also stop codon corresponds to ordinary AA.

How to concretely realize emotions as music of light?

Music expresses emotions and also create higher level emotions. As all art, it also induces experience of beauty. Since $h_{eff}/h = n$ [?, K85] serves as a kind of IQ in the evolutionary hierarchy, there are good reasons to expect that the emotions/feelings induced by music and other art forms are assignable to MB.

The dynamics of MB involves oscillations characterized by frequencies and in EEG frequencies are of key importance for the part of MB outside biological body. The communications from cell membrane to MB involve modulation of EEG frequencies identified as generalized Josephson frequencies by nerve pulse patterns [K92] and would define a coding of sensory data to higher level emotions. The control signals from MB via DNA inducing gene expression would use dark photons at cyclotron frequencies to control BB. How to realize the music of genes represented as sequences of 3-chords of dark light as a communication tool between dark and ordinary DNA/RNA and possibly even dark and ordinary variants of tRNA and amino-acids?

- 1. Communication between ordinary and dark matter levels must be possible. This is guaranteed if the transition energy spectra at different levels of $h_{eff}/h = n$ hierarchy contain common transition energies so that a resonant interaction by exchange of dark photons becomes possible. This condition is extremely demanding and could explain why basic bio-molecules are selected amongst numerous alternatives [L77] - this is indeed one of the hen-egg problems of pre-biotic evolution.
- 2. A hypothesis worth of studying is that the cyclotron transition energies of both ordinary DNA and RNA nucleotides and their dark variants represented as dark proton sequences are same [L77]. Cyclotron transition energies should cover several octaves and the natural proposal is that magnetic field strength associated with the flux tube codes for the notes. In music experience roughly 10 octaves are needed corresponding to the range of audible sounds.
- 3. The cyclotron frequencies of DNA nucleotides A, T, C, G are very nearly the same and near 1 Hz for $B = B_{end} = .2$ Gauss since their masses do not differ much. Since the nucleotides are negatively charged, also the cyclotron energies for codons and codon sequences are around 1 Hz. $h_{eff} = h_{gr}$ hypothesis states that the cyclotron energies of DNA are in the energy range of bio-photons in visible and UV [K85, K20, K31] [L83].

There should be correspondences between a) the 64 ordinary DNA codons and allowed 3-chords and b) 64 dark variants of DNA codons and allowed 3-chords. These correspondences fix that between ordinary and dark codons. One would have triality.

1. To realize music of genes one the value of B must have values in a range of several octaves. The magnetic field strengths B associated with the flux tubes accompanying DNA strand should have a spectrum given by 12-note scale. Both 64 dark DNA codons and $4^3 = 64$ ordinary DNA codons should correspond to 20 + 20 + 20 + 4 = 64 allowed 3-chords formed from the notes of 12-note scale.

2. Dark codons correspond to entangled states of 3 dark protons. The positions of dark protons are different so that ermutations of the positions of dark protons are involved. The invariance of 3-chord under permutations of notes would correspond to fermionic statistics. These permutations are lifted to braidings if dark protons are connected by flux tubes to some other system, for instance ordinary DNA.

If the dark protons are ordered linearly along flux tube, it would seem that these these positions correspond to those of ordinary code letters. This does not make sense. If the letters of codon are connected to the dark protons by flux tubes, the permutations of dark codons induce braiding of the flux tubes but do not affect the order of the letters of the ordinary codon. Braiding would become an essential part of the correspondence between ordinary and dark codons.

3. One should understand the correspondence of dark codons with the allowed 3-chords of a given harmony and also with the ordinary DNA codons. Bio-harmony is defined as a composite of 3 harmonies with 20 allowed 3-chords and having symmetries Z_6 , Z_4 , and Z_2 and of tetrahedral harmony with 4 chords. Tetrahedron can be regarded as disjoint object or attached to DNA, and this gives two variants of code.

How could these the icosa-tetra-hedral Hamilton cycles relate to the physical realization of dark proton triplets? Each icosahedral cycle should give rise to 20 dark proton triplets. Why the icosahedral geometry with Hamiltonian cycle should make itself manifest in the quantum physics of dark proton triplet?

4. Could icosahedral geometry quite concretely correspond to a tensor network? The vertices of the icosahedron would be connected by a sequence of flux tubes connecting nearest neighbors to form a Hamiltonian cycle. Dark proton triplets would quite concretely be localized at the triangular faces of the icosahedron.

Braided triplet of flux tubes would emerge from the vertices of an icosahedral triangle defining 3-chord and would connect it to the nucleotides of the corresponding ordinary DNA codon. Magnetic field strengths at these flux tubes would correspond to the notes of 12-note scale as defined by the Hamiltonian cycle in question. The permutations of the dark proton states at the vertices of the triangle would induce braidings of the flux tube triplet actually defining minimal braid in topological quantum computation (sic!) The braiding accompanying the states of 3 dark protons would make the correspondence with ordinary ordered DNA codons possible.

Note that each dark proton triplet could be also connected (without braiding) to its conjugate dark proton triplet by a triplet of flux tubes so that one would obtain closed flux loops and one could speak of knots instead of braids.

Remark: Braiding brings strongly in mind the many TGD inspired proposals for DNA as topological quantum computer [K7, K122]: maybe DNA as topological quantum computer could be (also?) realized in this manner.

What physical objects could the 20 vertices of icosahedron correspond to? Hydrogen bonded water clusters give rise to both tetrahedral and icosahedral structures. Could one associate dark proton triplets to the dark parts of these structures? Could one try to experimentally identity possible sequence of icosahedral water molecule clusters with vertices connected by hydrogen bonds associated with the DNA sequence? If the hydrogen bonds correspond to flux loops as suggested, they can be rather long (proportional to $h_{eff}/h = n$) so that even distant water molecules can become hydrogen bonds and one could have a fractal hierarchy of icosahedra.

5. Resonance condition suggests that at the level of ordinary DNA double strand the cyclotron energies of dark protons associated with the hydrogen bonds connecting DNA nucleotides correspond to those of flux tube triplets connecting ordinary and dark DNA codons. The magnetic field strengths associated with the dark flux tubes accompanying hydrogen bonds would correspond to those associated with the triangles of icosahedral triangle. This would make possible communication between the two dark sectors by dark-photon triplets as music of genes. This leaves unanswered questions.

- 1. Why the 20+20=60 3-chords from 3 harmonies with different icosahedral symmetries (Z_6, Z_4, Z_2) and 4 chords from tetrahedral harmony would combine to form single bioharmony with 64 chords? This requires the presence of 3 Hamiltonian cycles with different symmetries. Why all three different symmetry types for DNA and RNA? Could the 20 amino-acids correspond to single symmetry type? Could tRNA codons correspond to two symmetry types?
- 2. How the 3-chords of dark photons could be played? 3-chord should be a collective effect affecting both dark and ordinary codon by inducing emission of 3-photon state like like playing a chord by string instrument. The notes of the light chord need not emerge simultaneously but as arpeggios. Could there be a pulse travelling along the Hamiltonian cycle and picking all the cyclotron notes at the vertices containing dark proton and sending a cyclotron signal along flux tubes to ordinary DNA codon. This pulse would travel along dark DNA and play the music defined by dark DNA sequence.

4.5.3 Can one imagine a modification of bio-harmony?

The model for how one can understand how 12-note scale can represent 64 genetic codons has the basic property that each note belongs to 16 chords. The reason is that there are 3 disjoint sets of notes and given 3-chord is obtained by taking 1 note from each set. For bio-harmony obtained as union of 3 icosahedral harmonies and tetrahedral harmony note typically belongs to 15 chords. The representation in terms of frequencies requires 16 chords per note.

If one wants consistency one must somehow modify the model of icosahedral harmony. The necessity to introduce tetrahedron for one of the 3 fused harmonies is indeed an ugly looking feature of the model. The question is whether one of the harmonies could be replaced with some other harmony with 12 notes and 24 chords. If this would work one would have 64 chords equal to the number of genetic codons and 5+5+6=16 chords per note. The addition of tetrahedron would not be needed.

One can imagine toric variants of icosahedral harmonies realized in terms of Hamiltonian cycles and one indeed obtains a toric harmony with 12 notes and 24 3-chords. Bio-harmony could correspond to the fusion of 2 icosahedral harmonies with 20 chords and toric harmony with 24 chords having therefore 64 chords. Whether the predictions for the numbers of codons coding for given amino-acids come out correctly for some choices of Hamiltonian cycles is still unclear. This would require an explicit construction of toric Hamiltonian cycles.

Previous results

Before discussing the possible role of toric harmonies some previous results will be summarized.

1. Icosahedral bio-harmonies

The model of bio-harmony [L16, L92] starts from a model for music harmony as a Hamiltonian cycle at icosahedron having 12 vertices identified as 12 notes and 20 triangular faces defining the allowed chords of the harmony. The identification is determined by a Hamiltonian cycle going once through each vertex of icosahedron and consisting of edges of the icosahedral tessellation of sphere (analog of lattice): each edge corresponds to quint that is scaling of the frequency of the note by factor 3/2 (or by factor $2^{7/12}$ in well-tempered scale). This identification assigns to each triangle of the icosahedron a 3-chord. The 20 faces of icosahedron define therefore the allowed 3-chords of the harmony. There exists quite a large number of icosahedral Hamiltonian cycles and thus harmonies.

The fact that the number of chords is 20 - the number of amino-acids - leads to the question whether one might somehow understand genetic code and 64 DNA codons in this framework. By combining 3 icosahedral harmonies with different symmetry groups identified as subgroups of the icosahedral group, one obtains harmonies with 60 3-chords.

The DNA codons coding for given amino-acid are identified as triangles (3-chords) at the orbit of triangle representing the amino-acid under the symmetry group of the Hamiltonian cycle.

The predictions for the numbers of DNAs coding given amino-acid are highly suggestive for the vertebrate genetic code.

By gluing to the icosahedron tetrahedron along common face one obtains 4 more codons and two slightly different codes are the outcome. Also the 2 amino-acids Pyl and Sec can be understood. One can also regard the tetrahedral 4 chord harmony as additional harmony so that one would have fusion of four harmonies. One can of course criticize the addition of tetrahedron as a dirty trick to get genetic code.

The explicit study of the chords of bio-harmony however shows that the chords do not contain the 3-chords of the standard harmonies familiar from classical music (say major and minor scale and corresponding chords). Garage band experimentation with random sequences of chords requiring conservability that two subsequent chords have at least one common note however shows that these harmonies are - at least to my opinion - aesthetically feasible although somewhat boring.

2. Explanation for the number 12 of notes of 12-note scale

One also ends up to an argument explaining the number 12 for the notes of the 12-note scale [L92]. There is also second representation of genetic code provided by dark proton triplets. The dark proton triplets representing dark genetic codons are in one-one correspondence with ordinary DNA codons. Also amino-acids, RNA and tRNA have analogs as states of 3 dark protons. The number of tRNAs is predicted to be 40.

The dark codons represent entangled states of protons and one cannot decompose them into a product state. The only manner to assign to the 3-chord representing the triplet ordinary DNA codon such that each letter in {A,T,C,G} corresponds to a frequency is to assume that the frequency depends on the position of the letter in the codon. One has altogether $3 \times 4 = 12$ frequencies corresponding to 3 positions for given letter selected from four letters.

Without additional conditions any decomposition of 12 notes of the scale to 3 disjoint groups of 4 notes is possible and possible chords are obtained by choosing one note from each group. The most symmetric choice assigns to the 4 letters the notes $\{C, C\sharp, D, D\sharp\}$ in the first position, $\{E, F, F\sharp, G\}$ in the second position, and $\{G\sharp, A, B\flat, B\}$ in the third position. The codons of type XXX would correspond to $CEG\sharp$ or its transpose. One can transpose this proposal and there are 4 non-quivalent transposes, which could be seen as analogs of music keys.

Remark: CEG between C-major and A-minor very often finishes finnish tango: something neither sad nor glad!

One can look what kind of chords one obtains.

- 1. Chords containing notes associated with the same position in codon are not possible.
- 2. Given note belongs to 6 chords. In the icosahedral harmony with 20 chords given note belongs to 5 chords (there are 5 triangles containing given vertex). Therefore the harmony in question cannot be equivalent with 20-chord icosahedral harmony. Neither can the bio-harmony with 64 chords satisfy the condition that given note is contained by 6 3-chords.
- 3. First and second notes of the chords are separated by at least major third as also those second and third notes. The chords satisfy however octave equivalence so that the distance between the first and third notes can be smaller even half step and one finds that one can get the basic chords A-minor scale: Am, Dm, E7, and also G and F. Also the basic chords of F-major scale can be represented. Also the transposes of these scales by 2 whole steps can be represented so that one obtains $A_m, C\sharp_m, F_m$ and corresponding major scales. These harmonies could allow the harmonies of classical and popular music.

These observations encourage to ask whether a representation of the new harmonies as Hamiltonian cycles of some tessellation could exist. The tessellation should be such that 6 triangles meet at given vertex. Triangular tessellation of torus having interpretation in terms of a planar parallelogram (or perhaps more general planar region) with edges at the boundary suitable identified to obtain torus topology seems to be the natural option. Clearly this region would correspond to a planar lattice with periodic boundary conditions.

Is it possible to have toric harmonies?

The basic question is whether one can have a representation of the new candidate for harmonies in terms of a tessellation of torus having V = 12 vertices and F = 20 triangular faces. The reading of the article "Equivelar maps on the torus" [A22] (see http://tinyurl.com/ya6g9kwe) discussing toric tessellations makes clear that this is impossible. One however have (V, F) = (12, 24) (see http://tinyurl.com/y7xfromc). A rather promising realization of the genetic code in terms of bio-harmony would be as a fusion of two icosahedral harmonies and toric harmony with (V, F) = (12, 24). This in principle allows also to have 24 3-chords which can realize classical harmony (major/minor scale).

- 1. The local properties of the tessellations for any topology are characterized by a pair (m, n) of positive integers. m is the number of edges meeting in given vertex (valence) and n is the number of edges and vertices for the face. Now one has (m, n) = (6, 3). The dual of this tessellation is hexagonal tessellation (m, n) = (3, 6) obtained by defining vertices as centers of the triangles so that faces become vertices and vice versa.
- 2. The rule V E + F = 2(1 g) h, where V, E and F are the numbers of vertices, edges, and faces, relates V E F to the topology of the graph, which in the recent case is triangular tessellation. g is the genus of the surface at which the triangulation is im eded and h is the number of holes in it. In case of torus one would have E = V + F giving in the recent case E = 36 for (V, F) = (12, 24) (see http://tinyurl.com/y7xfromc) whereas in the icosahedral case one has E = 32.
- 3. This kind of tessellations are obtained by applying periodic boundary conditions to triangular lattices in plane defining parallelogram. The intuitive expectation is that this lattices can be labelled by two integers (m, n) characterizing the lengths of the sides of the parallelogram plus angle between two sides: this angle defines the conformal equivalence class of torus. One can also introduce two unit vectors e_1 and e_2 characterizing the conformal equivalence class of torus.

Second naïve expectation is that $m \times n \times sin(\theta)$ represents the area of the parallelogram. $sin(\theta)$ equals to the length of the exterior product $|e_1 \times e_2| = sin(\theta)$ representing twice the area of the triangle so that there would be $2m \times n$ triangular faces. The division of the planar lattice by group generated by $pe_1 + qe_2$ defines boundary conditions. Besides this the rotation group Z_6 acts as analog for the symmetries of a unit cell in lattice. This naïve expectation need not of course be strictly correct.

4. As noticed, it is not possible to have triangular toric tessellations with (V, E, F) = (12, 30, 20). Torus however has a triangular tessellation with (V, E, F) = (12, 36, 24). An illustration of the tessellation can be found at http://tinyurl.com/y7xfromc. It allows to count visually the numbers V, E, F, and the identifications of the boundary edges and vertices. With good visual imagination one might even try to guess what Hamiltonian cycles look like.

The triangular tessellations and their hexagonal duals are characterized partially by a pair of integers (a, b) and (b, a). a and b must both even or odd (see http://tinyurl.com/y7xfromc). The number of faces is $F = (a^2 + 3b^2)/2$. For (a, b) = (6, 2) one indeed has V = 12 and F = 24. From the article [A22] (see http://tinyurl.com/ya6g9kwe) one learns that the number of triangles satisfies F = 2V for p = q at least. If F = 2V holds true more generally one has $V = (a^2 + 3b^2)/4$, giving a tight constraints on a and b.

Remark: The conventions for the labelling of torus tessellation vary. The above convention based on integers (a, b) used in the illustrations at http://tinyurl.com/y7xfromc is different from the convention based on integer pair (p,q) used in [A22]. In this notation torus tessellation with (V, F) = (12, 24) corresponds to (p,q) = (2, 2) instead of (a,b) = (6,2). This requires (a,b) = (3p,q). With these conventions one has $V = p^2 + q^2 + pq$.

1. The number of triangles in the 12-vertex tessellation is 24: curse or blessing?

One could see as a problem that one has F = 24 > 20? Or is this a problem?

1. By fusing two icosahedral harmonies and one toric harmony one would obtain a harmony with 20+20+24 =64 chords, the number of DNA codons! One would replace the fusion of 3 icosahedral harmonies and tetrahedral harmony with a fusion of 2 icosahedral harmonies and toric harmony. Icosahedral symmetry with toric symmetry associated with the third harmony would be replaced with a smaller toric symmetry. Note however that the attachment of tetrahedron to a fixed icosahedral face also breaks icosahedral symmetry.

This raises questions. Could the presence of the toric harmony somehow relate to the almost exact $U \leftrightarrow C$ and $A \leftrightarrow G$ symmetries of the third letter of codons. This does not of course mean that one could associated the toric harmony with the third letter. Note that in the icosa-tetrahedral model the three harmonies are assumed to have no common chords. Same non-trivial assumption is needed also now in order to obtain 64 codons.

- 2. What about the number of amino-acids: could it be 24 corresponding ordinary aminoacids, stopping sign plus 3 additional exotic amino-acids. The 20 icosahedral triangles can correspond to amino-acids but not to stopping sign. Could it be that one of the additional codons in 24 corresponds to stopping sign and two exotic amino-acids Pyl and Sec appearing in biosystems explained by the icosahedral model in terms of a variant of the genetic code. There indeed exists even third exotic amino-acid! N-formylmethionine (see http://tinyurl.com/jsphvgt) but is usually regarded as as a form of methionine rather than as a separate proteinogenic amino-acid.
- 3. Recall that the problem related to the icosa-tetrahedral harmony is that it does not contains the chords of what might be called classical harmonies (the chords assignable to major and minor scales). If 24 chords of bio-harmony correspond to toric harmony, one could obtain these chords if the chords in question are chords obtainable by the proposed construction.

But is this construction consistent with the representation of 64 chords by taking to each chord one note from 3 disjoint groups of 4 notes in which each note belongs to 16 chords. The maximum number of chords that note can belong to would be 5+5+6=16 as desired. If there are no common chords between the 3 harmonies the conditions is satisfied. Using for instance 3 toric representations the number would be 6+6+6=18 and would require dropping some chords.

4. The earlier model for tRNA as fusion of two icosahedral codes predicting 20+20=40 tRNA codons. Now tRNAs as fusion of two harmonies allows two basic options depending on whether both harmonies are icosahedral or whether second harmony is toric. These options would give 20+20=40 or 20+24=44 tRNAs. Wikipedia tells that maximum number is 41. Some sources however tell that there are 20-40 different tRNAs in bacterial cells and as many as 50-100 in plant and animal cells.

2. A more detailed model for toric harmonies

One can consider also more detailed model for toric harmonies.

- 1. The above discussed representation in terms of frequencies assigned with nucleotides depending on their position requires the decomposition of the notes to 3 disjoint groups of 4 notes. This means decomposition of 12 vertices of Hamiltonian cycle to 4 disjoint groups such that within given group the distances between the members of group are larger than one unit so that they cannot belong to same triangle. There are $Bin(12, 4) \times Bin(8, 4)$ decomposition to 3 disjoint groups of for vertices, where Bn(n, k) = n!/(n-k)!k! is binomial coefficient.
- 2. Once the Hamiltonian cycle has been fixed and is one assumes that single step along cycle corresponds to quint, one knows what the notes associated with each vertex is and given the note of the 12-note scale one knows the number $0 \le n < 12$ of quint steps needed to obtain it. For instance, for the proposed grouping $\{C, C\sharp, D, D\sharp\}$ and its two transposes by 2 hole steps one can assign 4 integers to each group. The condition is that within each group the notes labelled by the integers have minimum distance of 2 units between themselves.
- 3. One could try to understand the situation in terms of the symmetries of the system.

- (a) Could the triplet {C, E, G♯} and its four translates be interpreted as Z₃ orbits. Could suitable chosen members from 4 disjoint quartets quite general form Z₃ orbits. **Remark**: Particle physicists notes the analogy with 4 color triplets formed by u and d quarks having spin 1/2. Z₄ would correspond to spin and color spin and Z₃ to color.
- (b) Z_4 acts as symmetries of the tessellation considered and these symmetries respect distances so that their action on a quartet with members having mutual distances larger than unit creates new such quartet. Could the triplet $\{C, E, G\sharp\}$ and its four translates by an *n*-multiple of half note, n = 0, 1, 2, 3 correspond to an orbit Z_4 ? Could the groups of 4 notes quite generally correspond to the orbits of Z_4 ? This can

Could the groups of 4 notes quite generally correspond to the orbits of Z_4 ? This can be true only if the action of non-trivial Z_4 elements relates only vertices with distance larger than one unit.

4. The group of isometries of the toric triangulation acts as symmetries. $Z_{24} = Z_6 \times Z_4$ is a good candidate for this group. Z_6 corresponds to the rotations of around given point of triangulation and should leave the tessellation invariant. The orbit of given triangle defining the set of DNA codons coding the amino-acid represented by the orbit would correspond to orbit of subgroups of Z_{24} . Only orbits containing orbits containing 1,2,3,4 or 6 triangles are allowed by the degeneracies of the genetic code. These numbers would correspond to degeneracies that is the numbers of codons coding for given amino-acid. All these numbers appear as degeneracies.

3. What one can say about toric Hamiltonian cycles?

First some basic notions are in order. The graph is said to be equivelar if it is a triangulation of a surface meaning that it has 6 edges emanating from each vertex and each face has 3 vertices and 3 edges [A22]. Equivelarity is equivalent with the following conditions;

- 1. Every vertex is 6-valent.
- 2. The edge graph is 6-connected.
- 3. The graph has vertex transitive automorphism group.
- 4. The graph can be obtained as a quotient of the universal covering tessellation (3,6) by a sublattice (subgroup of translation group). 6-connectedness means that one can decompose the tessellation into two disconnected pieces by removing 6 or more vertices
- 5. Edge graph is *n*-connected if the elimation of k < n vertices leaves it connected. It is known that every 5-connected triangulation of torus is Hamiltonian [A48] (see http://tinyurl. com/y7cartk2). Therefore also 6-connected $(6,3)_{p=2,q=2}$ tessellation has Hamiltonian cycles.
- 6. The Hamiltonian cycles for the dual tessellation are not in any sense duals of those for the tessellation. For instance, in the case of dodecahedron there is unique Hamiltonian cycle and for icosahedron has large number of cycles. Also in the case of (6,3) tessellations the duals have different Hamilton cycles. In fact, the problem of constructing the Hamiltonian cycles is NP complete.

Can one say anything about the number of Hamiltonian cycles?

1. For dodecahedron only 3 edges emanates from a given vertex and there is only one Hamiltonian cycle. For icosahedron 5 edges emanate from given vertex and the number of cycles is rather large. Hence the valence and also closely related notion of n-connectedness are essential for the existence of Hamilton's cycles. For instance, for a graph consisting of two connected graphs connected by single edge, there exist no Hamilton's cycles. For toric triangulations one has as many as 6 edges from given vertex and this favors the formation of a large number of Hamiltonian cycles.

2. Curves on torus are labelled by winding numbers (M, N) telling the homology equivalence class of the cycle. M and M can be any integers. Curve winds M(N) times around the circle defining the first (second) equivalence homology equivalence class. Also Hamiltonian cycles are characterized by their homology equivalence class, that is pair (M, N) of integers. Since there are only V = 12 points, the numbers (M, N) are finite. By periodic boundary conditions means that the translations by multiples of $2e_1 + 2e_2$ do not affect the tessellation (one can see what this means geometrically from the illustration at http://tinyurl.com/y7xfromc). Does this mean that (M, N) belongs to $Z_2 \times Z_2$ so that one would have 4 homologically non-equivalent paths.

Are all four homology classes realized as Hamiltonian cycles? Does given homology class contain several representatives or only single one in which case one would have 20 non-equivalent Hamiltonian cycles?

It turned out that there exist programs coding for an algorithm for finding whether given graph (much more general than tessellation) has Hamiltonian cycles. Having told to Jebin Larosh about the problem, he sent within five minutes a link to a Java algorithm allowing to show whether a given graph is Hamiltonian (see http://tinyurl.com/y7y9tr5t): sincere thanks to Jebin! By a suitable modification this algorithm find all Hamiltonian cycles.

1. The number N_H of Hamiltonian cycles is expected to be rather large for a torus triangulation with 12 vertices and 24 triangles and it is indeed so: $N_H = 27816!$ The image of the tessellation and the numbering of its vertices are described in figure below (see **Fig. 4.1**). Incide matrix A characterizes the graph: if vertices *i* and *j* are connected by edge, one has $A_{ij} = A_{ji} = 1$, otherwise $A_{ij} = A_{ji} = 0$ and is used as data in the algorithm finding the Hamiltonian cycles.



Figure 4.1: The number of the vertices of (V, F) = 12, 24 torus tessellation allowing path (0, 1, 2, 3, 4, 6, 5, 8, 10, 7, 11, 9, 0) as one particular Hamiltonian cycle.

The cycles related by the isometries of torus tessellation are however equivalent. The guess is that the group of isometries is $G = Z_{2,refl} \rtimes (Z_{4,tr} \rtimes Z_{n,rot})$. $Z_{n,rot}$ is a subgroup of local $Z_{6,rot}$. A priori $n \in \{1, 2, 3, 6\}$ is allowed.

On basis of [A22] I have understood that one has n = 3 but that one can express the local action of $Z_{6,rot}$ as the action of the semidirect product $Z_{2,refl} \times Z_{3,rot}$ at a point of tessellation (see http://tinyurl.com/ya6g9kwe). The identity of the global actions $Z_{2,refl} \times Z_{3,rot}$ and $Z_{6,rot}$ does not look feasible to me. Therefore $G = Z_{2,refl} \rtimes (Z_{4,tr} \rtimes Z_{3,rot})$ with order ord(G) = 24 will be assumed in the following (note that for icosahedral tessellation one has ord(G) = 120 so that there is symmetry breaking).

 Z_4 would have as generators the translations e_1 and e_2 defining the conformal equivalence class of torus. The multiples of $2(e_1 + e_2)$ would leave the tessellation invariant. If these arguments are correct, the number of isometry equivalence classes of cycles would satisfy $N_{H,I} \ge N_H/24 = 1159$.

2. The actual number is obtained as sum of cycles characterized by groups $H \subset Z_{12}$ leaving the cycle invariant and one can write $N_{H,I} = \sum_{H} (ord(H)/ord(G))N_0(H)$, where $N_0(H)$ is the number of cycles invariant under H.

What can one say about the symmetry group H for the cycle?

- 1. Suppose that the isometry group G leaving the tessellation invariant decomposes into semidirect product $G = Z_{2,refl} \rtimes (Z_{4,tr} \rtimes Z_{3,rot})$, where $Z_{3,rot}$ leaves invariant the starting point of the cycle. The group H decomposes into a semi-direct product $H = Z_{2,refl} \rtimes (Z_{m,tr} \times Z_{3,rot})$ as subgroup of $G = Z_{2,refl} \rtimes (Z_{4,tr} \times Z_{3,rot})$.
- 2. $Z_{n,rot}$ associated with the starting point of cycle must leave the cycle invariant at each point. Applied to the starting point, the action of H, if non-trivial - that is $Z_{3,rot}$, must transform the outgoing edge to incoming edge. This is not possible since Z_3 has no idempotent elements so that one can have only n = 1. This gives $H = Z_{2,refl} \rtimes (Z_{m,tr}, m = 1, 2 \text{ and } m = 4 \text{ are possible.}$
- 3. Should one require that the action of H leaves invariant the starting point defining the scale associated with the harmony? If this is the case, then only the group $H = Z_{2,refl}$ would remain and invariance under Z_{refl} would mean invariance under reflection with respect to the axis defined by e_1 or e_2 . The orbit of triangle under $Z_{2,refl}$ would consist of 2 triangles always and one would obtain 12 codon doublets instead of 10 as in the case of icosahedral code.

If this argument is correct, the possible symmetry groups H would be Z_0 and $Z_{2,refl}$. For icosahedral code both Z_{rot} and $Z_{2,refl}$ occur but $Z_{2,refl}$ does not occur as a non-trivial factor of H in this case.

The almost exact $U \leftrightarrow C$ and $A \leftrightarrow G$ symmetry of the genetic code would naturally correspond to $Z_{2,refl}$ symmetry. Therefore the predictions need not change from those of the icosahedral model except that the 4 additional codons emerge more naturally. The predictions would be also essentially unique.

4. If H is trivial Z_1 , the cycle would have no symmetries and the orbits of triangles would contain only one triangle and the correspondence between DNA codons and amino-acids would be one-to-one. One would speak of disharmony. Icosahedral Hamiltonian cycles can also be of this kind. If they are realized in the genetic code, the almost exact $U \leftrightarrow C$ and $A \leftrightarrow G$ symmetry is lost and the degeneracies of codons assignable to 20+20 icosahedral codons increase by one unit so that one obtains for instance degeneracy 7 instead of 6 not realized in Nature.

What can one say about the character of toric harmonies on basis of this picture.

- 1. It has been already found that the proposal involving three disjoint quartets of subsequent notes can reproduce the basic chords of basic major and minor harmonies. The challenge is to prove that it can be assigned to some Hamiltonian cycle(s). The proposal is that the quartets are obtained by Z_{rot}^3 symmetry from each other and that the notes of each quartet are obtained by $Z_{4,tr}$ symmetry.
- 2. A key observation is that classical harmonies involve chords containing 1 quint but not 2 or no quints at all. The number of chords in torus harmonies is $24 = 2 \times 12$ and twice the number of notes. The number of intervals in turn is 36, 3 times the number of the notes. This allows a situation in which each triangle contains one edge of the Hamiltonian cycle so that all 3-chords indeed have exactly one quint.
- 3. By the above argument harmony possesses Z_2 symmetry or no symmetry at all and one has 12 codon doublets. For these harmonies each edge of cycle is shared by two neighboring triangles containing the same quint. A possible identification is as major and minor chords with same quint. The changing of the direction of the scale and the reflection with respect to the edges the Hamiltonian cycle would transforms major chords and minor chords along it to each other and change the mood from glad to sad and vice versa.

The proposed harmony indeed contains classical chords with one quint per chord and for F, A, C^{\sharp} both minor and major chords are possible. There are 4 transposes of this harmony.

- 4. Also Hamiltonian cycles for which n triangles contain two edges of Hamiltonian path (CGD type chords) and n triangles contain no edges. This situation is less symmetric and could correspond to a situation without any symmetry at all.
- 5. One can ask whether the classical harmonies corresponds to 24 codons assignable to the toric harmony and to the 24 amino-acids being thus realizable using only amino-acids. If so, the two icosahedral harmonies would represent kind of non-classical exotics.

Appendix: Some facts about toric tessellations

Genus g = 1 (torus) is unique in that it allows infinite number of tessellations as analogs of planar lattices with periodicic boundary conditions. g = 0 allows only Platonic solids as tessellations and g > 1 allows very few tessellations. The article [A22] gives a nice review about toric tessellations.

- 1. Toric tessellations correspond to tessellations of plane by periodic boundary conditions. Torus tessellation allows a universal covering identifiable as counterpart of infinite lattice in plane. There are infinite number of coverings of given tessellation labelled by two integers (m, n) since the homology group of torus is $Z \times Z$. The tessellation is obtained by dividing $Z \times Z$ by its normal subgroup. Also the rotation group Z_6 acts as group leaving the tessellation invariant and correspond to the rotation leaving invariant the lattice cell consisting of 6 vertices around given vertex.
- 2. The tessellation is called decomposable if there is a k-sheeted covering map (map corresponds to a collection of charts) characterized by the subgroup of the isometries of the covering of the tessellation which corresponds to a sub-tessellation. This subgroup is charactrized by a pair (p,q) of integers being generated by the translation $pe_1 + qe_2$ and $2\pi/6$ rotation. The unit vectors can be chosen to be $e_1 = (1,0)$ and $e_2 = (1,\sqrt{3})/2$ for triangular tessellation (presumably this tessellation is regular tessellation with the conformal equivalence class of torus fixed by the angle between e_1 and e_2). Line reflection transforms $(3,6)_{p,q}$ to $(3,6)_{q,p}$ (see Fig 1 of http://tinyurl.com/ya6g9kwe). The tessellation is invariant under reflections - regular -if pq(p-q) = 0. The peculiar looking form of the conditions follows from the identitity $(3,6)_{q,p} = (3,6)_{p+q,-q}$ (also p = 0 or q = 0 is possble) Note that the tessellation $(3,6)_{2,2}$ is invariant under reflection and thus non-chiral.
- 3. The number V of vertices of the triangular itessellation is given by $V = p^2 + q^2 + pq$. The regular tessellation (p,q) = (2,2) has 12 vertices and is the interesting one in the recent case. It is the smallest regular tessellation. For given (p,q) one can have several non-equivalent pairs (p,q) defining combinatorially non-equivalent tessellations. My interpretation is that they correspond to different conformal equivalence classes for torus: the intuitive expectation is that this should not affect the topology of tessellation nor Hamiltonian cycles. For $(6,3)_{p,q} = (6,3)_{2,2}$ with s (V = 12, F = 24) there are 1+6=7 combinatorially non-equivalent tessellations: one non-chiral and 6 chiral ones.

Quite generally, the tessellations with V vertices with V mod 4 = 0 (as in the case of V = 12) allow one map (chart consisting of faces) with isotropy group of order 2 and 6 maps with isotropy group of order 4. These variants are labelled by an SL(2,Z) matrix (a, b; 0, c) with determinant equal to V = ac. For V = 12 one has decompositions $12 = 1 \times 12$, $12 = 2 \times 6$, $12 = 3 \times 4$. -c < b < a - c is unique modulo a. In the recent case one as ac = 12 allowing $(a, c) \in \{(1, 12), (2, 6), (3, 4)\}$ and pairs obtained by permuting a and c. These matrices need not define combinatorially different tessellations since modular transformations generate equivalent matrices.

4.5.4 Icosa-tetrahedral and icosa-dodecahedral bioharmonies as candidates for genetic code

Both the icosa-tetrahedral [L16] and icosa-dodecahedral harmony to be discussed below can be considered as candidates for bio-harmony as also the harmony involving fusion of 2 icosahedral harmonies and toric harmony [L79]. The basic reason is that the third harmony corresponds to doublets. One cannot exclude the possibility of several equivalent representations of the code.

Icosa-tetrahedral harmony

Icosahedral harmonies can be characterized by a subgroup of icosahedral isometries A_5 having 60 elements. If reflections are included the isometry group, oneas $A_5 \times Z_2$ with 120 elements. The group of symmetries is Z_6, Z_4 , or Z_2 . There are two choices for Z_2 and the interpretation has been that Z_2 correspond to either reflection or rotation by π . A_5 however allows also $Z_2 \times Z_2$ as subgroup. AAs correspond to orbits of the symmetry group and DNA codons coding for the AA correspond to triangles (3-chords) at the orbit. In purely icosahedral model on obtains 20+20+20 codons. A fusion with tetrahedral harmony gives 64 codons.

- 1. Z_6 gives rise to 3 AAs coded by 6 codons each (leu,se,arg) and 2 AAs coded by 2 codons: the choice of the doublet would require additional conditions. One option is ile doublet.
- 2. Depending on whether one includes reflection or not, one can have either $Z_4 \subset A_5$ (60 = 4×15) or $Z_4 = Z_{2,rot} \times Z_2 \subset A_5 \times Z_2$. I have assumed that $Z_4 = Z_{2,rot} \times Z_2$ but the recent argument suggests the first option. This does not have any implications for the earlier model. Icosahedral Z_4 gives rise to 5 AAs coded by 4 codons each (5 × 4 = 20). This leaves 11 AAs and 3 "empty" AA formally coded by stop codons.
- 3. Icosahedral Z_2 gives rise to 10 dublets. These 4-plets would correspond to (phe, tyr, his, gln, asn, lys, asp, glu, cys, stop-doublet) This leaves (stop,trp) double and (ile,met) doublet with broken Z_2 symmetry.

The fusion with tetrahedral code with 4- codons and 4 AAs should explain these 4 AAs. Tetrahedral isometries form group S_3 and reduce to group Z_3 for tetrahedral cycle.

- (a) One could argue that ile-triplet and met correspond to 3-element orbits with 1-element orbit. (stop,trp) would be formed by Z_2 symmetry breaking from trp doublet and there is no obvious mechanism for this.
- (b) If one tetrahedral face is fixed as a face shared with icosahedron, the symmetry group of tetrahedral cycle reduces to Z_1 . This would give 4 singlets identifiable as (ile,met) and (stop,trp) symmetry broken doubles. Since ile appears also in doublet, tetrahedral 1-orbit and icosahedral 2-orbit must have a common doubled triangle identifiable as the common face of icosahedron and tetrahedron. The doubling of the common triangle replaces ile-doublet with ile-triplet. This option looks rather reasonable.

Dodecadedral harmony

Dodecahedral harmony correspond to the unique Hamilton cycle at dodecahedron. Dodecahedral harmony as 20 notes and 12 5-chords. If one assumes that the octave divides to 20 notes, this brings in mind "eastern" view about harmony.

The obvious objection against dodecahedral harmony is that dodecahedral faces are pentagons so that dodecahedral chords would be 5- rather than 3-chords so that the correspondence between chords and DNA codons would be lost. The situation changes if 3 notes - 3-chord - determine the 5-chord completely and one can assign a unique 3-chord to each pentagon. This is indeed the case!

1. 3-edges meet in every dodecahedral vertex (this makes the dodecahedral cycle unique apart from rotations) and each edge pair in the vertex belongs to same pentagon (in the case of icosahedron there are 5 edges per vertex so that this is not true). Therefore each pentagon must contain at least 2 edges of Hamilton's cycle.

The cycle must visit all vertices of pentagon, and the visit to the vertex means that the cycle shares at least one edge with pentagon. Since all vertices of the pentagon must be visited, there are two options. For option a) given pentagon shares with the cycle disjoint 2-edge with 3 vertices and 1-edge with two vertices. For option b) the pentagon shares with the cycle 4-edge with 5 vertices.

2. The numbers n_a of pentagons with 4-edges and $n_b = 12 - n_a$ 2-edge+ 1-edge (making 3 edges) can be deduced easily. Cycle has 20 edges. Pentagon of type a) shares 3 edges with
the cycle and the edge is shared by 2 pentagons. This gives $3n_a/2$ edges. Pentagon of type b) shares 4 edges with the cycle. This gives $2n_b = 2(12 - n_a)$ edges. The total number of edges is $3n_a/2 + 2n_b = 20$, which gives $n_a = 8$ and $n_b = 4$. Dodecahedral Hamilton's cycle can be found from web (see http://tinyurl.com/y5woajcb). The structure is as deduced here.

For case a) the 3-chords correspond naturally to the 3 vertices of the 2-edge shared with the cycle. Therefore it is possible to assign unique 3-chords to the dodecahedral harmony and to obtain connection with codons in this case. One however obtains also 12 2-chords: could they have some genetic counterpart?

What about 5-chords for pentagons of type b)? Hamiltonian cycle can be oriented and this is induces orientation of the pentagons. One can say that the first vertex in the 4-edge is the vertex at which cycle arrives to the pentagon and identify the 3-chord as the first three vertices. It turns out that for the replacement of quint cycle this is not actually necessary.

Is icosa-dodecahedral harmony consistent with the genetic code?

One must check whether icosa-dodecahedral harmony is consistent with the degeneracies of the genetic code.

- 1. A fusion of 2 icosahedral harmonies and 2 copies of dodecahedral harmony would be in question. As in the case of icosahedral harmony already discussed, the two icosahedral harmonies would have symmetry groups Z_6 and Z_4 and give the codons coding for 3 6-plets and 1 doublet+ 5 4-plets + two copies of dodecahedral harmony.
- 2. Can the model predict correctly the numbers of codons coding for AAs? It is known that dodecahedral Hamilton cycle divides dodecahedron to two congruent pieces related by Z_2 symmetry (see http://tinyurl.com/yy6pcogt). Also the Hamiltonian cycle defining the common boundary has Z_2 symmetry. A good guess is that these Z_2 :s corresponds to reflection symmetry and rotation by π but I am not able to exclude $Z_4 \subset G_0$, where G_0 consists of 60 orientation preserving isometries. In this case some orbits - presumably all 3 of them could contain 4 pentagons. This is not consistent with the condition that one has doublets and singlets.

If the second symmetry corresponds to reflection, it can be excluded by simply assuming that reflections change the orientation of the cycle.

3. Rotation by π has two fixed points corresponding to opposite poles so that one has 5 2-orbits and 2 1-orbits giving 12 triangles for each copy. Two copies of dodecahedral harmony would give 5+5=10 doublets and 2+2=4 singlets. A possible interpretation would be as (ile,met) and (stop,trp).

Consider now objections against dodecahedral harmony.

- 1. Why two copies of dodecahedral code? What distinguishes between them? If imirror symmetry leaves the cycle invariant apart from orientation the copies could be mirror images and consist of same faces. The second option is that they related by a rotation?
- 2. The number of dodecahedral AAs is 24 rather than 20. Could the additional 4 AAs as orbits have interpretation as AAs in some sense. Could the "empty" AAs coded by stop codons be counted as AAs exceptional in some sense. In TGD framework one can consider the possibility that although AA is "empty", there is analog of AA as physical signature for the end of protein telling what stopping codon it corresponds. The magnetic body of protein is a good candidate.

Genetic code has several slightly differing variants. Could the 2 additional exotic AAs Pyl and Sec correspond in some situations to the additional AAs?

3. Essential for the bio-harmony as a fusion of harmonies is that one can select from each orbit single face as a representative of the AA it codes - kind of gauge choice is in question - and that the orbits corresponding to different AAs can be chosen to be disjoint. Otherwise codons

belonging to the orbits of different Hamilton cycles can code for the same AA if the AA can be chosen to be in intersection. If not, the same codon can code for 2 different AAs - this can indeed occur in reality [L87]!

The condition that orbits of different cycles do not interesect seems quite stringent but has not been proven. But what if it is actually broken? Indeed, in the case of icosahedral harmony with Z_1 symmetry tetrahedron and icosahedron could have common a doubled face the breaking of this condition would geometrically explain why ile belongs to both icosahedral and tetrahedral orbit.

Ile is the problem also in the case if icosa-dodecahedral harmony. Dodecahedral singlet codes for ile as also icosahedral doublet. Could one talk about doubling of ile face so that it corresponds to a pair of triangle and pentagon (in 1-1 correspondence with triangle as chord).

4. The two copies of the dodecahedral code should correspond to 5 doublets and 2 singlets each. One expects that together they give rise to 10+2+10+2=24 faces. Do they? Mirror symmetry and rotation by π act as symmetries of the cycle so that neither can map the two cycles to each other. Dodecahedral (equivalently icosahedral) rotations give rise to new equivalent cycles. The action on pentagons corresponds to the action on vertices of icosahedron so that it easy to understand what happens.

Each symmetry corresponds to a rotation around some axis and has opposite icosahedral vertices at this axis as fixed points. Hence any two cycles obtained in this manner have 2 common pentagons. This means reduction $24 \rightarrow 22$ unless one interprets the situation in terms doubled faces? Could the disappearing doublet correspond to stop-doublet? What about the remaining stop of the vertebrate code pairing with trp? Why does second singlet correspond to empty AA and not something else such as exotic AA.

5. There is also further problem. Suppose that an intersection of orbits takes place at single triangle. Suppose that one cannot choose this triangle to be "AA" triangle for both orbits. In this case it is not clear to which AA the codon codes. This kind of phenomenon actually takes place in some cases and is known as homonymy [L87]. It is associated with the deviations of the code from the vertebrate code and involves exotic AAs Pyl and Sec. Codons can serve as a stop codon or code for an exotic AA.

Clearly, the notion of bio-harmony involves many unclear aspects but my strong feeling is that there is very beautiful mathematics involved.

4.6 Appendix

4.6.1 Chord tables for some harmonies and their inverses

The formula for inversion of the harmonic keeping note X as fixed can be represented as a product of translation takin X to C, inversion keeping C fixed, and translation taking C back to X. The inversion maps the chord having C as basic note to its mirror image so that the order of notes can change and basic note can change. For instance, the major chord CM = CEG goes to minor chord $CG \sharp F = Fm$ so that k = 0 goes to $k \equiv \Delta k_{inv} = 11$. This delicacy must be taken into account. If X remains fixed inversion is just the transformation

$$k \to k_{inv} = (2 \times k(X) - \Delta k_{inv}) \mod 12 . \tag{4.6.1}$$

Table 4.7 gives the inversion of the scale leaving C (and also $F\sharp$) invariant:

The inversion for the types of the chords does not depend on the basic note as is clear from the distance preserving character of the inversion. **Table 4.8** gives the inversion of for the types of the chords leaving C fixed. The elements of the rows give the type of the chord and the number of quints k corresponding to it. For chords having C as basic note one has k = 0. It is easy to deduce the transformation formula in more general case from the table.

The following tables give the chords and corresponding inverse chords for the 11 icosahedral harmonies.

C	G	D	А	Е	Η	F+	C+	G+	D+	B-	F
С	F	$B\flat$	D+	G+	C+	F+	Η	Е	А	D	G

Table 4.7: Inversion of the scale leaving C (and also $F\sharp$) invariant.

M, 0	m, 0	sus4, 0	aug, 0	4, 0	9, 0	4+, 0	9-, 0	6-, 0	maj7, 0
m, 11	M, 11	sus, 0	aug, 0	4, 0	9, 10	9-, 11	4+, 11	maj7, 11	6-, 11
6, 0	7, 0	ex1, 0	ex2, 0	ex3, 0	ex4, 0	ex5, 0	ex6, 0	ex7, 0	ex8, 0
7, 11	6, 11	ex1, 10	ex3, 3	ex2, 3	ex4, 8	ex6, 8	ex5, 80	ex8, 6	ex7, 6

Table 4.8: Table gives the transformation of inversion leaving C invariant on the basic chords having C as basic note.

ro6	iro6	re41	ire41	re42	ire42	ro21	iro21
F.aug	F.aug	D.7	A.6	C.ex3	A.ex2	E.m	F.M
G.aug	D+.aug	D.6	A.7	E.ex2	F.ex3	Bm	B.M
C.m	F.M	G+.7	D+.6	F+.ex3	D+.ex2	C.m	A.M
D.m	D+.M	G+.6	D+.7	Bex2	B.ex3	F+.m	D+.M
E.m	C+.M	G.4+	E.9-	D.maj7	B.6-	G.6	D.7
F+.m	B.M	A.9-	D.4+	E.9-	A.4+	C+.6	G+.7
G+.m	A.M	C+.4+	B9-	A.7	E.6	A.6	C.7
Bm	G.M	D+.9-	G+.4+	A.6	E.7	D+.6	F+.7
F.6	C.7	E.maj7	G.6-	G+.maj7	F.6-	D.4+	G.9-
G.6	B7	G.maj7	E.6-	B9-	D+.4+	G+.4+	C+.9-
A.6	G+.7	Bmaj7	C+.6-	D+.7	B6	B.4+	B9-
B.6	F+.7	C+.maj7	B6-	D+.6	B7	F.4+	E.9-
C+.6	E.7	C.9-	B.4+	F.9	D+.9	C.maj7	A.6-
D+.6	D.7	A.9-	D.4+	C.9	G+.9	F+.maj7	D+.6-
C.9	C.9	F+.9-	F.4+	G.9	C+.9	G.6-	D.maj7
D.9	B9	D+.9-	G+.4+	E.9	E.9	C+.6-	G+.maj7
E.9	G+.9	B.9	G.9	B.9	A.9	D.9	D.9
F+.9	F+.9	E.9	D.9	F+.9	D.9	G+.9	G+.9
G+.9	E.9	F.9	C+.9	C+.9	G.9	E.9	C.9
B9	D.9	B9	G+.9	B9	B9	B9	F+.9

Table 4.9: Pairs "X" and "iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures ??, ??, ??, ??.

ro22	iro22	ro23	iro23	re21	ir21	re22	ir22
A.ex4	G.ex4	A.ex2	Bex3	F+.ex3	D+.ex2	D.ex4	E.ex4
D+.ex2	C.ex3	H.ex8	Bex7	H.ex4	Bex4	H.ex4	F+.ex4
A.m	BM	D+.ex2	E.ex3	A.m	E.M	F.M	E.m
D+.m	E.M	F.ex8	F.ex7	D+.M	Bm	F.m	E.M
G.9-	C.4+	D.7	A.6	A.6	E.7	C.6-	A.maj7
C+.9-	F+.4+	G+.7	D+.6	D+.7	B6	Bmaj7	B.6-
C.4	C.4	A.maj7	D.6-	D.7	B.6	C.9-	A.4+
F+.4	F+.4	D+.maj7	G+.6-	B6	D+.7	D.7	G.6
E.4+	D+.9-	A.4+	D.9-	G.6-	F+.maj7	G+.6	C+.7
B4+	A.9-	D+.4+	G+.9-	F.maj7	G+.6-	G.maj7	D.6-
D.maj7	F.6-	E.7	G.6	D.4+	B.9-	D+.6-	F+.maj7
G+.maj7	B.6-	B7	C+.6	B9-	D+.4+	C+.4	C+.4
B.maj7	G+.6-	B9	G+.9	G+.4+	F.9-	A.4+	C.9-
F.maj7	D.6-	G.9	B.9	E.9-	A.4+	E.4+	F.9-
C.9	D.9	C+.9	F.9	C.9	G+.9	F+.6	D+.7
F+.9	G+.9	A.9	A.9	F.9	D+.9	D+.9	C+.9
A.9	F.9	B.9	G.9	B.9	A.9	C+.9	D+.9
D+.9	B.9	F.9	C+.9	F+.9	D.9	E.9	C.9
D.9	C.9	E.9	D.9	E.9	E.9	B.9	F.9
G+.9	F+.9	D+.9	D+.9	C+.9	G.9	D+.9	C+.9

Table 4.10: Pairs "X" and "iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures ??, ??, ??, ??.

re23	ire23	re24	ire24	re25	ire25
F.ex1	F.ex1	H.ex3	G.ex2	F+.ex2	F.ex3
D+.ex3	G+.ex2	E.ex7	F+.ex8	F.ex3	F+.ex2
G+.ex1	D.ex1	D.7	A.6	F.M	Bm
A.ex2	D.ex3	G+.6	D+.7	Bm	F.M
E.7	B.6	GM	B.m	C.7	D+.6
E.6	B.7	D+.m	G+.M	G+.6	G.7
A.maj7	F+.6-	F.M	F+.m	A.maj7	F+.6-
B.9-	E.4+	F.m	F+.M	B.9-	E.4+
G.M	G+.m	C.6-	B.maj7	E.6	B.7
C+.m	D.M	Bmaj7	C+.6-	E.7	B.6
D.7	C+.6	A.9-	D.4+	G.M	G+.m
F+.6	A.7	C+.4+	B9-	C+.m	D.M
B9	C.9	E.7	G.6	D.7	C+.6
D.9	G+.9	F+.6	F.7	B.6	E.7
B.9	B.9	C.9	F+.9	D+.9	G.9
C.9	B9	D+.9	D+.9	C.9	B9
F.9	F.9	D.9	E.9	C+.9	A.9
G+.9	D.9	C+.9	F.9	B9	C.9
D+.9	G.9	E.9	D.9	D.9	G+.9
C+.9	A.9	B.9	G.9	H.9	B9

Table 4.11: Pairs "X" and "iX" of columns give the chords of the bio-harmonies and their inversions depicted in figures ??, ??, ??.

4.6.2 Calculation of incidence matrices

The most stringent definition of harmonic chord progression is as a chord sequence in which two subsequent chords have at least one common note: the distance between subsequent chords defined as the minimal distance between triangles representing them vanishes. Some general comments are in order.

- 1. Incidence matrices can be computed by using expressions of chords as sets of three notes (possible in Python) and just counting the number of common notes defining the value of the element of the incidence matrix. The quint distance between the chords vanishes if they have common notes. More general incidence matrices would correspond to a larger quint distance.
- 2. In the case of genetic code and a mino-acids one Hamilton cycle from each class labelled by $Z_n, n \in \{6, 4, 2\}$ is involved.
 - (a) There are $N = 1 \times 3 \times 8 = 24$ cycle combinations if one does not allow the inverse harmonies. Allowing them gives $N = 8 \times 24$ combinations. If transitions between all representations are possible, there are $M = N^2 20 \times 20$ -dimensional incidence matrices to be calculated for the icosahedral restriction of the code. Incidence matrices are symmetric so that only D(D+1)/2 = 20(20+1)/2 = 210 independent matrix elements need to be calculated for given 20×20 -D incidence matrix.
 - (b) Equivalently, one can calculate the incidence matrix for a space with $N \times 20$ points which is Cartesian product of N amino-acid spaces with 20 points. N has values 24 and 8×24 . Remarkably, the magic number 24 of also stringy mathematics appears.
 - (c) If the transitions can be restricted to single triplet of cycles, one must calculate 6 20×20 -dimensional incidence matrices. This situation could be realistic for portions of the genetic code if the transitions between different cycle triplets are analogous to phase transitions. The number of incidence matrices (one can also use single 60×60 incidence matrix) is still reasonably small and can be documented in written form. In a model for random chord sequences one must specify the probabilities for the transitions between chords with different n for Z_n . Simplest starting point assumption is that the probabilities are identical.
- 3. For the extended genetic code the most natural assumption is that the extension of the code to icosa-tetrahedral code take places place only in Z_2 sector meaning the extension of amino-acid space by 4 amino-acids and the increase of the number of DNA codons from 60 to 64. There are two kinds of transitions between icosahedral and tetrahedral codons. Tetrahedral codon can correspond to a codon, which is outside the icosahedron having at least one common vertex with the icosahedral codon: this allows 3+3 transitions. Tetrahedral codon can correspond also to punct. Unless the codon/amino-acid contains at least one of these notes, it cannot precede stopping codon. These chords extend the harmony by the counterparts of CM and Am and punct corresponds to C6 = CGA.
- 4. Also the situation in which tetrahedral and icosahedral codes are disjoint must be considered. In this case there are no transitions between tetrahedral and icosahedral sectors. In tetrahedral sector the distances between faces always vanish so that the calculation of this part of the incidence matrix is trivial. Icosa-tetrahedral part of the incidence matrix can be readily written. The difficult part of the calculation of incidence matrices reduces to that for the icosahedral case such that the common face corresponds to either punct or Sec/Pyl. This gives selection rules telling which codons/amino-acids can precede stopping codon/punct in given bio-harmony.

4.6.3 Simulation of harmonic DNA sequence

The following sequence represents a random harmonic sequence based on zero quint distance between neighboring chords (at least one common note). The harmony if combination 3 harmonies ??, ??, and ?? extended by adding chords $B\flat$, Gm and G7 and associated $B\flat$ 6 representing stopping codon and punct in tetra- icosahedral codeandSec or Pyl in their unfused variants. These three harmonies correspond to groups of 20, 20, and 24 DNA codons at orbits of Z_6 , Z_4 , and Z_2 which is now taken to be Z_2^{refl} . To deduce DNA sequence one must assume detailed correspondence between the codons at the orbits and corresponding chords.

It is assumed that all transitions between neighboring DNAs occurs with the same probability and induce the transitions between amino-acids.

F+m, Dm, G6, G6, G6, Em, G6, Cm, G6, F6, Faug, Dm, G6, G6, Faug, A6, Dm, Dm, F+m, Dm, F6, F6, B-m, F6, Gaug, G+m, Cm, F6, B-m, C+6, Dm, G6, G6, G6, Gaug, G+m, Cm, Gaug, G6, Dm, B-m, F6, Faug, A6, G6, Gaug, G+m, F6, F6, G6, Gaug, Cm, F6. Faug, Cm, Gaug, B6, Gaug, G6, Gaug, Em, Gaug, Gaug, A6, Faug, B-m, Faug, F6, Em. A6. F+m, B-m, F6, Cm, Em, B-m, G6, G6, F6, Dm, F+m, Dm, G6, F6, Faug, F6, Dm, F+m, A6, Faug, F6, Faug, Dm, B-m, B-m, C+6, C+6, G+m, B6, A6, F+m, Faug, B-m, Dm, B-m, C+6, B-m, Dm, Cm, F6, F6, B-m, Dm, Em, F+m, Β6, Gaug, Cm, G+m, F6, F6, G6, Dm, G6, G6, C+6, A6, G6, Cm, Cm, G+m, B6, G+m, C+6, C+6, Faug, B-m, Dm, Dm, G6, Cm, Cm, Cm, F6, G6, Gaug, G6, F6, Dm, F6, Faug, Faug, Faug, A6, Gaug, Em. Em, G6, Dm, Faug, F6, B-m, F6, Cm, F6, B-m, F+m, Dm, G6, F6, F6, Cm, Cm, A6, A6, F+m, B-m, B-m, B-m, B6, G+m, Em, G+m. Em, Em, F+m, A6, Em, B6, Faug, G6, Dm, B-m, Dm, Dm, B-m, Dm, F6, Cm. B6. Em. Faug, G6. Gaug, B6. Em, G6, G6, Dm, Faug, Faug, F6, Cm, B6, F+m, A6, G+m. Gaug, G+m, Gaug, Gaug, G6, Em, Cm, F6, Dm, Dm, Dm, G6, Em, Em, A6, Em, Gaug, Em, Cm, Cm. G6, G6, Cm, F6, Dm, Faug, A6, Faug, A6, Faug, F+m, F+m, B-m, C+6, G+m, Gaug, G6, Gaug, G6, G6, Dm, G6, G6, Cm, Em. Dm, Dm, F6, B-m, F6, G+m. G+m, B6, G+m, Cm, Cm, F6, Faug, Em. Faug, Faug, F6, Dm, G6, Dm, F+m, Faug, Faug, B-m, C+6, G+m, C+6, Faug, F+m, B-m, Faug, Faug, A6, G6, Em, Cm, F6, G6, Cm.

4.6.4 Illustrations of icosahedral Hamiltonian cycles with symmetries

The figures below illustrate the Hamiltonian cycles involved. Quite generally, the Z_n symmetry acts by a shift by 12/n quints along the cycle and the orbits of chords consist of at most n chords of same type as the reader is encouraged to verify.



Figure 4.2: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 6-fold rotation symmetry acting shifts generated by a shift of 2 quints.



Figure 4.3: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 4 reflection symmetries generated by reflections in vertical and horizontal directions.



Figure 4.4: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 4 reflection symmetries.



Figure 4.5: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 2-fold rotational symmetry realized as 6-quint shift along the cycle.



Figure 4.6: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold rotation symmetry.



Figure 4.7: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold rotation symmetry.



Figure 4.8: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry realized as horizontal reflection



Figure 4.9: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 4.10: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 4.11: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 4.12: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.

Chapter 5

An Overall View about Models of Genetic Code and Bio-harmony

5.1 Introduction

During last years kind of brain storming period has occurred in the model of bio-harmony [L16]. A lot of ideas, some of them doomed to be short lived, have emerged, and it seems that now it its time for a thorough cleanup and integration with the general ideas of TGD inspired quantum biology.

TGD leads to 3 basic realizations of genetic code: this is now relatively well established part of TGD inspired quantum biology. One can also consider 3 realization also for bio-harmony. The question is which of them is the realistic one or whether several options can be considered.

5.1.1 3 basic realizations of the genetic code

In TGD Universe there are at least 3 realizations of the genetic code.

Besides biochemical realization one has a realization in terms of dark nuclei realized as dark proton sequences and possibly in terms of more general sequences involving effective dark neutrons. The states of 3 dark protons defining the dark codon have multiplet decomposition 64 + 64 + 40 + 20 corresponding to dark variants of DNA, RNA, tRNA, and amino-acids (AA). I will denote these dark variants by DDNA, DRNA, DtRNA, and DAA.

If one allows also dark analogs of neutrons by allowing negatively charged color bonds between protons, the number of code letters doubles: this could relate to the recently constructed Hachimoji DNA [I43] (see http://tinyurl.com/y2mcjb4r) discussed from TGD viewpoint in [L109].

Dark photon 3-chords assignable to the realization of bio-harmony with the note scale identified as Hamilton cycle on a polytope with triangular faces gives a third realization coupling dark and ordinary representations together. I have proposed 3 realizations in terms of icosahedral and tetrahedral [L16], icosahedral and toric [L79], and icosahedral and dodecahedral [L109] geometries (for the latter 5-chords would effectively reduce to 3-chords).

If there is DDNA-DNA, DRNA-RNA, DAA-AA pairing, the negative charges of DNA, RNA, and tRNA nucleotides finds explanation in terms of positive charge of dark proton sequence. For AAs the situation is not clear since the charge per unit length for amino-acids varies and depends on pH. DAA-AA pairing would require that dark analogs of neutrons are present in the dark proton sequence.

5.1.2 3 models of bioharmony

There are now 3 models of bioharmony [L16, L79, L109] making very similar pedictions. Harmony for given graph is defined as a Hamiltonian cycle connecting neighboring points and going through all points of the graph without self-intersections. Scale is identified by assigning notes to the vertices and faces correspond to the chords of the harmony obtained in this way. Bio-harmonies are fusions of 3 or 4 sub-harmonies.

1. The original proposal - icosa-tetrahedral bio-harmony - is based on the fusion of 3 icosahedral harmonies with symmetry groups Z_6 , Z_4 and Z_2 permuting the triangles of given orbit of Z_n . Given icosahedral harmony corresponds to an imbedding of 12-note scale as a Hamilton cycle at icosahedron. The 12 vertices of icosahedron are identified as the notes of 12-note scale and 20 triangular faces define the 3-chords of the harmony.

The distance between nearest vertices is assumed to correspond to quint that is scaling of the frequency by 3/2. Each cycle defines a collection of 20 3-chords defining an icosahedral harmony. Octave equivalence is used to map the 12 frequencies obtained to single octave. There is however a slight inconsistency since 12 quints corresponds to slightly more than 7 octaves as already Pythagoras realized. The addition of tetrahedron to icosahedral harmony is interpreted as an addition of one vertex adding one note which should be very near to one of the 12 notes.

Icosahedral harmonies are characterized by a symmetry group Z_n , n = 6, 4, 2, 1, n = 1 corresponds to chaotic cycles, which might serve as correlate for dis-harmony and might relate to the correlates of emotions: at the level of genetic code is AA would be coded by single DNA codon.

Icosahedron decomposes to orbits of Z_n consisting of triangles or equivalently chords. The chords can be classified further by the frequency ratios correlating with the emotional effect. One has the orbits $3 \times 6 + 2 = 20$ for Z_6 , $5 \times 4 = 20$ for Z_4 and 10×2 for Z_2 . Z_6 harmony is unique but there are $3 Z_4$ and even more Z_2 harmonies for which Z_2 can correspond to rotation by π or reflection. This can be understood as breaking of symmetry splitting the Z_6 orbits to pieces. This gives 60 = 2 + 20 + 20 3-chords. The numbers of chords at give orbit rather neatly correspond the numbers of DNA codons coding for given AA.

4 chords and DNAs and AAs are however missing. Tetrahedral harmony would add 3+1=4 chords: Z_3 would the symmetry group instead of Z_4 . This would be due to the symmetry breaking due to gluing of one-tetrahedral face with icosahedral face, which is however counted as separate face and corresponds to 1-triangle orbit under Z_3 permuting its vertices. This gives 64 3-chords corresponding to codons of genetic code.

3 + 1 decomposition would naturally correspond to (*ile*, *ile*, *ile*, *met*) 4-plet coded by codons AUX. The numbers of codons coding given AA identified as orbit of Z_n come out almost correctly. The only exception is trp-stop doublet for which doublet decomposes to stop and singlet. One must understand the reason for this symmetry breaking - it might just the need to have stop codon and this could be arranged if there is no tRNA coupling to this codon. Note that for some code variants stop codon UAG corresponds to Pyl and UGA to Sec.

Since music generates and expresses emotions, the interpretation would be in terms of moods. Even molecules would have moods.

2. Also icosa-dodecahedral and icosahedral-toric harmonies contain the Z_6 and Z_4 icosahedral harmonies (20₁ and 20₂) so that one must only add the missing 10 doublets and 3+1 codons assigned to tetrahedron in icosa-tetrahedral case.

The dodecahedral harmony with 6 chords arranged in doublets is unique from the uniqueness of the Hamiltonian cycle [L109]. The icosa-dodecahedral harmony would give $20_1 + 20_2 + 12_1 + 12_2 = 64$. 12 decomposes into 6 Z_2 doublets so that one has 12 doublets. The realization of scale for dodecahedral harmony would in 20 powers of rational scaling x such that x^{20} is as near to a power of two as possible [L109]. $x = 2^{1/20}$ would correspond to the Eastern variant of well-tempered scale.

There are objections against icosa-dodecahedral harmony. Chords are 5-chords rather than 3chords. The 5-chords of dodecahedral harmony however turn out to be equivalent to 3-chords as far as information content is considered [L109]. The number of vertices for dodecahedron is 20, not 12, but one could argue that dodecahedron corresponds to Eastern harmony having micro-intervals. Two copies of the dodecahedral harmony are needed. What could distinguish between these copies will be discussed later. Also 3+1 is missing. 3. The icosahedral-toric harmony [L79] decomposes as $20_1 + 20_2 + 24 = 64$ involving torus with 24 triangles and 12 vertices. Toric harmony has Z_{24} as isometries and gives 12 doublets. One could argue that the fusion of icosahedral and toric harmonies is geometrically un-natural. One must be however cautious if the geometric realization is in extension of rationals. Also now 3+1 is missing.

The considerations in the sequel suggests that the icosa-tetrahedral option is the most realistic if not unique.

5.1.3 About the geometric interpretation of icosahedral and other symmetries

The geometric interpretation of icosahedral and possible other geometries is a challenge. The 60-element group A_5 of rotations - alternating group of 5-letters - acts as orientation preserving isometries of icosahedron.

1. Since Galois group is central in adelic physics, and all finite groups can appear as Galois groups, one can ask whether icosahedral group and tetrahedral groups could act as Galois group for some extension of rationals relevant for biology. Going to web gives an affirmative answer [A41] (see http://tinyurl.com/y4qsea6h)! Icosahedral symmetry appears as Galois group of the general quintic equation! The lowest order polynomial equation not allowing closed expressions for the roots.

Galois theory (see http://tinyurl.com/y6e955ke) allows to understand the situation in terms of the discriminant defined as product $D = \prod_{i < j} (r_i - r_j)^2$, where r_i are the roots of the irreducible polynomial considered. S_n is the symmetry group in the generic case and odd permutations of S_n change the sign of D. If D is square of rational number in the field K considered (which can be also extension of rationals now), Galois group reduces to alternating group A_5 .

Remark: For octahedron and its dual cube the group is S_4 and can be realized as Galois group of 4^{th} order polynomials. For tetrahedron the group is A_4 and can be also realized as Galois group of 4^{th} order polynomials for which discriminant is square in K.

- 2. Icosahedral and dodecahedral geometries having the same isometry group are common in biology, and one can wonder whether there could be a gometric realization perhaps at the level of magnetic body. This might somehow relate also to the frequent appearance of Golden mean involving $\sqrt{5}$ in biology and Golden angle rated to the fifth root of unity.
- 3. $M^8 H$ duality provides besides the usual formulation of TGD also a formulation in complexified M^8 identified as complexified octonions [L58]. The associativity of the tangent or normal space of space-time surface is assumed as a dynamical principle and implies quaternionicity. Quaternions have SO(3) as automorphism group analogous to Galois group and have the finite isometry groups of Platonic solids as finite subgroups.

Could quaternionicity give a connection with the geometric picture? In adelic physics discretizations of space-time points as points with coordinates in the extension of rationals are in central role. Could discretizations contain orbits of the Platonic isometries as quaternionic Galois groups? This could also give to the geometric picture although icosahedral symmetries are not obvious in the geometry of say DNA.

4. Is the genetic code really unique as its dark nucleus realization and the fact that the isometry groups of Platonic solids are finite subgroups of quaternionic isomorphisms suggests? Could any Galois group give rise to an analog of bioharmony and of genetic code? Could the recent genetic code correspond to a first step in the process going beyond the solvable polynomial equations?

What about toric code? The group of toric isometries is Z_{24} and 24 is one of the magic number of mathematics, and dimension 24 is crucial in bosonic string model. Could Z_{24} correspond to the Galois group for 24:th roots of unity defining 24-D algebraic extension of rationals. We cannot sensorily imagine higher dimensions but can do this cognitively. I have proposed that the ability to imagine higher dimensions could be due to the possibility of higher-dimensional extensions of rationals and p-adics.

Could one realize the icosahedron and 24-torus as imagined object in the algebraic extension of rationals? Could the *n*-dimensional discrete geometric objects assignable to *n*-dimensional extensions of rationals have quite generally this kind of representations as a generalized Platonic solid in algebraic extension. Could they define cognitive harmonies as Hamiltonian cycles? Could one imagine also cognitive variant of genetic code whereas as sensory/biological variant of genetic code would be forced by dark proton physics?

5.1.4 Mistracks

In the attempts to understand the connection with standard realization of the genetic code I have also considered the possibility that the frequencies of 3-chord might be mapped to their sum in the interactions. This possibility was considered in the model of homonymy [L87]. In the light of afterwisdom this proposal looks ad hoc.

Also a proposal for how 12-note scale could quite concretely correspond DNA codons was discussed [L92]. The idea was to assign notes with individual letters of the codon such that the note depends on the position of the letter whereas the model of harmony assignment the chord to the entire codon represented as entangled state of 3 dark protons. It is now clear this proposal very probably cannot realize all possible harmonies and is in conflict with the general model which as such fixes the correspondence between chords and codons without any additional assumptions.

5.2 Interactions between various levels

One challenge is to understand how the various realizations of the genetic code interact with each other. There are DX-DY interactions, DX-Y interactions and X-Y interactions and in living matter they should occur in long length scales so that they should be mediated by dark photons.

- 1. How dark photon triplets assumed to be generated by dark nucleon sequences interact with ordinary DNA? Here one can bring in rather stable ideas of TGD inspired view about quantum biology. Dark matter in TGD sense represents long length scale quantum coherence and bio-chemistry short scale coherence. The interaction is therefore between long and short scales.
- 2. There are two ways to interact: frequency resonance and energy resonance. Frequency resonance mediates long length scale interactions and if DX-X pairing exists, the exchange of dark photon triplets 3-chords allows long range DX-DY interactions. DX-X interaction by energy resonance is short range interaction so that X-(DX-DY)-Y interaction would give rise to long range interaction between X-Y as interaction induced by dark level (MB).
- 3. DX-X interaction involves energy resonance and transformation of dark photons to ordinary photons with the same energy. Bio-photons would be an outcome of the transition $h_{eff} \rightarrow h$. Also the reversal of this transition and more general transitions $h_{eff,1} \rightarrow h_{eff,2}$ are of course possible.

Bio-photons have a universal energy spectrum corresponding to molecular and atomic transition energies. This is possible if they result from dark cyclotron photons if the condition $h_{eff} = h_{gr} = GMm/v_0$ introduced originally by Nottale and implying that the cyclotron energy does not depend on the mass of the charged particle producing the dark cyclotron photons.

5.2.1 The independence of the interaction energy on frequency

Dark matter as a hierarchy phases labelled by $h_{eff}/h_0 = n$ identifiable as a dimension of extension of rationals implies evolutionary hierarchy: n serves as a kind of IQ. This strongly suggests that ordinary matter is controlled by dark matter at MB and mimics its behavior.

Evolution would not proceed by change and necessity but would be a process controlled and guided by MB. MB would be an active intentional agent guiding the evolution. Situation in biology

would be much like that in modern technological society where intentional technical progress leads to more and more refined products. How could this be realized at the level of basic bio-molecules? One should also understand how genetic code evolves gradually to a more refined form.

1. The selection of basic bio-molecules having energy resonance with their dark variants mediated by dark photon 3-chords by change would be extremely in-effective process. MB should have mechanisms of tuning the energies of dark photons to achieve energy resonance.

This is achieved if the value of h_{eff} at the flux tubes mediating the interaction can be controlled. Since the length of flux tube is proportional to the h_{eff} by Uncertainty Principle, the variation of h_{eff} would mean variation of the length L of the flux tube: a kind of motor action of MB. Cyclotron frequencies are proportional to the value of monopole magnetic field B at flux tube and by flux quantization one has $B \propto 1/S$, S the area of flux tube cross section (which for monopole flux tubes is closed 2-surface). The variation of the thickness/area of the flux tube, second motor action of MB, would allow to vary cyclotron frequencies.

2. The ideal situation concerning the coupling to ordinary matter would be that same chemical transition with fixed energy for given molecule could couple to several frequencies. This would be achieved if the cyclotron energy is constant.

The condition that the cyclotron energies in a coupling to a given molecule do not depend on the frequency requires that $h_{eff,i}$ at flux tube *i* compensates this dependence. MB can vary the value of *B* to vary frequencies and the value of $h_{eff,i}$ to keep energy unaffected. The areas *S* and length *L* of flux tubes are varied so that the volume remains unaffected. $B \propto 1/S$ and $L \propto h_{eff}$ by Uncertainty Principle. $E_c \propto \hbar_{eff}B = constant$ implies that L/S is constant. *S* increases like $S \rightarrow x^2S$ and $L \rightarrow x^2L$ in the scaling changing $f_c \rightarrow f_c/x^2$. The magnetic energy $E_{magn} = B^2SL \propto L/S$ of the flux tube is not changed. Kind of energy criticality would be in question - one would have a large number of flux tube configurations with the same energy and volume ideal for control purposes. Quantum criticality is actually basic dynamical principle of quantum TGD allowing to predict the spectrum of various coupling parameters.

- 3. Besides cyclotron frequences Josephson energies are central in TGD based model of nerve pulse and EEG. Josephson energy $E_J = ZeV$ and cyclotron frequency $f_c = ZeB/m$ do not depend on h_{eff} . An attractive possibility is that cyclotron photons couple to Josephson junctions meaning that they become Josephson photons and then transform to ordinary photons inducing molecular transitions.
- 4. In the case of bio-harmony the frequencies would be rational multiples of basic frequency and by separating common numerator they are certain integer multiples $f_i = n_i f_0$ of a basic frequency f_0 . The integers n_i have decomposition to products of powers of certain primes: $n_i = \prod p_i^{k_i}$ and each of p_i appears as some maximal power $k_{i,max}$. If one has $n = \prod_i p^{k_{i,max}} n_0$ one can obtain $h_{eff,i} = h_{eff}/n_i$. In this manner one would obtain the desired independence of $E_{c,i}$ on f_i . For Pythagorean scale only primes p = 2 and p = 3 would be involved.

All codons coding for given AA could have same coupling energy. Unless the values of Planck constants and frequencies associated with flux tubes coupling to given codon are fixed, one could have same transition energy for all letters but this is an unrealistic condition. Transition energies are naturally different and can code for letters if not even codons. For this option only the correct combination of frequencies and values of $h_{eff,i}$ allows resonant coupling.

The 3-chords associated with different harmonies would naturally correspond to the same energy. The physics of emotions would not be directly visible at the level of chemistry: chemist would certainly agree with this. The values of Planck constants would characterize the frequencies: I have indeed speculated that nucleotides could be labelled by values of h_{eff} . Number theory would be essential for the understanding life at the level of genes: Galois groups would characterize the nucleotides. Galois groups code for complexity at the level of dark matter so that the behavior guided by the MB of molecule would depend on the $IQ = n = h_{eff}/h_0$ of MB.

5.2.2 The independence of cyclotron energy on frequency and Nottale hypothesis

Is the independence of interaction energy on frequencies consistent with $h_{gr} = GMm/v_0$ hypothesis [E1] [K101, K85, K18]? Here one might encounter difficulties. The division by n_i should change one of the parameters appearing in the formula. The interpretation has been m corresponds to the dark proton mass at the end of the flux tube connecting it to large mass M. If so m cannot be varied.

Could M be varied?

- 1. The parameter $v_0 \simeq 2^{-11}$ can be varied by powers of two, which do not affect the notes identified by octave equivalence.
- 2. Could M correspond to atomic or molecular mass in good approximation equal to sum of atomic numbers A of atoms involved? The divisors of the total atomic number A_{tot} would define the allowed integers n_i characterizing the frequencies of Pythagorean scale in the model of bio-harmony. One must have $h_{gr}/h > 1$ with requires $M > \hbar/Gm = 1.3 \times 10^{19} m_p v_0$. For $v_0 = 2^{-11}$ this corresponds to $M > \hbar/Gm = 6 \times 10^{15} m_p$. The scale of a water blob with A = 20 containing this number of protons is about 70 μ , which is of order cell size. One can wonder how A_{tot} could be kept as divisible by n_i characterizing the frequencies of the Pythagorean scale. The problem is that an addition of one proton spoils the divisibility conditions completely.
- 3. The solution of the problem could be based on a more precise view about h_{eff} [L108]. The understanding of the variation of Newton's constant too large to be due to experimental errors led to the realization of the meaning of the fact that space-time surfaces can be regarded simultaneously coverings of n_2 -fold M^4 and n_1 fold CP_2 and that one has $n = n_1 n_2$ in $h_{eff}/h_0 = n$ and n_1 would have interpretation as the number of flux tubes which are parallel in M^4 and can be even disjoint. This would give $h_{gr} \propto n_1$ and the factors of n_1 should correspond to the integers characterizing the notes of the 12-note scale. One could perhaps say that effectively single proton is replaced with n_1 protons located at different flux tubes so that also proton mass becomes n_1m . One would have effectively a Bose-Einstein condensate like state of n_1 protons (at different flux tubes).
- 4. In the Pythagorean representation of octave the notes correspond to powers $(3/2)^k$, k = 0, 1, ..., 11, if 3/2)¹² $\simeq 2^7$ is not included. The corresponding integers are $3^k 2^{11-k}$. Only powers of primes p = 2 and p = 3 are involved and one just have $n_1 \propto 3^{11}2^{11}$. If one increases the number of octaves involved to 14 to get a representation for chords needed to avoid the mapping of two dark codons to same 3-chords, one must have $n \propto 3^{23}2^{23} = 6^{23}$. One can consider also simpler representations using integers expressible in terms of powers of primes p = 2, 3, 5 but one must give up exact quint cycle in this case. Interestingly, a good guess for the standard value h of h_{eff} is as $h = 6h_0$ [L41, L83].
- 5. Small p-adic primes p = 2, p = 3 and perhaps also p = 5 (Golden Mean) are expected to be of special importance in TGD inspired biology [K80]. p = 2 seems to appear everywhere and there is also support for p = 3 in biology [I127, I128] (see http://tinyurl.com/ycesc5mq): great evolutionary leaps seem to correspond to time scales coming in powers of 3.
- 6. The branching of the flux tube bundle to n_i sub-bundles $N_i = n/n_i$ could correspond to the reduction $h_{eff} \rightarrow h_{eff}/n_i$. This could be seen as reduction of h_{eff} . One can also consider phase transitions reducing n to n/n_i .

5.3 Homonymy of the genetic code

In the following I will discuss briefly the basic facts about genetic code at Wikipedia level with emphasis on the poorly understood aspects of the code. There are two interesting phenomena: synonymy and homonymy. Synonymy means several names for AA or tRNA codon so that several RNAs are mapped to the sama AA or tRNA codon: the understanding of the genetic code is the understanding of synonymy. Homonymy means that the same RNA codon can correspond to several tRNAs or even AAs. A general TGD based view about homonymy differing from that discussed in [L87] based on the recent understanding of the interaction between various representations of the genetic code is described below.

5.3.1 Variations of the genetic code

There exists also as many as 31 genetic codes (see http://tinyurl.com/ydeeyhjl) and an interesting question is whether this relates to the context dependence. Mitochondrial codes differs from the nuclear code and there are several of them. The codes for viruses, prokaryotes, mitochondria and chloroplasts deviate from the standard code. As a rule, the non-standard codes break U-C or A-G symmetries for the third code letter. Some examples are in order (see http://tinyurl.com/puw82x8).

- 1. UUU can code Leu instead of Phe and CUG can code Ser rather than Leu. In bacteria the GUG and UUG coding for Val and Leu normally can serve as Start codons.
- 2. UGA can code to Trp rather than Stop: in this case the broken symmetry is restored since also UGG codes for Trp.
- 3. There is variation even in human mitochondrial code (see http://tinyurl.com/puw82x8). In 2016, researchers studying the translation of malate dehydrogenase found that in about 4 per cent of the mRNAs encoding this enzyme the UAG Stop codon is naturally used to encode the AAs Trp and Arg. This phenomenon is known as Stop codon readthrough (see https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5133446/).
- 4. There is also a variant of genetic code in which there are 21st and 22nd AAs Sec and Pyl coded by Stop codons. UGA can code for Sec and Stop in the same organism. UAG can code for Pyl instead of Stop and introduces additional breaking of A-G symmetry for the third letter (UAA to Stop and UAG to Pyl).

5.3.2 Wobble base pairing

Wobble base pairing (see http://tinyurl.com/y73se8vs) emerges from the observation that the number of tRNAs pairing with mRNAs is smaller than 45 and considerably smaller than that of mRNAs. The needed minimum number of tRNAs is 32. Therefore the RNA-tRNA pairing cannot be 1-1 and some mRNA codons must correspond to several tRNA codons.

Remark: One could ask whether mRNAs code for tRNAs just like DNAs code for AAs. Homonymy for mRNA-tRNA pairing implies that the pairing can be many-to-1 only in given context.

- 1. According to the standard code, the first two bases of mRNA codon corresponds to two last bases of tRNA anti-codon and obey standard code. Wobble base pairing hypothesis applies to the pairing of the 3rd mRNA base to the 1st base in tRNA anticodon. At the level of chemistry the hypothesis is that the position of the first tRNA anticodon base pairing with the third mRNA base is variable and allows it to pair with several bases appearing as 3rd base in mRNA. This homonymy would be due to "wobbling" of the position of the first tRNA anticodon.
- 2. In the original model for wobble base pairing tRNA bases contain besides standard A, C, G, U also inosine I as a modification of G obtained by dropping NH₂ from the 6-cycle of G. It has turned out that there are actually variants of C and 5 variants of U (see http: //tinyurl.com/y73se8vs). The large amount of homonymy for tRNAs forces to ask whether chemistry alone really dictates the genetic code.
- 3. The first tRNA letter is assumed to be spatially wobbling so that the association of tRNA with RNA is not unique and mRNA-tRNA pairing involves both synonymy and homonymy as the two tables for the pairing of the 1st 5' anticodon base of tRNA and 3rd 3' codon base of mRNA show. In the second column bold letters for mRN bases allow to read the

standard pairing with tRNA codons in the first column and non-bold letters allow to deduce the non-standard behavior.

- 4. The first table (see http://tinyurl.com/y73se8vs) represents the original Watson-Crick proposal.
 - (a) The pairings of the 3rd letter of mRNA codon to the 1st letter of tRNA anti-codon are following.
 - $U \rightarrow G$.
 - $\bullet \ \mathrm{G} \to \mathrm{U}$
 - {A, C or U} \rightarrow I.

The 2nd and 3rd tRNA letters A and C are paired with the 1st and 2nd mRNA letters in the canonical manner. There are only 3 tRNA letters, which implies that the number of tRNAs is smaller than maximal.

- (b) There is single 1-to-many pairing: $U \rightarrow \{G, I\}$ giving rise to 2-fold homonymy.
- 5. Revised pairing rules (see http://tinyurl.com/y73se8vs) are more complex since the number of tRNA bases is larger (U has 5 variants and C has 2 variants). All mRNA letters have 1-to-many pairing. Even if one counts the variants of U as single U there is 4-fold homonymy for U and homonymies for other codons. For A one has 9-fold homonymy.

These variations do not induce variation in DNA \rightarrow AA pairing if the AA associated with the homonyms of tRNA are identical. This seems to be the case almost always since the variation of the genetic code is surprisingly small. This raises the question whether there is some mechanism eliminating to high degree the expected effects of homonymy in mRNA \rightarrow tRNA pairing.

5.4 TGD view about homonymies

One should understand the homonymies of the genetic code [L87]. One can imagine homonymies at the level of DDNA-3-chord and DRNA-3-chord correspondences and between RNA-AA and RNA-tRNA correspondences.

5.4.1 Homonymies for DRNA-3-chord correspondence

It is possible that homonymies are present already at the dark photon level in the sense that the sub-harmonies have common chords.

1. Are the icosahedral orbits for different symmetry groups Z_6 , Z_4 , Z_2 disjoint? If they contain common triangles, the outcome is homonymy for dark codons unless one can scale the 12-note scales with respect to each other (different keys) to avoid common chords.

This question finds an answer from the tables of [L16] representing the chords. If the two scales considered contain 3-chords with the same frequency ratios this can happen. Z_6 harmony contains chords of same type with whole note intervals: $C_x, D_x, E_x, ..., x = m, 6, 9$ coding the frequency ratios as is done in popular music. If second harmony contains several types such that they are not separated by a multiple of whole note interval, at least one common chord is unavoidable also for shifted harmonies.

2. From the tables 11.2 and 11.3 of Appendix one finds that for Z_6 and 2 Z_4 harmonies this is indeed the case and they have 2-chords involving 2 quints in common: 6-orbit and 4-orbit containing x = 9 3-chords have 2 common chords. One has homonymy at dark level. If entire orbits are mapped to the same AA there would be 8 AAs in the same multiplet. Some DDNA and DRNA codons are mapped to the same 3-chord of dark photons. This problem is shared by all 3 models of bio-harmony.

- 3. For the unique Z_6 harmony and 3 $Z_{2,rot}$ (table 11.4 of Appendix) of harmonies common chords can be avoided by shifting the latter harmonies by a half-note. The reason is that the chords of same type are now separated by a multiple of whole note interval. For $Z_{2,refl}$ harmonics (table 11.5 of Appendix) the chords of same type are separated by odd number of half-notes so that common chords are unavoidable since 3-chords of the same type appear. There are also common chords with Z_4 harmony.
- 4. Z_6 and $Z_{2,rot}$ harmonies possess no common chords by a shift by odd number of half notes. Z_4 and $Z_{2,rot}$ and Z_4 and Z_6 possess at least 2 common chords. $Z_{2,refl}$ possesses more common chords with Z_4 and Z_6 .

The fusion of Z_6 , Z_4 , and $Z_{2,rot}$ harmonies with 2 common chords between in $Z_6 \cap Z_4$ $Z_4 \cap Z_{r,rot}$ seems to be best that one can achieve. This would give $1 \times 2 \times 3 = 6$ harmonies altogether unless one obtains new harmonies by by relative shifts of the key.

How to solve the problem?

- 1. The above described homonymies involving 6-plets involve either 6-plet or 2-plet as second multiplet so that these deviations cannot be due to homonymy at the level of DRNA-3-chord correspondence.
- 2. Should one take seriously the puzzle that teased Pythagoras and led him to seriously consider that the structure of the Universe based on rationals has serious flaw in it. 12 quints give slightly more than 7 octaves: one has $(3/2)^{12} = 129.746337890625$ rather than $(3/2)^{12} = 128$ so that one obtains slightly more than octave under octave equivalence.

Why not represent notes as powers of algebraic number $2^{1/12}$ and this is indeed done in practice (in rational approximation of course) but very musical people notice the difference and dislike this representation. There should be something deep in the representation of the scsale in terms of rationals as TGD indeed predicts. Note that a strict resonance is not required, it represents only the optimal situation.

- 3. Repeating the quint cycle gives slightly displaced chords: one can of course do this several times [L109]. Could these slightly displaced chords represent DDNA and RNA codons as 3-chords otherwise mapped to the same chords? This would also mean that the corresponding DNAs and RNAs correspond to 3-chords with at least one note differing only slightly. This kind of notes is shared by 5 chords in icosa-tetrahedral harmony. The addition of second quite cycle means that the integers $n_i = 2^k 3^{23-k}$ characterize the notes of the 3-chords and $2^k 3^{23-k}$ and $2^{k+12} 3^{11-k}$ represent the nearby notes.
- 4. The minimal modification would replace only minimum number of notes in the problematic chords with new ones. A stronger modification would replace the problematic chords with displaced variants with notes in the second quint cycle. One could also do the same for all chords and say that the number of codons for non-problematic dark codons is doubled.

One could also consider the doubling of each letter of the codon so that each chord would be replaced with 8 almost copies except in the case of homonymic AAs. A non-homonymic AA coded by n RNAs would be coded by 8n 3-chords. If the frequency differences are small enough this is not seen at the level of transition energies of AAs: this must be the case for non-homonymous AAs. For homonymous RNAs the energy differences must be seen and remove the homonymy. This DRNA-3-chord homonymy would be analogous to the RNA-tRNA homonymy.

5. One can consider the problem from a different perspective. For Hachimoji DNA [I43] (see http://tinyurl.com/y2mcjb4r) the number of DNA letters seem to double so that codon is replaced with 8 codons. An explanation based on the Pythagorean dilemma was discussed in [L109]. In the model it was however assumed that the doubling of dark DNA and DNA is real being due to the possibility of having also negatively charged color bonds between dark protons so that dark proton is effectively dark neutron (this might happen even in ordinary nuclear physics in nuclear string model [L1]). The Pythagorean double covering of 3-chords could describe the doubling of codons. The doubling would not occur for the codons for which one has the homonymy - a prediction, which could be perhaps tested.

5.4.2 The map DRNA-DtRNA by 3-chords

The map $64 \rightarrow 40$ for DRNA-DtRNA inducing the corresponding map for RNA - tRNA is not unique since there are many ways to reduces 64 to 40. Could this relate to tRNA-RNA homonomy? Consider icosa-tetrahedral code $20 + 20 + 20 + 4 = (3 \times 6 + 2) + (5 \times 4) + (10 \times 2) + (3 + 1)$ as example.

- 1. Suppose Z_2 is the divisor group (also Z_4 and $Z_3 \subset Z_6$ can be considered) so that the orbit can split to two and two tRNAs are associated with given amino-acid coded by n codons. At the first step one can take $20_1 + 20_2 + 20_3 + 4 \rightarrow 20_1 + 10_2 + 10_3 + 4 = 44$. Also $10_1 + 20_2 + 10_3 + 4$ and $10_1 + 10_2 + 20_2 + 4$ can be considered. Since Z_n has Z_2 as subgroup, the simplest manner to achieve $20_k = 10_k$ is to divide all orbits to $2Z_2$ cosets. This can be carried out in 3 ways.
- 2. One must get rid of 4 tRNAs. This can be achieved in several ways. In $20_1 = 3 \times 6 + 2$ one could have $6 + 2 \rightarrow 3 + 1$: there are 3 alternatives. In $20_2 = 5 \times 4$ one could have $5 \times 4 \rightarrow 3 \times 4 + 2 + 2$ (10 ways). In $20_3 = 10 \times 2$ one can take two 2:s to 1 (45) ways.
- 3. Could all these maps be realized and could they correspond to different maps at the level of dark codons? If the independence of resonances energies on frequencies is true with an appropriate choice of $h_{eff,i}$, it would seem that in all these cases same chemical tRNA is possible.

5.4.3 Homonymies for RNA-AA correspondence

There are two basic types of homonymies involving bio-molecules.

1. RNA-AA correspondence can vary somewhat and there are 31 variants of genetic code. RNA-tRNA homonymies are common and wobble phenomenon could be regarded as as such homonomy. This homony is poorly understood.

I made the first attempt to understand homonymies in [L87] but failed to realize one absolutely essential feature. Despite RNA-tRNA homonomies there are practically no RNA-AA homonymies. They might be completely absent for given genetic code. There must be a simple explanation for this.

2. In TGD framework the genetic code is replaced with 3 codes. There is DRANA-DtRNA code mapping 64 DRNA codons to 40 DtRNA codons and *DtRNA – DAA* code mapping 40 DtRNA codons to 20 DAAs. The composition of these codes gives DRNA-DAA code inducing the RNA-AA code.

The highly non-trivial fact is that one has what mathematician would call commuting triangle: RNA-tRNA-AA = RNA-AA for given code. All the homonymies of RNA-tRNA code are possibly completely compensated for given RNA - AA code. This must have simple explanation and once one has made this question, one also knows its answer in TGD framework.

3. For Hamiltonian cycles the n(A) codons coding for given AA corresponds to orbit of a fixed codon at the orbit having symmetry group $Z_{n(A)}$. Genetic code maps the codons at the orbit to the AA corresponding to the orbit and replaces the symmetry group Z_n with trivial group $Z_n/Z_n = Z_1$.

Remark: There are 6 chaotic icosahedral Hamiltonian cycles with symmetry group Z_1 so that therefore 20 amino-acids each coded by single codon. Could one interpret the 20 amino-acids with the chaotic representation of chaotic icosahedral Hamiltonian cycle?

For RNA-tRNA correspondence similar process is possible. Now one replaces Z_n/Z_k where k is factor of n.

Consider icosa-tetrahedral code as an example. k = 2 is simplest choice since it divides n = 6, 4, 2 for icosahedral codes but not for tetrahedral code for which one has n = 3: (*ile*, *ile*, *ile*, *met*) would naturally correspond to the 2 orbits under tetrahedral Z_3 . This symmetry appears only for icosa-tetrahedral option. For other options one can explain it as

an outcome of symmetry breaking for doublets and (ile,ile) and symmetry broken (ile,met) would have ile in common. This looks un-natural.

One can indeed construct $64 \rightarrow 40$ map for DRNA and DtRNA codons by replacing some orbits with their Z_2 cosets but this map is not completely unique. This is possible for all code candidates, which all contain Z_6 and Z_4 symmetric icosahedral harmonies giving rise to amino-acids corresponding to 3 6-orbits and one 2-orbit for Z_6 symmetry and 5 4-orbits with Z_4 symmetry. The remaining orbits are 3-orbit and 1-orbit for tetrahedral symmetry broken to Z_3 and 2-plets for Z_2 orbits.

There are however codes for which RNA-AA correspondence is non-standard. As explained above, the simultaneous replacement UUC-Leu \rightarrow UUC-Phe and UUG-Leu \rightarrow UUG-Ser can take place. Also AUG-met \rightarrow CUG-met and GUG-met \rightarrow GUG-met can occur.

A general explanation could be as follows. If the two homonymous amino-acids - Phe and Leu and Leu and Ser in the first example and met and Leu and Val in the second example- have very nearly same transition energy, and if the 3-chords correspond transition energies of AA irrespective of frequencies, homonymy becomes possible.

This problem can be avoided if the tRNA pairing second AA with the RNA codon is not present. Both options might be realized in the same organism. It could also happen that second AA is so far from energy resonance that it is only rarely translated.

5.4.4 Homonymies for RNA-tRNA correspondence

Could the possibility of several harmonies/moods with different chords increase the number of tRNA codons from the minimal value 40? Are these homonymies forced by necessity or do their reflect freedom of MB to choose? Do dialects emerge already at the molecular level and do they have some practical advantage?

1. Could the possibility of several moods demand more than the minimal number of tRNAs. Harmonies correspond to different collections of triplets (n_1, n_2, n_3) characterizing the chord.

It was however already noticed that the variation of the Planck constants $h_{eff} \rightarrow h_{eff}/n_i$ associated with the flux tubes can modify the cyclotron energies. This would mean that the emotions are not directly seen at the level of molecular transitions as bio-chemist would certainly argue. If energy resonance couples dark photons to ordinary matter it could be possible to guarantee the coupling energy does not depend on the values of frequencies of the 3-chord at flux tubes. This would suggest that there is no motivation to increase the number of tRNAs for the lack of required resonance energies.

2. Could a large number of tRNAs as mediators of RNA-AA pairing be something chosen intentionally by MB rather than being forced by chemical limitations. Could surplus of different tRNAs be a safer option when some tRNAs are not produced. In natural languages there is large number of dialects and new are born all the time.

No hard-wired correspondence would exist at chemical level. MB would be to some degree creative and able to build tRNAs from the stuff that it happens to find from the lab! Biology could be creative already at RNA-tRNA level and this flexibility could emerge from the intelligence coded by $h_{eff} = n$: the larger the number of factors of n the higher the intelligence of the system would be.

This flexibility might also explain the homonymy at RNA-AA level and different genetic codes as a formation of dialects.

5.5 About the details of the genetic code based on bioharmony

TGD suggests several realizations of music harmonies in terms of Hamiltonian cycles representing the notes of music scale, most naturally 12-note scale represented as vertices of the graph used. The most plausible realization of the harmony is as icosahedral harmony [L16] (see http://tinyurl.com/yad4tqwl and http://tinyurl.com/yjjpm25r).

- 1. Icosahedron (see http://tinyurl.com/l5sphzz) has 12 vertices and Hamiltonian cycle as a representation of 12-note scale would go through all vertices such that two nearest vertices along the cycle would differ by quint (frequency scaling by factor 3/2 modulo octave equivalene). Icosahedron allows a large number of inequivalent Hamiltonian cycles and thus harmonies characterized by the subgroup of icosahedral group leaving the cycle invariant. This group can be Z_6 , Z_4 , or Z_2 which acts either as reflection group or corresponds to a rotation by π .
- 2. The fusion of 3 icosahedral harmonies with symmetry groups Z_6 , Z_4 and Z_2 gives 20+20+20=603-chords and 3+1+5+10=19 orbits of these under symmetry group and almost vertebrate genetic code when 3-chords are identified as analogs of DNA codons and their orbits as amino-acids. One obtains counterparts of 60 DNA codons and 3+1+5+10=19 amino-acids so that 4 DNA codons and 1 amino-acid are missing.
- 3. The problem disappears if one adds tetrahedral harmony with 4 codons as faces of tetrahedron and 1 amino-acid as the orbit of the face of tetrahedron. One obtains 64 analogs of DNA codons and 20 analogs of amino-acids. I call this harmony bio-harmony. The predicted number of DNA codons coding for given amino-acid is the number of triangles at the orbit of given triangle and the numbers are those for genetic code.
- 4. How to realize the fusion of harmonies? Perhaps the simplest realization that I have found hitherto is based on union of tetrahedron of 3 icosahedrons obtained by gluing tetrahedron to icosahedron along its face which is triangle. The precise geometric interpretation of this realization has been however missing and I have considered several variants. I have proposed that the model could explain the two additional amino-acids Pyl and Sec appearing in Nature.

There is also a slight breaking of symmetries: ile 4-plet breaks into ile triplet and met singlet and trp double breaks into stop and trp also leu 4-plet can break in leu triplet and ser singlet (see http://tinyurl.com/puw82x8). This symmetry breaking should be understood.

5.5.1 Why 3 icosahedral harmonies and 1 tetrahedral harmony?

The following argument suggests a more detailed solution of these problems than proposed earlier.

1. The copies of icosahedron would differ by a rotation by multiples of $2\pi/3$ (Z₃) around axis through the common triangular face. This face unlike the other faces remains un-affected. Also tetrahedron remains un-affected so that it is counted only once.

If the 3 copies of the icosahedral common face are counted as separate (this is important!), one obtains 20+20+20 faces from icosahedron. If also tetrahedral shared faces is counted as separate, tetrahedron gives 4 faces: 64 codons altogether as required. One obtains 19 orbits from the 3 icosahedra and 1 orbit from tetrahedron: 20 orbits as counterparts of amino-acids altogether.

- 2. But can one really counter the 4 common faces as separate? One must do so. Could these faces be interpreted as somehow special codons? Maybe as stop codons or start codons for the vertebrate genetic code which also corresponds to the realization of DNA, RNA, tRNA, and amino-acids as dark proton triplets so that DNA sequences would correspond to dark proton sequences. Could the shared codons be assigned with various modifications of the vertebrate code involving also exotic amino-acids Pyl and Sec.
- 3. Consider first the tetrahedral face. If the common face is removed from the 4-face orbit of tetrahedron, the orbit has only 3 faces and correspond to an amino-acid coded by 3 DNA codons. ile is the only such amino-acid and the interpretation could be that one ile corresponds to the 3 tetrahedral faces and met acting as start codon to the fourth shared face.
- 4. Also 3 icosahedral amino-acids corresponding to orbits containing the shared face can lose 1 codon each. To nake this more concrete, one can look for the deviations from the vertebrate code.

- (a) There are 10 doublets if the doublet UAA, UAG acting as stop codons is counted as doublet coding for stop regarded formally as amino-acid.
- (b) The second member in the doublet UGA, UGG coding for tyr in code table could correspond to a common face and act as a stop codon.
- (c) For the modifications of genetic code UAG coding for stop can code for Pyl and UGA coding for stop can also code for Sec. UGA can also code for trp so that there would not be any symmetry breaking in this case. Could UAG and UGA correspond to common faces for two icosahedra?
- (d) There is also third icosahedral shared face. CUG coding for leu can also code for ser. Could this correspond to the third exceptional codon associated with the icosahedral part of the code?
- 5. If the answers to the questions are affirmative, all basic deviations from the vertebrate code can be understood. The translation of the codons associated with shared face would be unstable for some reason.
 - (a) 3-chord representation is more fundamental than the chemical one. This could mean that the chords associated with the shared faces are very near to each other so that the correspondence between 3-chord representation and chemical representation of codons becomes unstable if based on triple resonance.
 - (b) The proposal has indeed been that the 13th vertex implied by tetrahedron corresponds to a note very near to one of the notes of 12-note scale - this note is necessary since the 12-note scale defined by quints gives 12th note slightly more than octave under octave equivalence as discovered already by Pythagoras.

If this picture is correct, the symmetry breaking of the genetic code would be due to the presence of the face common to icosahedron and tetrahedron and reflect the problem discovered already by Pythagoras. The rational number based Pythagorean scale defined by quints is special: people with absolute pitch prefer it over the well-tempered scale involving powers of irrational number $2^{1/12}$ requiring extension of rationals.

5.5.2 Could stop codons correspond to dissonant 3-chords?

One can approach the situation also from the point of view of harmony - or rather, dis-harmony: could dissonance 3-chords act as stop codons. The 3-chords of icosahedral harmonies can be classified to three groups depending on whether the triangle representing the chord contains 0, 1, or 2 sides [L16]: in in other words, whether the chord contains 0, 1, or 2 quints. The harmonies can be labelled by the triplet (n_0, n_1, n_2) telling the numbers of chords with 0, 1, and 2 quints.

- 1. The unique Z_6 harmony necessarily present in the bio-harmony has (2, 12, 6). It has two augmented chords (transposes of $C_{aug} = CDG^{\sharp}$) containing two major thirds and defining the 3-chord of a harmony assignable to triangle). This beautiful chord to which finnish tangos so often end, cannot be regarded as dissonance.
- 2. The 2 Z_4 harmonies have $(n_0, n_1, n_2) = (0, 16, 4)$ and (4, 8, 8). For the latter harmony one has genuine dissonances since the highest and lowest note of 3-chord are separated by major or minor third. The chords with 0 quints labelled by script "ex1", "ex2",...,"ex6" (for the notation see [L16]) are dissonances in this sense. "ex7" and "ex8" ($CDF\sharp$ and $CDG\sharp$) cannot be regarded as dissonances in this sense.
- 3. The 3 $Z_{2,rot}$ harmonies have (0, 16, 4), (2, 12, 6), and (4, 8, 8). Both 2-plets and 4-plets contain 2 dissonances.
- 4. There are 3 $Z_{2,refl}$ harmonies with (2, 12, 6) and 1 with (4, 8, 8). These harmonies have genuine dissonances. Interestingly, (2, 12, 6) corresponds to a doublet for which only the second member corresponds to dissonance.

5. For tetrahedral harmony single step should correspond to 1/4:th of octave (using suitable power of 3/2 as a rational approximation) so that the notes at the vertices of tetrahedron should correspond to $CE\flat F\sharp$ defining C_{dim} . This does not appear in the icosahedral code table as 0-quint chord. Although the triangles of tetrahedron and icosahedron would be shared in some sense, the chords cannot be same. This support the idea that ile triplet and met are coded by tetrahedral faces.

The chords containing 0 quints appearing in Z_4 and Z_2 harmonics can be regarded as dissonant. The minimization of dissonance would give a fusion of the unique Z_6 harmony (2, 12, 6), unique Z_4 harmony (0, 16, 4) and unique $Z_{2,rot}$ harmony (0, 16, 4). Bio-harmony would be unique and contain no dissonances. Recall however that the proposal is that bio-harmonies serve as correlates for moods realized even at the level of basic bio-molecules.

For other options one would have dissonant chords. $Z_{2,refl}$ harmony (2, 12, 6) has only single dissonant chord. Since stop codons would naturally correspond to dissonances, this observation raises some questions.

- 1. Could the dissonant chord of $Z_{2,refl}$ harmony (2, 12, 6) correspond to the triangle shared by tetrahedron and icosahedron? Could this correspond to (stop,trp) pair with stop coded by dissonant chord "ex"7 (CDF# defining part of D7 chord). This would fix the code to contain Z_6 harmony (2, 12, 6), unique Z_4 harmony (0, 16, 4) and unique $Z_{2,refl}$ harmony (2, 12, 6). There would be single dissonance coding for stop in stop,trp doublet.
- 2. The doublet coding for stop should formally code for amino-acid. One cannot realize this doublet as a doublet of dissonances with "ex"n, with $n \in \{1, .., 6\}$ for single bio-harmony. The second member of this doublet could however correspond to the shared triangle.

This tentative picture should be of course checked. There are also cycles without any symmetries. Could these chaotic cycles be interpreted as disharmonies.

5.5.3 How could the representations of genetic code as dark 3-chords and nucleotide triplets relate?

One of the poorly understood aspects of the model is how the various representations of the code relate.

Frequency coding of nucleotides is not possible

Frequency coding of nucleotides would look natural but it is easy to see that it is in conflict with bio-harmony.

1. The representations as dark proton triplets and dark photon triplets do not involve decomposition to ordered triplet of letters as the ordinary chemical representation does. Dark protons are entangled and one cannot order them and there is no obvious ordering of the frequencies of dark photons.

This is not a problem for the correspondence between dark proton triplets and dark photon triplets and one can even imagine assignment of dark cyclotron photons with 3 parallel flux tubes acting as wave guides. This could mediate the interaction between dark variants of basic biomolecules with same value of h_{eff} as frequency resonance.

- 2. The interaction between ordinary DNA/RNA/tRNA and its dark variant should involve the transformation of dark photon triplet associated with flux tube triplet emanating from dark bio-molecule to ordinary photons (possibly bio-photons) and energy resonance would be involved. Is the energy resonance involved with the formation of the dark-ordinary pairs or with the sustainment of these pairings? The example of benzene suggests sustainment.
- 3. The assumption that energy resonance is involved with dark-ordinary pairing indeed leads to problems. The first guess would be that ordinary photon triplet somehow carries information about the position of nucleotide in the codon. The 4 nucleotides would correspond to 4 frequencies with frequency scale depending on the position inside the codon. There are indeed

12 frequencies in the 12-note scale so that 3 frequency scales with 4 frequencies associated with each of them would give 64 combinations of frequencies.

Frequency coding of nucleotides however leads to a problem. The first two letters of the codon are known to determine the amino-acid coded by it to a high degree since the third letter typically distinguishes between 1 or 2 amino-acids only, and labels codons at the orbit of DNA codon defining amino-acid. Therefore for DNA codons coding same amino-acid the first two frequencies should be same. This is not the case for bio-harmony for the simple reason that the frequencies of 3-chords along the orbit defining amino-acids are different. Only the frequency ratios defining the type of the chord are same along the orbit.

The frequency ratios determine the correspondence so that the correspondence can be only between *entire* dark and ordinary codons, and cannot be reduced to correspondence between frequencies and letters. Holism does not reduce to reductionism.

Does the impossibility of frequency coding of nucleotides lead to problems with the models of replication and transription?

This becomes a potential problem in the model for DNA replication and transcription to RNA.

1. The basic picture about bio-catalysis in TGD framework is following. U-shaped magnetic flux tubes emanate from the reactants and can reconnect to form a pair of flux tubes connecting the reactants. The shortening of the flux tube pair by a reduction of h_{eff} brings the reactants together and liberates the energy needed to kick the reactants over the potential wall making the reaction rate extremely low otherwise.

The U-shaped flux tubes or flux tube triplets would be associated with dark codons of dark DNA accompanying DNA strand, and would be formed as the flux tube pair(s) connecting the strands split by the reversal of reconnection. The h_{eff} associated with resulting U-shaped flux tubes associated with replicating strands would increase requiring metabolic energy. They would get longer and could act as tentacles scanning the environment to spot similar flux tubes assignable to nucleotides or codons by resonance.

2. In the standard picture one assumes that nucleotides defining the letters of the codons appear as non-correlated molecules in the environment, and that each codon is built by a stepwise process in which letters attach to it. The letters can respond only to single frequency and cannot "know" which position to attach to. Thefrequency coding is not consistent with the idea that dark photon triplet assigned with the dark codon gives rise to energy resonance with the letters one by one.

Could the triple resonance occur as single step and attach all 3 nucleotides in single step? Or could the triple resonance be a collective frequency resonance with dark codon already attached to the ordinary codon in the environment. Ordinary-dark pairing by energy resonance would sustain rather than generate DNA strand since otherwise the Coulomb repulsion due to the large negative charge of DNA does not allow stability.

3. The problem is that it is nucleotides seem to appear in the environment rather than codons. Could the nucleotides of the environment actually form loose codons connected to dark codons by long flux tubes with large value of h_{eff} ? Could the reduction of h_{eff} bringing nucleotides together induce the reduction of flux tube lengths giving rise to ordinary codon? If the reduction of h_{eff} for flux tubes occurs nucleotide-by nucleotide, one would have consistency with the standard picture. The simplest picture is following.

Dark codons are paired with the loose variants ordinary codons. The opening of DNA double strand leads to the splitting of the flux tube pairs connecting the ordinary codons of strands to U-shaped flux tubes, which reconnect with U-shaped flux tubes coming dark codons paired with loose ordinary codons. The reduction of h_{eff} d pairs nucleotides of loose codons with those of ordinary codons.

4. The pairs of dark codons and loose codons would be analogous to tRNA molecules. One can imagine even pre-tRNA molecules with loose coupling of RNA and amino-acid so that

replication and transcription would be very similar topological processes. Also RNA transcription and translation of RNA to amino-acids would rely on similar mechanism. The only difference would be that only the second - active - strand would form U-shaped flux tubes connecting with dark RNA codons.

What about remote DNA replication

This model could also explain remote replication of DNA for which Montagnier *et al* have reported evidence [I92]. Also remote transcription is predicted to be possible. I have already earlier considered a model of remote replication [K136] in an article written together with Peter Gariaev who has reported this kind phenomenon already earlier. I have discussed the findings of Montagnier *et al* in [L4].

- 1. The experiment involves two vessels, call them A and B. A contains genes and B only nucleotides at least according to the standard picture. There is irradiation using 7 Hz frequency not far from the lowest Schumann frequency having a nominal value of 7.8 Hz. What happens is that the replicas of genes appear in B. It is also reported that the DNA generates em radiation possibly responsible for the information transfer.
- 2. The proposed model for the ordinary DNA replication generalizes easily to describe also remote replication. The new element would be that the U-shaped flux tubes from A would extend to B here 7 Hz radiation could be essential , would be parallel to each other, and have same average length, which is natural if they have same value of h_{eff} . Also the experimental arrangement could favor parallel flux tubes. In B the dark codons paired with loose codons formed from ordinary nucleotides would be present, and their U-shaped flux tubes would reconnect with those coming from A. Remote replication could take place: here it is essential that the U-shaped flux tubes are parallel and have very nearly the same length.

The TGD interpretation would be that the Earth's magnetic body is involved and generates quantum coherence in the length scale at least the size of the system studied. The reported em radiation would naturally relate to the dark photon triplets representing the codons.

Is ZEO needed to understand the replication?

In TGD one must give up thinking in terms of standard ontology of bio-chemistry in which the process is a kinetic process governed by differential equations for the populations of molecules and proceeding in step-wise manner nucleotide by nucleotide. ZEO suggests temporal holism - at least at the level of single dark codon, which cannot be built building brick by building brick.

- 1. An open question is in which time scale this temporal quantum holism holds true: in the time scale of addition of single codon or in the time scale of replication of gene or something else? In the following the possibility that temporal holism holds in the time scale for the pairing of dark codons.
- 2. In ZEO one could have state function reduction in which initial state corresponds to dark codon plus population of nucleotides and final state to dark codon paired with the ordinary codon formed from 3 nucleotides in energy resonance with the codon formed from nucleotides. What matters are only the initial and final states.
- 3. If "big" state function reduction (BSFR) is in question, the final state would correspond to a superposition of deterministic time evolutions leading from the outcome of the reduction to geometric past, possibly but not necessary to a state in which nucleotides do not form codon paired with the dark codon.
- 4. The process would create strong correlations between the position of nucleotides of the codon and between the positions of codon and its dark variant and therefore a generation of entanglement. Unitary evolutions followed by "small" state function reductions (SSFRs) would generate a state as a superposition of the states satisfying the criteria of the desired final state and other states and BSFR would select the desired final state. It could be followed by BSFR returning the original arrow of time but doing nothing for the state.

5.6 How to compose beautiful music of light in bio-harmony?

The topic of this section is the detailed definition of the notion of bio-harmony [L23, L24, L124]. A sequence of 3-chords of bio-harmony defines a music piece: what rules guarantee that this piece is beautiful? This question is interesting because the chords of bio-harmony correspond to DNA codons.

Bio-harmony as a realization of genetic code

TGD leads to a notion of bio-harmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron [L23, L24, L124]. Bio-harmonies are associated with the so-called Hamiltonian cycles , which go through every vertex of Platonic solid once. For icosahedron the number of vertices is 12, the number of notes in 12-note scale. The 64 codons of bio-harmony represented as light 3-chords formed by dark photon triplets are formed from 3 20-chord harmonies associated with icosahedron and the unique 4-chord harmony associated with tetrahedron.

The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino acid are predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bio-harmony in question corresponds to DNA codons coding for the amino acid assigned with the orbit.

Codon corresponds to 6 bits: this is information in the usual computational sense. Bioharmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bio-harmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it. For emotional expression at RNA level possibly involved with conditioning at synaptic level see [L81].

About generalizations of the notion of bio-harmony

One can consider several generalizations for the notion of bio-harmony.

1. All Platonic solids, in particult tetrahedron, cube, octahedron and dodecahedron are possible and one can consider the possibility that they also define harmonies in terms of Hamiltonian cycles. Dodecahedron would have 5-chords (pentagons as faces) as basic chords and there is only single harmony. Same mood always, very eastern and enlightened as also the fact that scale would have 20 notes.

Also octahedron gives 3-chords (triangular faces) whereas cube gives 4-chords (squares as faces). One can of course speculate with the idea that DNA could also represent this kind of harmonies: sometimes the 3N rule is indeed broken, for instance for introns.

2. Galois confinement [L139] allows the possibility to interpret dark genes as sequences of N dark proton triplets as higher level structures behaving like a single quantal unit. This would be true also for the corresponding dark photon sequences consisting of 3N dark photons representing the gene in bio-harmony as an analog of a music piece consisting of 3-chords and played by transcribing it to mRNA.

Basic biomolecules (DNA, RNA, tRNA, amino acids) would have names represented as a sequence of light 3-chords representing a piece of music and dark biomolecules with the same name could recognize and communicate with each other in 3N-resonance. Dark-ordinary communications could transform dark 3N-photon to single bio-photon so that resonance would be possible when the sum of energies coincides with a transition energy of the ordinary biomolecule. The resonance condition would very effectively select survivors in the fight for survival.

3. The picture can be viewed even more generally. Any discrete structure, defining graph, in particular cognitive representation providing a unique finite discretization of space-time surface as points with the coordinates of the 8-D embedding space coordinates in the extension of rationals, defines harmonies in terms of Hamiltonian cycles. Could also these harmonies make sense? The restrictions of the cognitive representations to 2-D partonic 2-surfaces would

define something analogous to bio-harmony as Hamiltonian cycle of 2-D graph (Platonic surfaces solids can be regarded as 2-D graphs). The interpretation as representations of Galois groups and the notion of Galois confinement is possible although one loses the symmetries of the Platonic solids allowing to identify genetic code.

During years I have indeed considered some modifications of the original bio-harmony base on the fusion of 3 icosahedral harmonies and tetrahedral harmony in partcular so called E_8 harmony and toric harmony [L40, L79] but the overall conclusion [L103] is that the original model is the most plausible candidate.

The challenges of the model

The model of bio-harmony is far from complete and this article discusses a more detailed definition. Also the question about the rules defining beautiful music by posing rules on chord sequences are considered. These aesthetic rules are also rules for the corresponding DNA and amino-acid sequences.

1. The fusion of the three harmonies having symmetry groups Z_n , n = 6, 4, 2 has been considered but not in the required detail. The Hamiltonian cycles of icosahedron are fixed only modulo isometries of icosahedron preserving the shape of the cycle, scalings of the cycle by a power of quint forming group Z_{12} leaving the cycle of invariant but inducings transponation (change of the key), and the change of the cycle orientation possibly related to minor-major dichotomy correlating with joyful-sad dichotomy. For a single icosahedral cycle these transformations do not change anything but for the fusion of 3 cycles realized at the same icosahedron the situation changes, and the number of harmonies increases dramatically.

Are all combinations of icosahedral harmonies allowed or are there some natural restrictions on them? I have considered this question but it seems that there is no good reason for posing any restrictions. The spectrum of harmonies determined by dark genetic codons and therefore the spectrum of emotions at the molecular level would be surprisingly rich.

2. Is it possible to reproduce the basic harmonies of the western music based on the 12-note system which inspired icosahedral harmonies? In particular, can one understand the chords C, F, G of C-major scale? By octave equivalence the nearest neighbors of the Hamiltonian cycle are related by quint scaling scaling frequency by factor 3/2 scaling C to G. The 3-chords containing at least one cycle edge contain quint ($C \rightarrow G$) and quint is the basic aspect of bio-harmony. For harmonies with opposite orientation quints become perfect fourths ($C \rightarrow F$) and FCG corresponds to transponantion of F by two quints.

For a single icosahedral harmony the chord-pairs analogous to C-F or C-G do not appear in any obvious manner. If the 3 icosahedral harmonies are related by quint scalings (FCG) the analogs of these chord pairs become natural. Could this be the solution to the problem?

3. What are the rules producing aesthetically satisfying music? I experimented with the ultraconservative assumption that only chord pairs containing common quint are allowed: the result was not ugly but it was boring. Already the transitions of CFG major scale are too radical for this option!

An attractive idea is that the sequence of 3-chords is continuous in some sense. Could the sense be strictly geometric: could chord pairs be nearest neighbors in some sense. For Option I nearest neighbors have a common edge (3 nearest neighbours). For Option II they have a common vertex (10 nearest neighbors). These options do not allow all 3-chord pairs and thus not all possible DNA pairs and all possible amino-acid pairs. A more abstract definition identifies the nearest neighbors with the orbits of nearest neighbors for Option I or II under the symmetry group Z_n (n = 6, 2). Codon is replaced with the codons coding for the same amino-acid. For Option II this allows to have all possible chord pairs and therefore DNA and amino-acid pairs.

4. Also the role of tetrahedral harmony and its relation to start and stop codons is interesting. One wants also to understand why the genetic code at the bio-chemical level is not quite complete and why there are several variants of it.

Symmetry	#(class)	#(repr)
Z_6	1	8
Z_4	2	12
$Z_{2,rot}$	3	24
$Z_{2,refl}$	5	24

Table 5.1: The number #(class) of equivalence classes of Hamiltonian cycles at the number #(repr) of representatives in the class for icosahedral Hamiltonian cycles. If the orientation is not taken into account the number of representatives reduces to #(repr)/2

5.6.1 About bio-harmonies

The set of allowed 3-chords define music harmony. The 12-note scale is essential for the western view about harmony. The TGD inspired geometric model for music harmony identifies bio-harmony as a fusion of 3 icosahedral harmonies with 12-note scale represented geometrically as a Hamiltonian cycle at icosahedron and 1 tetrahedral harmony represented as a unique Hamiltonian cycle of tetrahedron. Each icosahedral harmony has 20 3-chords identifiable as triangular faces of the icosahedron whereas tetrahedral harmony 4 3-chords. This gives 20+20+20+4=64 chords - the number of genetic codons.

Symmetries of icosahedral harmonies

There are 3 types of icosahedral harmonies with symmetries characterized by a subgroup of icosahedral isometries, which is Z_6 , Z_4 or Z_2 acting either as a rotation by π or as a reflection. The orbits of triangles are identified as counterparts of amino-acids coded by the DNA codons assigned with the triangles of the orbit.

- 1. For Z_6 given triangle gives rise to 3 6-orbits with 6 triangles and 1 2-orbit: Z_3 subgroup of icosahedral group permutes the 3 6-orbits and acts trivially to 2-orbit.
- 2. For Z_4 there are 5 4-orbits and Z_5 permutes these orbits.
- 3. For Z_2 there are 10 2-orbits and Z_{10} permutes them. Z_2 can act either as reflections or rotations.

There are also 6 cycles without any symmetries perhaps identifiable as dis-harmonies. They will not be considered in the sequel. For them the number of amino-acids coded by codon would be one.

Table 5.1 summarizes the numbers of equivalence classes of cycles and under icosahedral rotation group for various symmetry groups as well as the numbers of representatives in the class. These numbers allow to deduce the number of bio-harmonies by fixing one of the icosahedral harmonies, most naturally the Z_6 harmony for which one has only one class.

Remarkably, the combination of 3 icosahedral cycles with symmetries Z_k , k = 6, 4, 2 with the tetrahedral Hamiltonian cycle gives 64 codons and the model correctly predicts the numbers of DNA codons coding for a given amino acid. Could there be a connection between music and genetic code? Could one speak of bio harmonies as correlates of emotions at the molecular level?

The natural expectation is that the symmetries Z_n of a given harmony leave the ratios of frequencies of 3-chords invariant. This is true if the edge connecting nearest neighbors along Hamiltonan cycle corresponds to a quint that is scaling of frequency by 3/2 and projection to the basic octave (octave equivalence). Therefore the chords at the orbit of a given chord coding for the same amino-acid are replaced by a scaling by power of 3/2 so that the scalings are mapped to unitary rotations.

The factors of 12 include indeed 6, 4, and 2 so that the 12-element group of scalings modulo octave equivalence can be mapped to Z_{12} rotations. There is however a problem with rational quints due to the fact that - as already Pythagoras found - $(3/2)^{12} = 129.746...$ does not correspond exactly to $2^7 = 128$. One reason for introducing icosahedron could be that this brings additional note allowing to get rid of the problem. One can also construct the notes by powers of $2^{1/12}$ applied

to the basic frequency but now the frequencies are not rational. Furthermore, people with absolute pitch favor rational frequency ratios, which suggests that rational numbers and roots of unitary assignable with adelic physics as physics of cognition are really important.

Fusion of 3 icosahedral harmonies and tetrahedral harmony to bio-harmony

There is quite a large number of icosahedral Hamiltonian cycles and therefore of bio-harmonies. Although the isometries of icosahedron and their transponations do not matter for given icosahedral harmony, they matter when one has 3 icosahedral harmonies. A simple example from physics helps to understand this: although rotations are symmetries of an N-particle system the rotations of a single particle are not symmetries anymore and represent new degrees of freedom.

1. Bio-harmony assigns to the same icosahedron 3 Hamilton cycles with symmetries Z_k , k = 6, 4, 2. This means assigning to the same icosahedron 3 Hamiltonian cycles giving rise to 3 representations of 12-note scale each giving 20 chords so that one 20+20+20 chords coding 3 classes of amino acids. Tetrahedron gives the remaining 4 chords.

There are N_i , i = 1, 2, 3 cycles corresponding to $Z_{k(i)}$, k(i) = 6, 4, 2: for the values of N_i and detailed 3-chord contents of icosahedral harmonies see [L16]. From the table **Table 5.1** one has for $(Z_6, Z_4, Z_{2,rot}) \ \#(class) = (\#(class)_1, \#(class)_2, \#(class)_3) = (1, 2, 3)$ giving 6 different classes and $(Z_6, Z_4, Z_{2,refl}) \ (\#(class)_1, \#(class)_2, \#(class)_3) = (1, 2, 5)$ giving 8 different classes. This gives N = 14 different icosahedral Hamiltonian cycles.

The numbers of reresentatives for given equivalence class are for both $(Z_6, Z_4, Z_{2,rot})$ $(Z_6, Z_4, Z_{2,rot})$ #(repr) = (2, 12, 24).

2. The 3 cycles go through all points of the icosahedron. This means that for each point of icosahedron there are 3 cycles going through that point. There can be however situations in which there are common edges. 5 edges arrive at given icosahedral vertex. There are 3 cycles entering and leaving the vertex: this makes 6 cycle edges. There is necessarily one edge shared by two cycles. If the edge is shared by 3 cycle edges, one edge has no cycle edge. This kind of situation - 3-edge - is achieved by performing a suitable Z_5 rotation for the third cycle.

Do all bioharmonies have 3-edges? Could 3-edges have a special role concerning bioharmony and music experience? Could they define chords with preferred quints such as chords C, F, G in C major scale? The bio-harmonies having chord(s) with 3-edge could give rise to simple CFG type harmonies. Fusion of 3 icosahedral harmonies differing by quint scalings gives a CFG type situation, and one could assign all these 3 types of chords with a triangle with 3-edge. Geometrically the chord progression would reduce to a repetition of the same triangle! Allowing also the triangle at the other side of the 3-edge, the chord progression involving only these 2 triangles consists of 3+3=6 chords.

3. One can assume that the 3 Hamiltonian cycles start at the same almost arbitrarily chosen vertex of the icosahedron. As a special case one can assume that it corresponds to the same basic note (C). Since Z_6 allows only a single cycle, it is natural to fix it: the fact this cycle has 2 orientations gives degeneracy factor 2.

The other other cycles are determined apart from the rotation group Z_5 leaving the base point invariant. Therefore the Z_4 and Z_2 harmonies give rise to an additional $5^2 = 25$ -fold degeneracy of bio-harmonies $N \to 25N$. If the cycles are required to have a common first edge besides the base point, one does not obtain the degeneracy factor. This argument shows that common edges are possible and the vertices associated with them are definitely special.

Fixing the cycle types and the Z_6 cycle one can calculate the number of bioharmonies for a given equivalence classes as the number $\#(repr(Z_4)\#(repr(Z_2)$ One obtains 12×24 representatives for both choices of Z_2 . For r $Z_2 = Z_{rot}$ the total number of bioharmonies is

 $N(harmony, rot) = 2 \times 2 \times 12 \times 3 \times 24 = 2^7 \times 3^2$

 $N(harmony, refl) = 2 \times 2 \times 12 \times 5 \times 24 = 2^7 \times 3 \times 5$.

The first factor of 2 comes from the two orientations for the fixed Z_6 cycle.

4. The transponations realized as scalings along the Hamiltonian cycle define 1-to-1 map of icosahedral vertices which is however not an isometry but preserves the harmony. This gives a degeneracy factor 12^2 and one has

$$N(harmony, ...) \rightarrow 12^2 \times N(harmony, ...)$$
.

The formula for the total number of bioharmonies is

$$\begin{split} N(harmony) &= N(harmony, rot) + N(harmony, refl) = 2^{14} \times 3^3 , \\ N(harmony, rot) &= 2^{11} \times 3^4 , \\ N(harmony, refl) &= 2^{11} \times 3^3 \times 5 . \end{split} \tag{5.6.1}$$

How to understand the tetrahedral code and symmetry breaking of the perfect code?

The precise understanding of the relationship between tetrahedral and icosahedral codes has been a long standing challenge and have considered several scenarios. The geometric idea has been that tetrahedron is somehow glued to icosahedron along on faceand selects a unique codon of the icosahedron defining the basic chord. As found, another manner to fix this chord as a chord to which one can assign 3 cycle edges. There might be other faces with the same property.

One can get information about the situation by looking at the code table.

1. There are 10 unbroken icosahedral Z_2 doublets containing (stop,stop) plus 1 symmetry broken doublet (stop,tyr). What could cause the symmetry breaking? The energy resonance condition associated with the pairing of dark mRNA codons with dark tRNA codons could explain the presence of stop codons: translation would stop when no tRNA in energy resonance is found.

Dark 3-photon representing the dark stop codons could not couple to tRNA codon in energy resonance since there would not be tRNA with cyclotron resonance energy triplet resonating with that of dark stop codon. This would be the case for the (punc,punc) doublet and also for punc member of (puc,trp) doublet. The mimicry of dark level by biochemical level would not be complete. For the variants of the code it would be even less complete.

2. From the table one learns that both Z_6 and Z_4 codons are realized completely for the vertebrate code. This leaves only one conclusion: (ile,ile,ile,met) must correspond to a Z^4 symmetry breaking for tetrahedral rather than icosahedral 4-plet. The AGG coding for met, which is unique in the sense that it serves as a mark for the beginning of genes, would correspond to a tetrahedral face.

The failure of energy resonance could force the splitting of unbroken tetrahedral ile 4plet to (ile,ile,ile,met). Fourth codon in Z_4 4-plet would be in energy resonance with tRNA associated with met. Note that icosahedral code gives rise to 4+5+10=19 amino-acids and met provides the 20^{th} amino acid. Symmetry breaking would be necessary to mark the starting and stopping points of transcription and translation.

3-chords also depend on the icosahedral harmony and for some icosahedral harmonies energy resonance could fail so that the emotional state of at dark matter level would reflect itself at the biochemical level. The number of icosahedral harmonies is (1,2,3,5) for $(Z_6, Z_4, Z_{rot}, Z_{2, refl})$. For Z_4 and Z_2 the failure of energy resonance is possible.

Remark: I must confess that many earlier texts about the problem contain a stupid error. I have considered the proposal that (ile,ile,ile,met) could correspond to symmetry broken icosahedral 4-plet. Vertebrate code has however 5 unbroken 4-plets corresponding to (val,pro,thr,ala,gly) as also 3 unbroken 6-plets (leu,ser,arg)! For vertebrate code the symmetry breaking can therefore occur only for icosahedral Z_2 doublets and tetrahedral Z_4 4-plet.

Variations of the genetic code

There exists also as many as 31 genetic codes (see http://tinyurl.com/ydeeyhjl) and an interesting question is whether this relates to the context dependence. Mitochondrial codes differ from the nuclear code and there are several of them. The codes for viruses, prokaryotes, mitochondria and chloroplasts deviate from the standard code. As a rule, the non-standard codes break U-C or A-G symmetries for the third code letter.

In the proposed framework the failure of energy resonance conditions could be at the level of tRNA. The dark tRNA analog of RNA could be in energy resonance with "wrong" amino acid.

Some examples are in order (see http://tinyurl.com/puw82x8).

- 1. UUU can code Leu instead of Phe (symmetry breaks for Phe doublet) and CUG can code Ser rather than Leu (symmetry breaks for leu 6-plet). In this case it seems that the "problem" is at the level of tRNA. The dark RNA codon could couple with a "wrong" amino acid.
- 2. In bacteria the GUG and UUG coding for Val and Leu normally can serve as Start codons. In this case symmetry breaking for Z_4 4-plet would be in question. The problem could be also at tRNA level. Note however that both tetrahedral codons and icosahedral Z_4 codons have the same symmetry group. Could tetrahedral codons correspond to a different frequency scale and correspond to Leu and Val 4-plet instead of symmetry broken ile 4-plet.
- 3. UGA can code to trp rather than punc: in this case the broken symmetry would be restored since also UGG codes for trp. Both codons for (trp,trp) doublet would be in resonance: this supports the explanation for the emergence of the third stop codon.
- 4. There is variation even in human mitochondrial code (see http://tinyurl.com/puw82x8). In 2016, researchers studying the translation of malate dehydrogenase found that in about 4 per cent of the mRNAs encoding this enzyme the UAG Stop codon is naturally used to encode the AAs trp and arg. This phenomenon is known as Stop codon readthrough [I82]. Also this phenomenon could be understood at tRNA level.
- 5. There is also a variant of genetic code in which there are 21st and 22nd AAs Sec and Pyl coded by Stop codons. UGA in (punc,trp) doublet can code for Sec and punc in the same organism. UAG can code for (punc,punc) doublet Pyl instead of punc and UAG. This introduces additional breaking of A-G symmetry for the third letter of codon. Energy resonance at the level of tRNA could explain these deviations from the vertebrate code.

Peter Gariaev has introduced the notion of homonymy of genetic code meaning that the same codon can code for several amino-acids and the coding depends on context. I have considered this phenomenon from the TGD point of view in [L87]. Resonance could explain this phenomenon.

Dark mRNA codon could be in frequency resonance with dark tRNAs coding for different amino acids. The fraction of particular synonymous amino-acid produced in translation would naturally depend on how well the energy resonance condition is satisfied. Homonymy could also reduce to the level of tRNA: this happens if the coupling of the tRNA analog of RNA codon has energy resonance with several amino-acids.

5.6.2 How to produce beautiful bio-music?

Music expresses and produces emotions and harmonies in music correspond to emotions. Chemical representation of the genetic code should be the same irrespective of the emotional state of the gene represented at the magnetic body in terms of dark proton triplets also representing genetic codons and by music of light represents 3-chords of light with frequency ratios determined by one of the bio-harmonies.

This is achieved naturally. The correspondence between the chords of harmony and DNA and amino-acids does not depend on what vertex of icosahedron the base note (C for definiteness in the sequel) corresponds to. It also depends only on the shape of the Hamiltonian cycle invariant under isometries of the icosahedron. Furthermore, transponations of the scale by power of 3/2 plus projection to the basic octave do not affect the Hamiltonian cycle and therefore leave the correspondence with DNA codons and amino acids invariant.

The sequences of 3-chords would correspond to sequences of DNA codons mapped to sequences of amino-acids. Genes would be like music pieces. These music pieces would also serve as kind of names of passwords in 3N-fold resonance in communications between dark variants of basic biomolecules and between them and ordinary basic biomolecules. They would be like theme songs of TV series catching the attention or names essential for symbolic dynamics at the level of the basic biomolecules. The basic biomolecules in the same emotional state - that is having the same bio-harmony - could resonate and therefore couple.

What the rules for a beautiful bio-music could be? Could these rules select particular bioharmonies and/or particular DNA sequences as allowed chord progressions and allow a deeper understanding of why particular genes are selected? Note that the condition that the chords of bio-harmony define 3N-resonances assignable to transitions of the basic biomolecules could lead to the selection of both harmony and biomolecules. A weaker condition is that ordinary biomolecules couple only to the sum of frequencies appearing in 3N-frequency assignable to dark codon.

Are beautiful chord sequences continuous in some sense?

The original model discussed in [L16, L103] started from a very conservative idea for what harmonic change of chord could be. The two chords should have at least a single quint. This fails for the chords with no quints. The resulting music pieces were also boring which is not a surprise: for instance, the transitions between basic chords C, F, G of C major scale are not possible.

This suggests that one should not start from music but from geometry. Let us consider isohedral geometry for simplicity and the proposed picture for the bio-harmonies.

- 1. Continuity in some sense is a natural requirement. The natural definition of continuity is that the sequence of 3-chords of progression should define a sequence of neighbouring triangles at the icosahedron. But how should one define neighborhood?
- 2. Concerning the notion of nearest neighbor, there are 3 options to consider.

Option I: The strong form of continuity is that neighboring triangles have at least one common edge. This allows 4 different chord pairs. This would mean 4 possible DNA codon pairs for a given Hamiltonian cycle. For bio-harmony the symmetry of icosahedral harmony determined by Z_n (n = 6, 4, 2) can change and one would have 4+4+4=12 codon pairs. This kind of correlation for codon sequences would have been observed.

Option II: For a weaker option the neighboring triangles would have at least 1 common vertex. A given triangle would have 4+3+2+1=10 neighbors ("1" corresponds to the triangle itself as a neighbor). This would give 10+10+10=30 possible codon pairs.

Tetrahedral harmony gives further pairs but since one triangle of tetrahedron should correspond to a fixed triangle of icosahedron, this can change the situation for only a single chord. It is known that the minimum of 32 two codons are needed to code amino acids. The optimum situation very probably not reached for all bio-harmonies (if any), would be that the amino acid associated with the next codon can be any aminoacid. It should be easy to demonstrate by studying a sample of genes or more general DNA codon sequences to find that this prediction is wrong.

Option III: For the weakest option the nearest neighbors would correspond to triangles at the orbits of the nearest neighbors in the sense of **Option II** or perhaps even **Option I** under the symmetry group Z_n of a given cycle. For instance, the transitions which would not change the codon would be replaced with all codons coding for the same amino-acid. The notion of nearest neighbor would reduce to the level of amino-acids: only the transitions to codons coding for the same amino-acid would be possible.

For the generalization of **Option I** Z_6 cycle would give 4 orbits of which several must be identical so that there are no problems. Z_4 cycle would give 4 orbits with 4 codons so that one amino acid is missing. For the Z_2 option one obtains only 4 2-origi so that 6 amino-acids are missing.

For the generalization of **Option II** 10+10+10 nearest neighbours would be replaced with their orbits. For the Z_6 cycle there are nearest neighbor 10 orbits and since there are only 4 orbits, there are no problems. For the Z_4 cycle one there are 5 4-orbits so that the minimal degeneracy of a given orbit is 2.

For the Z_2 cycle there are 10 2-orbits, and this number is obtained unless some 2-orbit occurs more than once. The 10 nearest neighbor triangles must correspond to different amino-acids: whether this is possible for all bioharmonies, remains an open question. In any case, it is plausible **Option III** can produce all possible codon pairs although this need not be the case for all bioharmonies. Could preferred bioharmonies be selected by the condition that all codon pairs are possible?

What about melody?

Melody is also an important part of music. A rough rule of thumb is that a beautiful melody tends to contain notes of the chord accompanying it. Dissonance is of course what makes music really interesting. This can be understood as a resonant coupling of the notes of the melody with the notes appearing in the accompanying chords.

Can one apply this picture to the music of light? Could the dark 3-photon states bound to a single unit by Galois confinement tend to decay to ordinary 3-photon states (bio-photons) and could melody represented as a sequence of single photon states couples resonantly to these photons? Could melody correspond to as sequence dark photons 1-plets decaying to ordinary bio-photons coupling to the decay products of dark photon triplets representing genetic codons?

Summary

The basic results of the article are a precise definition of bio-harmony allowing to obtain the analogs of ordinary simple harmonies as special cases and a proposal that the 3-chord sequence defines a beautiful music piece if it corresponds to a continuous sequence for icosahedral faces. In principle this criterion allows bio-harmonies for which all possible codon pairings appear in chord sequences but some bio-harmonies might be excluded.

5.7 Is genetic code part of fundamental physics in TGD framework?

5.7.1 3 basic realizations of the genetic code

Topological Geometrodynamics (TGD) proposes 3 basic realizations of the genetic code [L103]. The first realization is the standard chemical realization. The second realization is in terms of dark proton sequences (dark nuclei) with proton triplet representing a codon. Ordinary DNA strands would be accompanied by dark magnetic flux tubes carrying the dark proton triplets. Also RNA, amino-acids and tRNA would have dark proton analogs.

The third realization is in terms of dark photon triplets and involves the notion of bioharmony described in terms of icosahedral and tetrahedral geometries with 3-chords of light (perhaps also sound) assigned to the triangular faces of icosahedron and tetrahedron. 12-note scale is realized as a Hamiltonian cycle for icosahedron with the step between nearest neighbor vertices for the cycle realised as quin (scaling of frequency by factor 3/2). The 3-chords correspond to the triangular faces of the icosahedron. Also tetrahedral realization of 4-note scale is necessary in order to obtain genetic code. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bio-harmony corresponds to DNA codons coding for the amino acid assigned with the orbit. Vertebrate genetic code emerges as a prediction.

The 3-chords of dark photon triangles are assigned with the triangular faces of icosahedron and tetrahedron [L16, L103, L135] such that their corners are labelled by the notes of the 12- and 4-note scales realized as a icosahedral and tetrahedral Hamiltonian cycles, which are closed paths connecting vertex to neighboring vertex and going through every vertex once.

Genetic code corresponds to a fusion of tetrahedral harmony with 4 chords and of 3 icosahedral harmonies with 20 3-chords having as group of symmetries Z_6 , Z_4 and Z_2 - Z_2 can correspond either to reflection or rotation by π . There are also 6 disharmonies without any symmetries (Z_1) with single DNA codon coding for single amino-acid. There is a considerable number of different icosahedral harmonies and the 3 icosahedral harmonies can be in different key so that a large number of bio-harmonies is possible [L135]. The details of the model of bio-harmony are not completely fixed. In particular, the understanding of stop codons is not completely satisfactory. The small deviations from the vertebrate code (say bacteria and mitochondria) could be understood as being due to the incomplete mimicry of the dark code by chemical code in accordance with the idea that the mimicry has gradually evolved more complete.

Dark photon 3-chords mediate interaction between various realizations. Both dark proton and dark photon triplets would be dynamical units analogous to protons as color confined states of 3 quarks and in the adelic vision the notion of color confinement is replaced with Galois confinement [L135, L228]. Also genes could be seen as Galois confined states of 3N dark protons and dark photons. 3N-photon exchange would be realized as 3N-fold frequency - and energy resonance (mere energy resonance) between dark levels with the same value (different values) of h_{eff} . The possibility to modify the value of h_{eff} for flux tube makes it possible to have for a given codon single resonance energy [L228, L226, L227].

There are several questions relating to the bio-harmony.

1. The gluing of icosahedron and tetrahedron along the face looks ugly in the original model. Why both icosahedron and tetrahedron and why the gluing? The recent progress with M^8-H duality [L127, L128] suggests an answer. The tessellations (honeycombs) of hyperbolic 3space H^3 appear at the fundamental level and induce sub-tessellations of the magnetic flux tubes. One of these honeycombs- tetrahedral-icosahedral honeycomb (TIH)- involves all Platonic solids with triangular faces - tetrahedron, octahedron, and icosahedron. Could genetic code relate to TIH?

Cognitive representation [L72, L114, L122] as a set of points of space-time surface in the space of complexified octonions O_c with points having O_c coordinates in extension of rationals associated with the polynomial defining the space-time surfaces are central for for both quantum TGD and TGD inspired theory of cognition leading to adelic physics [L66]. The cognitive representation is mapped to $H = M^4 \times CP_2$ by $M^8 - H$ duality [L127, L128].

Could the genetic code be realized at the level of fundamental physics as a TIH in H^3 emerging as a cognitive representation [L72, L114, L122, L139] for the space-time surfaces in M^8 and by $M^8 - H$ duality also in $H = M^4 \times CP_2$. If so, the biological realization could be only one particular realization of the code.

2. Why there should ber 3 icosahedral harmonies and one tetrahedral harmony? There is a partial answer to this question. The correspondence with 64 dark proton triplets representing codons and triangles requires 3 icosahedral harmonies. What distinguishes stop codons from other codons? It turns out that stop codons could be dark proton triplets for which the corresponding triangle does not exist in THI realization! The lack of dark proton triplet would mark the end of the gene.

It should be possible to unify various TGD inspired models of genetic code to a single unified description. Is the time ripe for this?

- 1. The realizations in terms of dark protons and dark photons are related: dark photon 3Nplets would be emitted by dark proton 3N-plets in 3N-proton cyclotron transitions. In the 3N-resonance interaction with DNA, RNA, amino-acids, and tRNA the dark photon 3N-plet would transform to ordinary photons (bio-photons). Energy resonance could select the basic information molecules.
- 2. How the dark level interacts with the ordinary matter? Music expresses and creates emotions. Light 3-chords for a given bio-harmony could therefore represent an emotional state of MB (emotions as sensory perceptions of MB?). Fourier transform in terms of frequencies represents non-local holistic information and emotional information indeed is holistic information. Codons as units of 6 bits would represent ordinary temporily local, reductionistic information.
Each emotional state corresponds to a particular collection of 3-chords as allowed chords of the bio-harmony and therefore the resonance occurs with different biomolecules or induces different transitions of these bio-molecules. Could this serve as a universal mechanism of bio-control? Could epigenesis as a control of DNA transcription rely on this mechanism? As a matter of fact, the model described in this article emerged from an attempt to understand epigenesis in the TGD framework.

3. Is it possible to unify all models of the genetic code to single model so that the representation of a codon as dark proton triplet is assigned to a representation as an "activated" triangle of icosahedron or tetrahedron of TIH containing at it vertices dark protons defining the same codon as the triangle as 3-chord for a given icosahedral harmony. Could these "activated" triangles be selected faces of TIH. Could genes correspond to sequences of these icosahedrontetrahedron pairs at magnetic flux tubes?

In the sequel the questions raised above are discussed.

5.7.2 Genetic code and hyperbolic tessellations

Why 3 different icosahedral harmonies with symmetries Z_6 , Z_4 , and Z_2 plus one (there is only one) tetrahedral harmony is needed to get $3 \times 20 = 60 + 4$ chords in correspondences with 64 codons of the genetic code?

Hyperbolic tessellations and genetic code?

What comes into mind, are fundamental lattice like structures - tessellations - having as basic building bricks icosahedron and tetrahedron - at least these. This would make sensical to speak about gluing of tetrahedron to icosahedron, which looks a strange operation in the original formulation of the model.

1. Platonic solids correspond to finite tessellations at 2-sphere or equivalently 3-D solid polyhedrons in 3-D space Euclidian space E^3 . Maybe one could answer the question by increasing dimension and by studying 3-D polyhedrons of 4-D space defining tessellations of the hyperbolic space H^3 .

By $M^8 - H$ duality [L127, L128], these tessellations appear at the fundamental level TGD as cognitive representations since the 3-D mass shells with the geometry of H^3 appear naturally in the solutions of dynamical equations as algebraic equations at the level of M^8 identifiable as real section of complexified octonions O_c . The dynamics reduces to the associativity of the normal space of the space-time surface determined as a root for the real part of an octonionic polynomial obtained as an algebraic continuation of a real polynomial. Real part is defined in quaternionic sense by decomposing octonion to two quaternions in the same manner as a complex number is decomposed to its real and imaginary parts.

The algebraization of the octonionic counterpart of Dirac equation forces its identification as the counterpart of momentum space version of the ordinary Dirac equations and the identification of M^8 as an analog of momentum space so that space-time surface is analog of Fermi ball.

- 2. The tessellations of H^3 are analogs of lattices in an Euclidian momentum space E^3 . In adelic physics they define cognitive representations providing unique discretizations of space-time surface both at the level of M^8 and H. $M^8 - H$ duality maps tessellations to their analogs of $H = M^4 \times CP_2$. Contrary to my long held belief, Uncertainty Principle forces the map to be instead of a direct identification an inversion for $M^4 \subset M^8 \to M^4 \subset H$ [L127, L128]. Mass hyperboloids correspond in H to light-cone proper time constant sections of space-time surface: light-cone proper time defines Lorentz invariant cosmic time.
- 3. The tessellations of H^3 can have several different analogs of unit cells glued together along their 2-D faces. The positive curvature of sphere forces Platonic solids as tessellations of 2sphere to be closed and be finite. H^3 as a negative curvature space does not allow a closure. This implies a large number of tessellations as infinite analogs of regular solid polyhedra.

Both icosahedron, octahedron and tetrahedron have triangular faces so that they might allow gluing together for the simplest tessellations. Also more complex tessellations are possible.

Details about hyperbolic tessellations

Consider now in more detail some tessellations of H^3 possibly relevant for the bio-harmony [L16, L103, L135] involving icosahedral and tetrahedral geometries.

Some basic concepts and notations are necessary to help the reader to understand the Wikipedia articles, which give detailed explanations and illustrations.

- 1. Regular polytopes are tessellations consisting of single polytope. There are subtle differences between tessellations and honeycombs: tessellations are more general than honeycombs. These differences are not relevant for what follows so that I will use both terms interchangeably.
- 2. Schläfli symbol [A11] https://cutt.ly/7jagV1T (p, q, r, ..) characterizes regular polytopes in both Euclidian spaces and hyperbolic spaces locally but does not tell anything about the object globally. For a 3-D regular polytope (p, q, r) in 4-D space (say tessellation of H^3 the faces have p vertices, q identical faces meet at given vertex, and r identical 3-cells meet along given edge. For instance, (3, 5, 3) characterizes a regular tessellation having icosahedron as fundamental cells with 3 icosahedrons meeting along given edge.
- 3. Vertex figure [A15] https://cutt.ly/yjagMQn) represents the neighboring vertices as seen from a given vertex. Formally it is defined by contracting all edges emanating from the vertex to their middle points and connecting these points by lines along faces. For a n-D polytope (p,r,s,..) the vertex figure is n-1-D polytope (r,s,...). For instance, for icosahedron (3,5) the vertex figure is (5) telling that 5 edges meet at vertex. For the regular honeycombs in H^3 the vertex figure is a regular polyhedron. For instance, for (3,5,3) it is (5,3) identifiable as dodecahedron. Second notation for the vertex figure is as the list of numbers of edges meeting at the vertices of the face: For icosahedron this list is 3.3.3.3.3 telling that the faces of the edge figure has 5 vertices at which edges meet.
- 4. Edge figure [A15] (https://cutt.ly/djag9Q9) is the vertex figure of the vertex figure of the polytope. For D-dimensional polytope it is polytope of dimension D-2. For a regular polytope (p, q, r, ..., s) the edge figure is (r, ..., p): for Platonic solids (r, s) edge figure is () telling that two faces meet along a given edge. For the regular polytope (r, s, p) the edge figure tells the number of identical 3-cells meeting at given edge. For cubic lattice it is 4. For semiregular honeycombs the 3-cells need not be identical.
- 5. The notion of dihedral angle (see https://cutt.ly/vjs20BI) is very useful in trying to understand whether a given tessellation of E^3 and H^3 is possible. Dihedral angle is defined as the angle between the faces of the polytope meeting along a given edge. For tetrahedron it is 120 °, for octahedron 90 ° and for icosahedron 138.19 °. Since at least 3 polyhedra must meet at a given edge, the sum of these angles must be smaller than 360 degrees in E^3 . This prevents icosahedral tessellations in E^3 .

In H^3 negative curvature allows the sum to be larger than 360 ° (think of polygons at a saddle surface as a visualization) so that 3 icosahedra might meet at a given edge as indeed occurs for (3, 5, 3) tessellation. The sum of the dihedral angles of T, O, and I assignable to to tetrahedral-icosahedral honeycomb in H^3 is 348.19 ° and smaller than 360 ° but rather near to it.

6. An important notion is Coxeter group [A3] (https://cutt.ly/FjdEJeG) acting as the symmetry group of the honeycomb. Coxeter group is generated by reflections meaning that honeycombs can be generated by reflections in suitable mirror planes. Honeycomb is constructed kaleidoscopically: a concretization of Leibniz's monadology is in question. Coxeter group and therefore also the honeycomb is characterized by Coxeter diagram [A2] (https://cutt.ly/SjdEZiH) having as its nodes the mirrors and connected by edges labelled by the dihedral angles $\phi = \pi/n$ between the mirror planes. The value of n is written explicitly to the diagram except when it is the minimal value n = 3. For instance, the

sequence [(5,3,3,3,3)] characterizing tetrahedral-icosahedral honeycomb in H^3 tells that the dihedral angles between the 5 mirror planes are $(\pi/5, \pi/3, \pi/3, \pi/3, \pi/3)$.

Consider now honeycombs in hyperbolic space H^3 .

- 1. The simplest tessellations regular honeycombs of H^3 consist of icosahedra and dodecahedra having the same isometry group. That 3 of the 4 most symmetric honeycombs in H^3 have icosahedral symmetries whereas the fourth has cubic symmetries, is a highly encouraging sign. These 4 regular honeycombs are icosahedral honeycomb $\{3, 5, 3\}$ with 3 icosahedrons meeting along edge; order-5-cubic honeycomb $\{4, 3, 5\}$ with 5 cubes (rather than 4 as in E^3) meeting along a given edge; and dodecahedral honeycombs of order 4 (5) with 4 (5) dodecahedra meeting along edge. In all these cases the sum of the dihedral angles is larger than 360 ° so that the negative curvature of H^3 is essential for the existence of these honeycombs.
- 2. What about the combinations of Platonic solids having triangles as faces tetrahedron, octahedron, and icosahedron? From Wikipedia article [L159] (https://cutt.ly/cjaheWC) one learns that there exists honeycombs of H^3 characterized by Schläfli symbol {(3,3,5,3)} and Coxeter group with symbol [(5,3,3,3)] consisting of reflections and generating the honeycomb. The regular honeycombs are characterized by 3 integers (say (3,5,3)) and the meaning of the code is not quite clear to me but must reflecs the fact that the honeycomb is semiregular.

Tetrahedron corresponds to (3,3) and icosahedron to (3,5) and octahedron (3,4) as a rectified tetrahedron obtained by contracting edges to their middle points and expanding vertices to faces, has symbol r(3,3). Perhaps (3,3) in (3,3,5,3) refers tCoxetergroupo both tetrahedron and its rectification and (3,5) in (3,3,5,3) to icosahedron. The last "3" tells that 3 identical solid icosahedra, tetrahedra, or octahedra meet at given edge.

In particular, the tetrahedral-icosahedral honeycomb (TIH) is a compact uniform but not a regular honeycomb, having icosahedra, tetrahedra, and octahedra, all of which have triangular faces, as analogs of unit cells [A8, A6, A14] (see https://cutt.ly/xhBwTph, https://cutt.ly/lhBwPRc, and https://cutt.ly/0hBwU00)). The Wikipedia article [L159] contains beautiful illustrations of these honeycombs.

One can wonder why "tetrahedral-icosahedral honeycomb" does not involve octahedron. This is said to reflect the fact that only tetrahedral and icosahedral cells of the tessellation are regular 3-cells. All these polyhedra are regular as Platonic solids, and it remains unclear to me what the lacking regularity of the octahedron as 3-cell means in the recent context.

For TIH {(3,3,5,3} the vertex figure is rhombicosidodecahedron (RID) [A10] (https://cutt.ly/yjahitS) discovered already by Kepler. Kepler talked about Harmonices Mundi and I cannot but smile as I recall how I read as a young man a book having fun with Kepler's medieval belief on celestial harmonies and laughed also! Maybe the celestial harmonies are making a glorious comeback!

RID is an Archimedean solid [A1] (https://cutt.ly/njahaGN) having 60 vertices corresponding to 12 disjoint pentagons and 20 disjoint triangles with 60 vertices both. RID has as faces 20 triangles assignable to icosahedron, 12 pentagons assignable to dodecahedron plus 30 squares - 62 faces altogether. RID is obtained by radially scaling the distance of icosahedral and dodecahedral faces from origin but keeping the area of the spherical faces the same: this yields squares as additional faces. Triangles and pentagons have only squares as edge neighbors.

Edge figure tells the number of edges meeting at given edge. For TIH it is 3. Regular and single-ringed Coxeter diagram uniform polytopes to which also TIH belongs have a single edge type. Therefore icosahedron, tetrahedron, and octahedron must meet at given edge. That vertex figure contains 3 types of faces (triangles, and squares, and pentagons) presumably reflects this. Recall that the sum of the dihedral angles of T,O, and I is 348.19 °.

One can try to build a more concrete picture about how the Platonic solids are glued together along their triangular faces in the icosahedral-tetrahedral honeycomb.

- 1. Must to make this concrete, one can regard Platonic solid as a kind of mini Earth with two other Platonic solids glued to its surface like mountains. In all cases one has Platonic analog of a planar lattice of triangles at this mini Earth. To minimize typing call the 3 different Platonic solids T, O, and I.
- 2. Due to the symmetries one expects that for O and I the triangles correspond to different Platonic solids if they are edge neighbors. For T this is not possible since all faces are edge neighbours. All 6 2+2 configurations of B and C are however related by a rotational symmetry. This already gives a rather satisfactory picture about what the situation looks like at the surface of each mini Earth (I cannot avoid the analogy with inner planets, the living Earth as the largest one would correspond to I!).
- 3. The radius R of circumscribed inner or or outer sphere gives an idea about the size scales of these Platonic solids when the edge length a is the same for them as it is in the recent case. The following gives the radii of the outer sphere.

tetrahedron
$$\frac{R_{T,out}}{a} = \sqrt{\frac{1}{2}} , \qquad \qquad \frac{R_{T,in}}{a} = \sqrt{\frac{1}{24}}$$

octahedron
$$\frac{R_{O,out}}{a} = \sqrt{\frac{3}{4}} , \qquad \qquad \frac{R_{O,in}}{a} = \sqrt{\frac{1}{6}} , \qquad (5.7.1)$$

icosahedron
$$\frac{R_{I,out}}{a} = \frac{1}{2}\sqrt{\phi\sqrt{5}} , \phi = \frac{(1+\sqrt{5})}{2} , \quad \frac{R_{I,in}}{a} = \frac{\sqrt{3}}{12}\sqrt{3+\sqrt{5}} .$$

4. The ratios of the outer radii are given by $R_{I,out} : R_{O,out} : R_{T,out} = \sqrt{\phi\sqrt{5}} : \sqrt{\frac{3}{4}} : \sqrt{\frac{1}{2}} \simeq 1.9021 : 0.8660 : 0.7071$. The ratios of the inner radii are given by $R_{I,in} : R_{O,in} : R_{T,in} = \sqrt{\phi\sqrt{5}} : \sqrt{\frac{3}{4}} : \sqrt{\frac{1}{2}} \simeq .756 : 0.408 : 0.2041$. That icosahedron has the largest size, is natural since the total solid angle defined as a sum of the solid angles of the 20 triangles is 4/pi and the contribution of an individual triangle is smallest for I and largest for the 4 triangles of T.

Could TIH allow to unify the models of genetic code?

Does this picture help to say anything interesting about the model of bio-harmony and even to unify the models of genetic code?

- 1. tessellations define in a natural manner discretizations of MB defining cognitive represenations suggested to relate to the geometric representations for the states of the brain at MB and more generally, for the states of various parts of the biological body at MB. There is evidence for an effective hyperbolic geometry of brain realized in a statistical sense [J13] (http://tinyurl.com/ybghux6d): functionally similar neurons are near to each other in this effective hyperbolic geometry. This evidence is discussed from TGD point of view in [L131]: one ends up with a proposal that the MB of the brain provides a geometric representation for the statistical aspects of the brain - kind of abstraction? Information from the brain would be sent by dark Josephson radiation from similar neurons to positions of MB near to each other. This model could generalize to other parts of organism. MBs could form a kind of abstraction hierarchy representing more and more abstract data about the state of organism.
- 2. Could the icosahedral-tetrahedral tessellation allow a justification for the fusion of 3 icosahedral harmonies with the tetrahedral harmony? Why does the octahedral harmony disappear? Octahedral harmony would mean 6 additional notes assignable to the vertices of octahedron and 8 3-chords and this does not fit with facts.

Remark: In the Wikipedia article about TIH it is said that octahedrons of TIH are not regular, unfortunately in the sense that I do not understand. Note also that tetrahedral and octahedral harmonies are unique because there is only a single Hamiltonian cycle.

3. Geometrically the tessellation means identification of the neighbouring faces, which gives a justification for the strange looking proposal of gluing tetrahedron to icosahedron in order to

fuse 3 icosahedral and one tetrahedral harmony. If also the 3-chords associated with the faces are identified, one can ask whether only icosahedral and tetrahedral harmonies are needed and the chords of the octahedral harmony are determined by them.

2 3-chords of tetrahedral harmony are the same as those for icosahedral harmony but the 2 3- chords associated with the 2 T-O faces are independent. This would give 62 independent chords (amusingly, 62 happens to be the number of faces of RID).

One of the tetrahedral chords is necessary since purely icosahedral harmony allows to get only 19 amino-acids identified as the orbits of the chords under the symmetries of a particular icosahedral harmony with 20 chords: one additional chord is needed for the missing aminoacid. Since two icosahedral triangles facing the tetrahedron "eat" 2 further tetrahedral chords, this leaves 1 tetrahedral chord from 4: 3 chords as tetrahedral codons are missing. Could the 3 missing tetrahedral 3-chords correspond to the ordinary DNA codons acting as stop codons? Could the stop codons lack a representation as dark photon triplets or could their frequencies be such that they do not allow 3-resonance with any tRNA?

4. How genes would be realized in the tessellation? Could dark genes correspond to flux tubes forming 1-D sub-tessellations of H^3 induced to the flux tubes? Could gene correspond to a sequence of icosahedron-tetrahedron pairs such that neighboring codons are associated with icosahedron-tetrahedron pairs as cell-neighbors. Two subsequent icosahedrons would have a tetrahedron between them.

Could the tessellation induced from H^3 to MB be dynamical involving an "activation" of a particular triangle as a codon inside each icosahedron and tetrahedron? Could dark genes at the flux tubes have these codons as induced dark codon sequences? Could "activation" mean that the triangle representing particular codon is accompanied by 3 dark protons at its vertices and representing the same genetic codon? The representations in terms of dark protons triplets, as triangles of icosahedron and tetrahedron, and as dark photon triplets would fuse to single representation. There could be a representation also for stop codons in terms of 3 dark protons but there would not be no triangle where to locate them so that coding would stop! The missing dark codon would signify the end of the gene.

This would give the long-sought connection between dark codons realized as dark triplets and dark codons realizing bio-harmony and dark codons realized as dark photon triplets generated in the cyclotron transitions of dark codons. An essential role would be played by Galois confinement [L135] stating that these triplets behave like dynamical units - just like 3 confined quarks forming a baryon. Galois confinement generalizes to the level of genes.

5. This proposal is of course one of the many variations of single theme developed during years. What is new that the proposal would make the roles of the icosahedral and tetrahedral geometries concrete, not at the level of bio-molecules but at the level of their MBs. A profound dramatic generalization of the notion of genetic code from biology to the level of fundamental physics is also suggestive. Even a hierarchy of genetic codes in various scales can be considered.

The interpretation of various harmonies as correlates of emotions implies that each icosahedraltetrahedral unit of the tessellation would have its own varying emotional state expressed and affected by biochemical level via different interaction actions with ordinary biomatter realized in terms of dark photon N-resonance with targets depending on the emotional state [L228, L226, L227]. This could serve as a universal mechanism of bio-control by MB applying also to epigenesis.

There are still several open questions: in particular, what is the deeper reason for the fusion of just 3 icosahedral bio-harmonies. That the number of the dark codons is 64 is a partial reason but is this enough.

- 6. There are reasons to ask whether the cell membrane and microtubuli could provide a 2-D realizations of the genetic code [L228]. If genes are induced as 1-D sub-tessellations from that of MB, there is no reason to exclude 2-D or even 3-D induced tessellations.
- 7. I cannot avoid the temptation of mentioning the notion of memetic code [K60], which was my first idea about genetic code and proposed as a generalization of genetic code by starting

from a speculated hierarchy of Mersenne primes, whose members would come as $M(n+1) = M_{M(n)}$, $M_n = 2^n - 1$, (M(2) = 2. This gives the Mersenne primes $M(2) = M_2 = 3$, $M(3) = 2^3 - 1 = 7$, $M(4) = M_7 = 2^7 - 1$, $M(5) = M_{127} = 2^{127-1}$. It is not known whether the hierarchy continues. M_7 would correspond to the ordinary genetic code and M_{127} to memetic code with codons realizable as sequences of 20 codons.

Could memetic code be realized by TIH? Could one consider a planar or cylindrical subtessellation with a width of 20 tetrahedral-icosahedral pairs? If the size assignable to single pair is that of DNA codon - 1 nm roughly - the width would be about 20 nm which might relate to the radial scale of the microtubuli.

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5.8 Galois groups and genetic code

Galois groups, in particular simple Galois groups acting on cognitive representations consisting of points, whose coordinates in a number theoretically preferred coordinate system of octonions belong to EQ, play a fundamental role in the TGD view of cognition [L139]. The TGD based model of genetic code [L16, L136] involves in an essential manner the groups A_5 (icosahedron (I)), which is the smallest non-abelian simple group, and A_4 (tetrahedron (T)). Genetic code has as building bricks Hamiltonian cycles of I and T. Genetic code relates to information and therefore to cognition so that the interpretation of these symmetry groups as Galois groups is suggestive.

The most recent step of progress was the realization that genetic code can be represented in terms of icosa-tetrahedral tessellation of a hyperbolic 3-space H^3 [L159] and that the notion of genetic code generalizes dramatically. Also octahedron (O) is involved with the tessellation but plays a completely passive role. The question why the genetic code is a fusion of 3 icosahedral codes and of only a single tetrahedral code remained however poorly understood.

The progress in the understanding of the role of Galois groups inspired by a summary of inverse Galois problem [A49] (https://cutt.ly/jmjpyDS) in TGD framework [L151] made it possible to answer this question. The proposal is that the symmetry groups of the I, O, and T can be identified as Galois groups.

Icosa-tetrahedral tessellation can be replaced with its 3-fold covering replacing I/O/T with the corresponding symmetry group acting as a Galois group. Octahedral codons can be regarded as icosahedral and tetrahedral codons so they do not contribute to the code. T has only only a single Hamiltonian cycle and its 3-fold covering behaves as a single cycle. T has only only a single Hamiltonian cycle and its 3-fold covering behaves effectively as a single cycle.

5.8.1 Could the symmetries of icosa-tetrahedral realization of the genetic code correspond to Galois symmetries?

Abelian groups Z_p , p prime, are simple and the alternating group A₅ with order 60 is the smallest non-Abelian simple group. All groups A_n , $n \ge 5$ are simple and have n!/2 elements. A₅ corresponds to the icosahedral group isomorphic with the symmetry group of the dodecahedron.

The TGD based model of genetic code [L16, L136, L159] involves in an essential manner the groups A_5 (icosahedron) and A_4 (tetrahedron). Simple groups play a fundamental role in the TGD view of cognition. Could this mean that genetic code represents the lowest level of an infinite cognitive hierarchy?

The TGD inspired model model of genetic code, cognition, and Galois groups

TGD based model of bioharmony [L16, L136, L159] provides a model of genetic code as a fusion of 3 icosahedral Hamiltonian cycles and the unique tetrahedral Hamiltonian cycle (what "fusion" precisely means is far from clear and I have considered several options).

Icosahedral Hamiltonian cycles is a non-self-intersecting path at icosahedron connecting nearest points if icosahedron going through all 12 points of the icosahedron. It is interpreted as a

representation of a 12-note scale with a scaling by quint assigned to a given step along the cycle. For a given Hamiltonian cycle, the allowed 3-chords of icosahedral harmony are identified as chords defined by the triangular faces of the icosahedron.

Remark: In the sequel I will use the shorthands IH, OH, and TH for icosahedral, octahedral, and tetrahedral harmonies. Also the notation I/O/T will be used for icosahedron/octahedron/tetrahedron unless there is a danger of confusing them with their symmetry groups with identical shorthand notations.

Galois groups are essential for cognition in the TGD framework. In particular, simple groups as primes for groups are also primes for cognition [L139]. Genes represent information and Galois groups are crucial for cognition in the TGD framework. Genes would correspond to sequences of 3-chords of bioharmony. This raises several questions.

Could genetic code relate to Galois group A_5 as the smallest simple non-abelian Galois group (and also to the fact that the only polynomials of order smaller than 5 are generically solvable)? Could genetic code correspond to the lowest level in a hierarchy of cognition and of analogs of genetic code?

The order n = 60 for A_5 suggests a fusion of 3 icosahedral codes to give 20+20+20 = 60 codons.

- 1. 3 Platonic solids, icosahedron (I), tetrahedron (T), and octahedron (O) which have triangles as faces so that one can consider the possibility of constructing a lattice like structure by gluing these Platonic solids together along their faces. Hyperbolic space H^3 indeed allows isosa-tetrahedral tessellation, which also involves O:s. I have proposed that this allows a realization of genetic code and also of genes [L159]. The notion of gene generalizes so that genes can also be 2- or 3-D lattice-like structures.
- 2. A_5 has $A_3 = Z_3$ as a subgroup and I(cosahedron) corresponds to A_5/Z_3 . I has several Hamiltonian cycles having as a symmetry group Z_6, Z_4 or Z_2 . Z_2 can act either as rotations or reflections.

Q: Could A_5 as a Galois group as 3-fold covering of I make it possible to understand why the fusion of just 3 icosahedral codes is possible?

3. Tetrahedral group T corresponds to the alternating group $A_4 = S_4/Z_2 = Z_4 \times Z_3$ with 12 elements and tetrahedron identification as A_4/Z_3 . The tetrahedral Hamiltonian cycle (4-scale) is unique and has 4 3-chords. The 3-fold copy would correspond to A_4 . Information about the unique Hamiltonian cycles of O and T can be found in [A24] (https://cutt.ly/9mlMiV8).

Q: Could the factor that there is only one tetrahedral cycle explain why only a single tetrahedron contributes?

4. Octahedral group O has 24 elements and is the wreath product of Z_3 and Z_2^3 and has also the decomposition $O = S_2 \times S_4$. Octahedron can be identified as O/Z_3 . Also octahedral Hamiltonian cycle representing 8-scale with 8 chords is unique.

Q: Why don't octahedral codons contribute?

A model of the genetic code based on icosa-tetrahedral tessellation of hyperbolic 3-space

TGD leads to a proposal for a geometric representation of the genetic code in terms of icosatetrahedral tessellation of the hyperbolic 3-space H^3 (mass shell or light-cone proper time a = constant hyperboloids of M^4) [L159]. Both I, O, and T having triangular faces appear in the tessellation. Recall that the corresponding harmonies are denoted by IH, OH and TH.

I do not completely understand the details of the icosa-tetrahedral tessellation. The following picture satisfies the constraints coming from the notion of harmony but I have not proven that it is correct. Here the help of a professional geometrician knowing about tessellations of H^3 would be needed.

1. The analog of the discrete translational symmetry for lattices can be assumed: all I:s , O:s and T:s are equivalent as far as common faces with neighboring Platonic solids are considered.

- 2. The term icosa-tetrahedral tessellation suggests that all octahedral faces are glued to tetrahedral and icosahedral faces so that octahedral chords reduce to either icosahedral or tetrahedral chords. OH would not be an independent harmony. This requires that the number of common faces between two O:s vanishes: $n_O^O = 0$.
- 3. T shares at least 1 face with a given I so that the number of tetrahedral chords is reduced to at most 3 for given T. 4 purely tetrahedral faces (not shared with I) are needed. I would have $n_{I^T} \leq 4$ purely tetrahedral faces in such a way that the total number of purely tetrahedral 3-chords is 4.

The simplest possibility is that I shares a common face with 2 T:s. Each T shares 2 faces with O providing 2 purely tetrahedral 3-chords and shares the remaining 2 faces with distinct I:s. One would have $n_T^I = 2$, $n_T^O = 2$, $n_T^T = 0$.

Since each I defines independently 20 chords, 2 I:s cannot have common faces. One would have $n_I^T = 2$, $n_I^I = 0$ and $n_I^O = 18$ to give $n_I^T + n_I^O + n_I^I = 2 + 18 + 0 = 20$.

4. What remains to be fixed are the numbers n_O^I and n_O^T satisfying $n_O^I + n_O^T = 8$. The conditions $n_O^T \ge 1$ and $n_O^I \ge 1$ must be satisfied since both T and I share faces with Os.

Music comes to rescue here. The 8 3-chords of OH could define OH sub-harmony of IH. Analogously, the 4 3-chords of TH could define TH as a sub-harmony of OH.

Could IH sharing 18 3-chords with OH contain 2 transposed copies of OH plus 2 chords of TH? IH cannot of course contain the entire TH as a sub-harmony.

Could OH contain one copy of TH? This would give $n_O^I = n_O^T = 4$. Could the IH part of OH actually be TH as a sub-harmony of IH so that OH would reduce to 2 copies of TH?

To sum up, if the answers to the questions are positive, the incidence matrix n_i^j , $i, j \in \{I, T, O\}$, telling how many faces *i* shares with *j* would be given by

$$\begin{bmatrix} n_I^I & n_I^O & n_I^T \\ n_O^I & N_O^O & n_O^T \\ n_T^I & N_T^O & n_T^T \end{bmatrix} = \begin{bmatrix} 0 & 18 & 2 \\ 4 & 0 & 4 \\ 2 & 2 & 0 \end{bmatrix} .$$
(5.8.1)

3-fold cover of the icosa-tetrahedral tessellation

The proposed model does not yet explain the fusion of 3 icosahedral Hamiltonnian cycles. A 3fold cover of the icosa-tetrahedral tessellation which replaces Platonic solids with their symmetry groups is highly suggestive. This raises a series of questions.

- 1. How could this representation relate to a possible interpretation in terms of the Galois groups $I = A_5$ and $O = S_2 \times S_4$ and $T = A_4$? Z_3 appears as a sub-group of all these groups and these Platonic solids are coset spaces I/Z_3 , O/Z_3 , and T/Z_3 .
- 2. Could one lift the icosa-tetrahedral tessellation to a 3-sheeted structure formed by the geometric representations of the Galois groups of this structure acting as symmetry groups? Platonic solids would be replaced with their symmetry groups acting as Galois groups.
- 3. Could the 3 different icosahedral Hamiltonian cycles correspond to different space-time sheets - roughly CP_2 coordinates as 3-valued functions of M^4 coordinates whereas 20 regions representing icosahedral vertices would correspond to different loci of $E^3 \subset M^4$ just as one intuitively expects?
- 4. Same should apply to the tetrahedral and octahedral parts of the tessellation. But don't the 3 identical copies of the tetrahedral Hamiltonian cycle give 64+8=72 codons? How can one overcome this problem?

The following is a possible answer to these questions.

- 1. $h_{eff} = 60h_0$ corresponds to 60-sheeted space-time (here also 60k-sheeted space-time is possible if 60-D extension of k-dimensional extension is in question). For T and O an analogous picture would apply. One could say that the projections of I and O and T are in M^4 . At each sheet one would have icosa-tetrahedral tessellation.
- 2. I has 3 types of Hamiltonian cycles with symmetry groups Z_6 , Z_4 , and Z_2 and can give 3 different copies. However, only a single copy of tetrahedral harmony appears in the model: otherwise the number of codons would be larger than 64. Could the 3 identical Hamiltonian cycles for T and O effectively correspond to a single Hamiltonian cycle?
- 3. The fusion of Hamiltonian cycles is analogous to a formation of many-boson states. For T and O all Hamiltonian cycles would be identical: one would have only one Hamiltonian cycle effectively. The 3-chords associated with the 3 octahedral and tetrahedral cycles are identical so that only single tetrahedral harmony would be present.

To sum up, the lift of the icosa-tetrahedral complex to that defined by the respective Galois groups could explain why just 3 icosahedral Hamiltonian cycles and effectively only 1 tetrahedral cycle.

5.9 MeshCODE theory from TGD point of view

Benjamin Goult has made an interesting proposal in the article *The Mechanical Basis of Mem*ory the MeshCODE Theory [J3] (https://cutt.ly/WzlrmrM) published in Frontiers of Molecular Neuroscience in 25 February 2021.

The proposal is that the cell or at least synaptic contacts realize mechanical computation in terms of adhesive structures consisting of hundreds of proteins known as talins, which act as force sensors. Talins are connected to integrins in the extracellular matrix, to each other, and to the actins in the cell interior.

This proposal does not conform with the TGD vision but inspires a series of questions leading to a rather detailed general vision for how magnetic body (MB) receives sensory input from biological body (BB) coded into dark 3N-photons representing genes with N codons and as a response activates same but differently realized genes, RNA or corresponding proteins as a reaction [L228, L16, L103, L136, L159]. This would mean a universal response function assigning to sensory input a unique response. Sensory input would code the response to it in terms of dark genes, which also generalize in TGD framework.

5.9.1 Some basic facts

The role of a protein known as talin [I36] (https://en.wikipedia.org/wiki/Talin_(protein)) is the topic of the article. Talin is associated with the cell-substratum contact and mechanically couples cytoskeleton and extracellular matrix (ECM) together. Adhesion units formed by integrin coupling to ECM, talin, and actin at cytoskeleton side form adhesion structures consisting of hundreds of adhesion units.

It is good to begin with by listing some basic definitions and facts.

 Cytoskeleton [I11] (https://en.wikipedia.org/wiki/Cytoskeleton) consists of microfilaments (actin), intermediate filaments, and microtubules (MTs) which in neurons are called neurotubules. Neurons contain neurotubules [I31] (NTs)(https://en.wikipedia.org/wiki/ Neurotubule) generated at MT organizing center (MTOC) and transferred to dendrites and axon, where they are parallel to the neuronal surface.

The cytoskeleton of an ordinary cell has as basic building bricks MTs and microfilaments and intermediate filaments. Both MTs and NTs are polarized. The + ends of MTs are at MTOC. + ends of NTs point towards the axon terminal and - end to the parent neuron. NTs in dendrites have mixed polarities.

2. ECM [I17] (https://cutt.ly/5zNYtP6) is a three-dimensional network consisting of extracellular macromolecules and minerals, such as collagen, enzymes, glycoproteins and hydroxyapatite that provide structural and biochemical support to surrounding cells. Cell adhesion, cell-to-cell communication and differentiation are common functions of the ECM.

- 3. Integrins [I24] (https://cutt.ly/xzNYk7n) are transmembrane receptors that facilitate cellcell and cell-extracellular matrix (ECM) adhesion. Upon ligand binding, integrins activate signal transduction pathways that mediate cellular signals such as regulation of the cell cycle, organization of the intracellular cytoskeleton, and movement of new receptors to the cell membrane. The presence of integrins allows rapid and flexible responses to events at the cell surface (e.g. signal platelets to initiate an interaction with coagulation factors).
- 4. Actins [I4] (https://cutt.ly/LzNYEo9) are a family of globular multi-functional proteins that form microfilaments. It is found in essentially all eukaryotic cells, where it may be present at a concentration of over 100 μ M; its mass is roughly 42-kDa, with a diameter of 4 to 7 nm. An actin protein is the monomeric subunit of two types of filaments in cells: microfilaments, one of the three major components of the cytoskeleton, and thin filaments, part of the contractile apparatus in muscle cells.

One can visualizetalin as a spring between cytoskeleton and ECM. Talincouples directly to integrins at ECM side and either indirectly or directly to actin at cytoskeleton side. Talin's role is to be a rope in a "tug-of-war" between integrins at ECM and actin and it acts as a force sensor and could give rise to a molecular sense of touch based on force.

The part of talin subject to forces from the cellular interior and environment consists of 13 proteins domains which can be in two thermodynamically stable states analogous to the opposite magnetizations of ferromagnet and the domain exhibits hysteresis curve under a varying external force. The phases correspond folded and unfolded configuration looking like a straight bar. The two phases can be labelled by a bit and the proposal is that the talin conformations define 13 bits.

The domains are not identical so that each equilibrium state under varying external net force could correspond to a unique configuration in which domains are folded or unfolded. If so, talin would serve as a 13-bit force sensor of external forces with finite resolution corresponding to 13 octaves in linear scale. It will be found that the response could actually be determined by 6 bits and correspond to genetic codon.

The abstract of [I130] summarizes the functions of talin.

... Talin forms the core of integrin adhesion complexes by linking integrins directly to actin, increasing the affinity of integrin for ligands (integrin activation) and recruiting numerous proteins. It regulates the strength of integrin adhesion, senses matrix rigidity, increases focal adhesion size in response to force and serves as a platform for the building of the adhesion structure. Finally, the mechano-sensitive structure of talin provides a paradigm for how proteins transduce mechanical signals to chemical signals.

It is clear that talin does not look only a passive sensory receptor. That integrins are not necessary for talins to function implies that they have emerged before integrins in the evolution. It is clear that talins are essential aspect of multicellular life.

5.9.2 Could adhesion structures act as classical computers?

The proposal of the article [J3] relies on computationalism and suggests that talin could be more than a sensory receptor and adhesion structures could act as a computer. The structures formed by the adhesion units consisting of integrin-talin-actin triplets would serve as 13-bit units. Adhesion units would perform mechanical computation based on what authors call MESHcode.

One can argue that mechanical computation requires that adhesion units are isolated from the environment during the computation. This is in conflict with the role as force sensors. A weaker proposal would be that computation occurs only in the synaptic contacts which should be isolated during the computation. The same could take place also in the contacts between neurons and glial cells.

Concerning the synaptic level, a more realistic view to my opinion is that learning as a strengthening of the synaptic strengths corresponds to a development of force equilibrium of adhesion units. Learning could be described as the change of the resting states of the talin units and lead to a higher tension and larger number of unfolded protein domains. Nerve pulse patterns could cause temporary changes of this pattern.

5.9.3 TGD interpretation of adhesion units as quantal force sensors

In the TGD framework all communications and control in biology should rely on genetic code whose fundamental realization would be at the level of dark proton sequences forming dark nuclei with $h_{eff} = nh_0 > h$ and dark photons.

Dark proton triplets - light 3-chords - would represent the counterparts for dark DNA, RNA, tRNA, and aminoacids and dark photon triplets could represent dark DNA codons [L16, L103, L136, L159]. Number theoretic vision [L66, L67] leads to a proposal that not only dark 3-photon 3-proton units act as single particle like units but also dark 3N-photons and 3-N protons do so and represent a gene consisting of N codons. Galois confinement would bind the photons and protons to larger particle units analgous to baryons as composites of 3-quarks.

All communications to MB would use dark 3N-photons coupling to corresponding dark 3N-proton by cyclotron resonances [L228, L226, ?]. Therefore 3N-photon as a dynamical gene with N codons would define its own address. Frequency modulation of frequencies of 3N-photon would give rise to a sequence of resonance peaks and the continuous signal would be transformed to a signal analogous to nerve pulse sequence and could realize motor action as a response.

Magnetic body containing dark matter as the master

MB has a hierarchical onion-like structure with levels labelled by the value of $h_{eff} = nh_0$ giving rise to increasing scales. The dark analogs of DNA, RNA, tRNA, and amino-acids define flux tubes accompanying their ordinary variants with codons realized as dark 3-proton units.

In TGD genetic code in terms of 3-chords would be realized in a universal manner for the simplest tessellation of hyperbolic space known as icosa-tedrahedral honeycomb involving icosahedrons and tetrahedrons (also octahedrons are involved but they would be in passive role) [L159]. This would suggest that genetic code using dark proton- and dark photon triplets is realized at all layers of MB. Chemical realization would represent the lowest level in the hierarchy.

The layers of MB with increasing value of h_{eff} would define a hierarchy of abstractions. There is evidence for an effective statistically determined hyperbolic geometry [J13] in the sense that neurons functionally but not necessarily spatiall near to each other are near to each other in this effective geometry. This hyperbolic geometry would be realized quite concretely at the level of MB [L131] for which hyperbolic geometry of proper time constant hyperboloid of the light-cone gives a concrete meaning.

One particular implication could be that sensory receptors of a given structure (say adhesion units of given cell-environment pair) could communicate their sensory data to neighboring icosatetrahedral units of the honeycomb of some layer of MB representing the codons of genetic code. The states of the icosahedrons and tetrahedrons of the honeycomb would be dynamical and selected by the 3-chord (actually pair of 3-chord and conjugate) to actualize genetic codon as 3-quark units assignable to the corresponding triangle of icosahedron or tetrahedron.

This would define sensory representation at MB, and the simplest option is that it automatically determines motor response as a sequence of resonance peaks communicated back to the biological body (BB) where they would initiate gene expression, RNA or protein activity, MT activity, or nerve pulse activity. The feedback would be directly to DNA (or RNA, amino-acid of protein, or even tRNA, microbuli, or cell membrane).

The biochemical motor actions of MB would be realized as bursts of dark cyclotron 3Nphotons induced by the cyclotron resonances at MB transforming to ordinary photons (biophotons or IR photons with energy above thermal energy) controlling biochemistry by inducing molecular transitions.

This condition constrains the value of h_{eff} for a layer of MB. The size of the layer should be of the order of wavelengths involved. For valence bonds the values of $h_{eff} = h_{em}$ would be rather small and assignable with small layers of MB. For frequencies in EEG range the large value of gravitational Planck constant $h_{eff} = h_{gr}$ [L78, L228] assignable to the gravitational flux tubes would guarantee that the energies are in the required range.

The following picture about how sensory input induces gene expression or some other activity with communication and control realized in terms of genetic code might apply completely generally, not only in the case of adhesion units. 1. Suppose the sensory receptors of a given structure (say adhesion units of a given cell) are organized into coherent structures in the sense that the signals from them go along flux tubes to nearby cells of icosa-tetrahedral honeycomb at some layer of MB.

Adhesion structures consting of few hundred adhesion units are indeed connected to each other. Coherence would be forced by the quantum coherence at the level of MB as a forced coherence. One could assume that the cells of the honeycombinvolved are organized linearly but even 2-D and 3-D structures are possible.

For a structure consisting of N units, the dark 3N-photon signal would define a dark gene of N codons. The nice feature of the representation is that there is no need to organize the sensory receptors (say adhesion units) linearly at the level of the cell. The level of ordinary biomatter would be like RAM with ordering realized at the level of MB.

2. The naive picture is that if the dynamical gene realized in this manner has a dark counterpart at the level of flux tube accompanying DNA, gene expression could be initiated automatically as a feedback signal realized as a sequence of resonance peaks. Also RNA, proteins or MTs could be activated in an analogous manner.

There would be a one-one correspondence between sensory inputs to MB and corresponding gene expressions and give a meaning for the genetic code. All sensory inputs to MB would be realized as N-genes in terms of generalized Josephson radiation which is frequency modulated and generates a sequence of resonance peaks inducing gene expression or RNA and protein activation.

3. The dynamical gene at MB need not correspond to an existing or expressible gene so that the response is not possible. This would give rise to an evolutionary pressure. Epigenesis controlled by MB could make the gene expressible. Also a suitable mutation for existing gene or emergence of new gene could produce the needed gene. Whether MB is able to induce this kind of mutations is an interesting question. Could a dark gene as a flux tube containing dark proton sequence representing the desired gene pair with ordinary DNA codons and give rise to a new gene?

Or could MB "use scissors" to replace codon-anticodon pairs in an existing gene: this would mean reconnection of a closed flux tube pair containing the codon-anticodon pairs of the added gene fragment. Could a piece of dark DNA as a flux tube carrying the dark proton sequence pair with ordinary DNA codons and give rise to a new gene? Or could one add to an existing gene a piece represented as a dark DNA paired with the ordinary DNA. Most viruses have single stranded RNA genomes. Bacteriophages have double stranded DNA genomes. They are known to give rise to the modifications of the genome. Could these DNA modifications be induced by a reconnection of darkmagnetic flux tubes.

Universality of the genetic code and its higher dimensional representations

If genetic code at space-time surface is induced from a universal code assignable to the icosatetrahedral honeycomb of hyperbolic 3-space, representations of genetic code with dimensions D = 0, 1, 2, 3 are possible as induced representations. The codons associated with the cells of honeycombes projected to the space-time surface would define the induced codons [L159].

tRNA would be a 0-D representation and DNA, RNA, amino acids would be 1-D representations of the code. Also higher-dimensional representations are possible and could be associated with the basic biological structures.

- 1. I have proposed that cell membrane defines a 2-D representation of the genetic code [L159]. Also microtubuli could define a 2-D representation of genetic code. These 2-D representation could be dynamical and independent of genome and make genome dynamical. This would be a biological analog for AI able to write genes as program modules needed in a given situation.
- 2. Could a 3-D representation of genetic code be associated with the ECM and make it possible for MB to receive sensory input from ECM and control it? This layer of MB could also receive sensory information also from adhesive structures. The frequency range involved would be probably below EEG frequencies or at least below conscious frequencies since we

do not experience the interior of body consciously and the time scale of dynamics is slow as compared to EEG scales.

Hydrozyapatite molecules are present in bones forming a part of ECM. Fisher has proposed that the Posner molecules associated with hydroxyapatite molecules could have important role in quantum biology [J36]. This inspired the proposal that they provide a realization of genetic code [L37]. One cannot exclude the possibility that the code is 3-D. This would fit with the general idea that the genetic code serves as a universal code for communications and control.

Some TGD inspired numerology

If one takes the proposed general picture seriously, one must ask how the 13-bits codons assignable to talins and MTs could reduce to genetic codons. It is good to start with numerology or should one call it physics inspired poor man's number theory.

- 1. The number of protein domains in talin is 13. Also the number of tubulin dimers in 13-tubulin unit of MT/neurotubule appearing in cytoskeleton is 13. Could one think of communication between MTs and talins using 13 bit code? Or could the code using 13 bits be for some reason special? Could this code somehow reduce to the proposed universal 6-bit code defined by genetic code?
- 2. There are 4 protein domains consisting of 4 alpha helices and 9 domains with 5 alpha helices. This gives 61 alpha helices altogether. Numerologist might notice that 61 is the number of DNA codons with stop codons excluded. Could one assign to helices genetic codons and could these configurations labelled by 61 bits code for genes with length not longer than 61 units?
- 3. Numerologist might also notice that both $M_{13} = 2^{13} 1$ and $M^{61} = 2^{61} 1$ are Mersenne primes. If one has n bits and does not count the configuration with all bits 0 but assuming that at least single bit is always equal to 1, one has 2^{n-1} full bits.

For M_{13} this corresponds to 12 full bits which corresponds to 2 genetic codons. To obtain 2 codons, single fixed talin should be unfolded and represent 1. Could this have interpretation in terms of a force threshold? One can argue that there is some minimal force unfolding some fixed talin. If the force is below the threshold, there is no need to communicate. Also in the case of MT the conformation of preferred tubulin, say the first or last one in 13-unit should always correspond to 1.

4. One cannot exclude the possibility that the responses of talin units correspond to two independent codons. This could be true also for13-bit units MTs.

The alternative option is that both talins and 13-tubulin units of MT correspond to codonanticodon pairs so that information content would reduce to that of single DNA codon. Half of the bits would serve as check bits. Also the purpose of the conjugate strand of DNA would be to serve as check codons.

If this is the case, the adhesion unit would have only 2^6 different responses and would represent a genetic codon. The number of talins is few hundred that this would correspond to a DNA sequence of length of order 10^{-7} meters. In the case of MT 6 bits would be check bits.

- 5. The proposal would have far reaching consequences: the genetic code realized by MTs and talins would be dynamical rather than fixed and could represent a step to a higher evolutionary level.
- 6. The dynamics of the codon or of a pair of pair of independent codons assignable to the adhesion unit would mean change of the "sensory codon" possibly corresponding to a real codon assignable to it. The slow time variation of the gene assignable to the collection of adhesion units could define varying gene expression or some other activations (of say microtubuline).

These speculations encourage the question whether the codon-anticodon pairs possibly assignable to adhesion units integrate to sequences or perhaps even 2-D structures representing 2-D adhesion structures of DNA codon-anticodon pairs defining genes.

If these 2-D honeycomb structures at the level of MB decompose to piles of 1-D structures as microtubules do, they could even induce the expression of gene groups. Also 2-D gene expression in terms of microtubules modifying the cytoskeleton can be considered. Note that the honeycomb structures are not needed at the level of ordinary biomatter.

A simple model for the adhesion units

In TGD framework magnetic body (MB) containing dark matter controls ordinary living matter. MB receives sensory input from organism in terms of dark Josephson radiation arriving from cell membranes acting as generalized Josephson juctions. Sensory information is coded by the modulation of membrane potential. For ordinary cells only small modulations of membrane potential would induce modulations of Josephson frequency. For neurons nerve pulse patterns introduce more drastic modulation.

- 1. The two states of the protein domains could correspond to different values of h_{eff} . The reduction of h_{eff} at the magnetic flux tube accompanying the protein would induce the shortening of the flux tube associated with the unfolded protein to the folded configuration.
- 2. Cohesion units would aserve as sources of sensory information about the net force acting on the cohesion unit and coded by 13 bits unless the bits are independent. For instance, different bits would correspond to different signals, say different frequencies of dark photons. If one takes the interpretation as a pair of codons seriously, the signal could consist of a dark 3-chord and its conjugate 3-chord sent to MB and defining at the MB a representation of gene to be possibly activated.
- 3. Josephson radiation as dark 3-photons from the part of the cell membrane considered would mediate the 13 bit signal defined coded to a local change of membrane potential with 2¹² values defining 12 octaves if there is threshold corresponding to activation of a preferred talin. Note that the frequencies audible for humans are in the range 20 Hz- 20 kHz and correspond to 10 octaves.
- 4. MB would receive the sensory input and react by possibly sending control signal to DNA inducing gene expression or inducing activity of proteins or RNA. This means that talin molecules would not be active but MB receiving the sensory input from adhesion units.

MB could also send control signal to microtubuli if MT contains a sequence of 13-tubulin units corresponding to the dynamical gene [?] [I29] (https://en.wikipedia.org/wiki/ Microtubule). This would reflect itself in the dynamics of MTs. This control loop would modify the force equilibrium by a modification of the shape of the cell.

- 5. MTs could represent an evolutionary step making the genome dynamical and independent of genes and extending ordinary genome as the microtubular response possible for eukariotes suggests. Also the long MTs inside axons conform with this interpretation.
- 6. MTs are highly dynamical. Their lengths are continually varying. According to "searchand-catch" model MTs inside cells are scanning their 3-D environment and whey the find a target attach to it and MT is stabilized. This conforms with general vision about Ushaped dynamical flux tubes serving as tentables and forming a reconnection with a similar U-tube of the target. Immune system would be rely on this mechanism at the fundamental level and allow the system to detect and catch invader molecules on basis of their cyclotron energy/frequency spectrum [K62, L228].
- 7. The general vision suggests that the feedback loop should involve also microfilaments and intermediate filaments. It would be interesting to see whether the structure of microfilaments and intermediate filaments could allow realization of the counterpart of genetic code. The basic signature are GTP and ATP molecules providing metabolic energy for motor action.

5.9.4 An application to memory and learning

Since the increase of synaptic strengths is believed to be behind the formation of memories as behaviors and habits, it is appropriate to discuss the notion of memory in TGD framework and consider connections with the model for the adhesion units at synaptic contacts.

The major issue with memory is potentiation (repeat of same memory which facilitatesmemory recall and learning) and amnesia, Alzheimer disease and memory when dreaming. There should be a compatible explanation for these phenomena.

In TGD one distinguishes between two kinds of memories. Episodal-/sensory memories and memories as associations/learned behaviors.

Memories as learned behaviors

Neuroscience explains learned behaviors in terms of strengthening of synaptic contacts and I believe that this is part of the story.

The formation of associations in conditioning is a highly emotional process and here the surprising finding [J12] (see http://tinyurl.com/ycqxyeqk) few years ago (roughly) was helpful. The popular article "Scientists Sucked a Memory Out of a Snail and Stuck It in Another Snail" tells about the finding (see http://tinyurl.com/y92w39gs).

The RNA of a sea snail which had learned by (presumably painful) stimulus a behavior was scattered on the neuronal tissue of another sea snail in a Petri dish. The neuronal tissue learned the same behavior!

The TGD based explanation is following.

- 1. Emotions are realized already at the molecular level [L84] in terms of music of light bioharmony [L16, L103, L136, L159]. The emotional stimulus at the MB of RNA induced learning by changing the allowed 3-chords of bioharmony. Also the sequences of 3-chords characterizing 3N-genes and other basic linear biomolecules changed. The resonant couplings to the basic biomolecules changed so that also chemical behavior changed.
- 2. The emotional state of the conditioned seanail RNA infected the RNAs and probably also DNAs and proteins of neurons and induced learning.
- 3. Synaptic strengths had to change and the molecular emotions as music of light would have induced this.

If the idea about mechanical control of synaptic strengths by talin molecules by push and pull from ECM and cytoskeleton is correct, the molecular mood had to induce a strong force changing the talin conformations. Emotion would quite concretely correspond to a force!

This would have induced a reaction at the level of microtubules with the mediary of MB as a response making the change permanent. Neurotubules of the cytoskeleton in dendrites and axons would be involved in realizing the learning as a permanent change.

Potentiation and two kinds of memories

The notion of potentiation applies to both kinds of memories.

- 1. The repetition of stimulus generating the learned behavior increases the synaptic strength. Perhapsby inducing a memory recall of the emotional experience at molecular level.
- 2. Potentiation for sensory memories creates an almost copy of sensory memory mental image at "geometric now": the re-experience and the more one has these almost copies in the geometric future of "geometric now", the higher the probability that the attempt to remember by sending dark photon signals to the future hits the memory mental image are successful. The latest memory recalls create memories mental images nearest to "geometric now" and the probability for memory recall is highest for them.

Why oldest sensory memories are those which survive when one begins to lose memories at old age?

- 1. There are a lot of almost copies about the oldest memories: does this mean that the memory recall has a higher probability to be successful?
- 2. One can also argue that the memory mental images of young age have also gone through a long sequence of re-incarnations which have gradually increased the value of h_{eff} .

Large h_{eff} means that the frequency f needed to produce a dark photon with energy $E = h_{eff}f$ in biophoton range is lower and therefore the period T = 1/f is longer. Uncertainty Principle says that the time period over which memories are optimally recalled is of order T = 1/f.

Amnesia, Alzheimer, and why we forget dreams so fast

Amnesia might relate to the inability to recall sensory memories by sending signals with a correct frequency to the memory mental images. The energy of the dark photons is proportional to h_{eff} and if it is reduced in the recalling end as tends to happen in the absence of metabolic energy feed, the ability to recall memories is weakened or lost. For instance, alcoholism can lead to a loss of memory recall and this could be the reason.

Alzheimer means a loss of memories as behaviors and inability go generate new ones. In TGD framework [L63] the weakening of the synaptic connections would make the build up of connection between magnetic flux tubes associated with presynaptic dendrite and postsynaptic axon and the dark photon signal could not propagate because the connection is broken.

Also the propagation along axonal flux tubes could be impossible or highly attenuated if the value of h_{eff} for them is reduced. Also the energy for a given frequency would be reduced below the biophoton energy range.

Why do we forget dreams so fast? We do not remember anything about sleep without dreams. In ZEO this can be understood if sleep corresponds to "small death" for an appropriate layer of MB meaning re-incarnation with an opposite arrow of time. Dreams would correspond to states in which part of the brain is awake and possibly receives information from the sleeping part of the brain realized as a dream. Dream would be due to a communication of virtual sensory input from MB with opposite arrow of time to sensory organs.

This does not yet explain why we forget dreams so fast. As the memory image ages, it shifts to the future of "geometric now" in CD, and the needed frequency as inverse of the age decreases. Could it be that we cannot generate the frequencies of dark photons needed for the memory recall.

Memories change

Episodal memories are not carved in stone. They are modified in memory recalls. In TGD framework, the modification of (episodal) memory mental images is unavoidable. Memory mental images are living entities and evolve re-incarnation by re-incarnation. Memory recalls are basically analogous to quantum measurements of memory mental images induced BSFR and quantum measurement indeed changes the state of the system measured.

- 1. The sub-selves of self as mental images continue to live at sub-CDs which in the proposed model drift to the geometric future of CD increasing SSFR by SSFR. These sub-CDs experience BSFRs and evolve incarnation by incarnation. In general evolution happens and they become smarter and wiser. Memories are indeed said to grow sweeter in time.
- 2. Each memory recall must take the memory subself to a state in which it has arrow of time opposite to that of recaller so that the signal about the memory propagates to the geometric past to "geometric now" [the ball at center of CD at which future and past directed cones glued together].

The BSFR for memory subself with the same arrow of time as recaller induces memory recall. Memory recall is a murderous process. If the memory recall occurs spontaneously, the murder is not not the recaller.

Confabulation

The phenomenon of confabulation relates most probably to episodal/sensory memories, not memories as behaviors and habits. Confabulation could be understood in the following manner. Memory mental images are just glimpses about what happened since only those aspects of the event which receive the attention form memory mental images. Memory recaller builds a logical sounding story around these glimpses so that confabulation is unavoidable.

Even our sensory perception is fabrication of stories [L57]. Sensory organs are seats of primary sensory experience and there is feedback from MB and brain to sensory organs as virtual input. This feedback loop generates standardized mental images by pattern completions and recognition.

If the sensory input is meager the story can be non-realistic as I know as a person with a poor eye sight. REM dreams and hallucinations are an excellent example of this: in this case there is only virtual sensory input present.

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5.10 Appendix: Tables of basic 3-chords for the icosahedral harmonies with symmetries

The tables below give list for the three types of 3-chords for the 11 harmonies possessing symmetries. One must remember that the reversal of the orientation for the cycle induces the transformation $C \leftrightarrow C$, $F \sharp \leftrightarrow F \sharp$, $H \leftrightarrow C \sharp$, $F \leftrightarrow G$, $D \leftrightarrow B \flat$, $E \leftrightarrow G \sharp$, $A \leftrightarrow D \sharp$ and produces a new scale with minor type chords mapped to major type chords and vice versa. Also one must remember that all 3-chords except those which are simple majors or minors lack the third so that their emotional tone remains uncharacterized. For instance, C6 does could be replaced with Cm6 and G7 with Gm7. The reader can check the chords by direct inspection of the figures. The convention used is that vertex number one corresponds to C note.

$\boxed{(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})}$	0-chords	1-chords	2-chords
(2, 12, 6)	(Faug, Gaug)	$(Cm, Dm, Em, F \sharp m, G \sharp m, B \flat m),$	$(C9, D9, E9, F\sharp 9, G\sharp 9, B\flat 9).$
		$(F6, G6, A6, B6, C \sharp 6, D \sharp 6).$	

Table 5.2: Table gives various types of 3-chords for harmonies with Z_6 rotational symmetry. Note that half-octave shift is an exat symmetry. Note that $G^{aug} = CEG\sharp$, F^{aug} act as bridges between the groups related by half octave shift. The chords have been arranged so that they form orbits of Z_6 . "Amino-acid chords" correspond to preferred chords at the orbits.

$\boxed{(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})}$	0-chords	1-chords	2-chords
(0, 16, 4)		$(D7, D6, G\sharp 7, G\sharp 6),$	$(B\flat 9, B9, E9, F9).$
		$(G4+, A9-, C\sharp 4+, D\sharp 9-),$	
		$(Emaj7, Gmaj7, Bbmaj7, C\sharp maj7),$	
		$(C9-, A9-, F\sharp 9-, D\sharp 9-).$	
(4, 8, 8)	$(Cex3, Eex2, F \sharp ex3, B \flat ex2).$	(Dmaj7, E9-, A7, A6),	$(B\flat 9, F9, C9, G9).$
		$(G \sharp maj7, B \flat 9 -, D \sharp 7, D \sharp 6).$	$(E9, B9, F \sharp 9, C \sharp 9).$

Table 5.3: Table gives various types of 3-chords for the two harmonies with $Z_4 = Z_2^{rot} \times Z_2^{refl}$ symmetry. 4-plets represent the orbits. First cycle has no harmonic loners. Second cycle gives rise to bio-harmony (4, 8, 8) for which 0-quint chords are dissonant.

$[\mathbf{(n_0,n_1,n_2)}]$	0-chords	1-chords	2-chords
(0, 16, 4)		$(Em, B\flat m), (Cm, F\sharp m),$	$(D9, G\sharp 9),$
		$(G6, C\sharp 6), (A6, D\sharp 6),$	$(E9, B\flat 9).$
		$(D4+, G\sharp 4+), (B4+, F4+),$	
		$(Cmaj7, F \sharp maj7), (G6-, C \sharp 6-).$	
(2, 12, 6)	$(Aex4, D \sharp ex2).$	$(Am, D\sharp m), (G9-, C\sharp 9-),$	$(C9, F \sharp 9),$
		$(C4, F \sharp 4), (E4+, B\flat 4+),$	$(A9, D\sharp 9),$
		$(Dmaj7, G \sharp maj7),$	$(D9, G\sharp 9).$
		(Bmaj7, Fmaj7).	
(4, 8, 8)	$(Aex2, Hex8, D \sharp ex2, Fex8).$	$(D7, G\sharp 7), (Amaj7, D\sharp maj7),$	$(G9, C\sharp 9), (A9, D\sharp 9),$
		$(A4+, D\sharp 4+), (E7, B\flat 7).$	(B9, F9), (E9, Bb9).

Table 5.4: Table gives various types of 3-chords for harmonies with Z_2 rotation symmetry acting as half-octave shift. The doublets represent 2-chord orbits.

$(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})$	0-chords	1-chords	2-chords
(2, 12, 6)	$(F \sharp ex3, Hex4),$	$(Am, D\sharp), (A6, D\sharp7),$	$(C9, F9), (B9, F\sharp 9),$
		$(D7, B\flat 6), (G6-, Fmaj7),$	$(E9-,C\sharp 9).$
		$(D4+,B\flat9-),(E9,G\sharp4+),$	
(2, 12, 6)	(Dex4, Hex4).	$(F, Fm), (C6-, B\flat maj7),$	$(C9, D\sharp 9),$
		$(D7, G\sharp 6), (Gmaj7, D\sharp 6-).$	$(D\sharp 9, C\sharp 9),$
		$(C \sharp 4-, A4+), (E4+, F \sharp 6).$	(E9, B9).
(4, 8, 8)	(Fex1, D # ex3, G # ex1, A ex2).	(E7, E6), (Amaj7, B9-),	$(D9, B9), (C9, C\sharp 9),$
		$(G, C \sharp m), (D7, F \sharp 6).$	$(F9, G\sharp 9), (D\sharp 9, B\flat 9).$
(2, 12, 6)	(Hex3, Eex7).	$(D7, G\sharp 6), (G, D\sharp m),$	$(C9, D\sharp 9),$
		$(F,Fm), (C6-, B\flat maj7),$	$(D9, C\sharp 9),$
		$(A9-, C\sharp 4+), (E7, F\sharp 6).$	(E9, B9).
(2, 12, 6)	(F # ex2, Fex3).	$(F, B\flat m), (C7, G\sharp 6),$	$(B\flat 9, D\sharp 9),$
		(Amaj7, B9-), (E6, E7),	$(C9, C\sharp 9),$
		$(G, C \sharp m), (D7, B6).$	(D9, H9).

Table 5.5: Table gives various types of 3-chords for harmonies with single reflection symmetry.

Chapter 6

About honeycombs of hyperbolic 3-space and their relation to the genetic code

6.1 Introduction

 $M^8 - H$ duality and the realization of holography in M^8 strongly suggests the importance of tessellations of H^3 (analogous to lattices of E^3) in the TGD based physics. These tessellations form a scale hierarchy and can thus appear in all scales. The hierarchy of effective Planck constants labelling dark matter as phases of ordinary matter indeed predicts quantum coherence in arbitrarily long scales and gravitational quantum coherence corresponds to the largest scales of quantum coherence among basic interactions.

The 4 regular honeycombs correspond to cubic, icosahedral, and 2 dodecahedral tessellations. The quasiregular icosa-tetrahedral honeycomb has tetrahedra, octahedra and icosahedra as cells having triangular faces as cells. These honeycombs serve as candidates for physically interesting tessellations. These 5 honeycombs are unique in that they involve only Platonic solids. I have proposed that the icosa-tetrahedral tessellation might define a universal realization of the genetic code as an induced structure so that the genetic code would be much more than a biochemical accident. The details of this realization are discussed in [L159, L103].

These 5 Platonic tessellations (or honeycombs, I will used these terms interchangeably in the sequel) could occur also in astrophysical scales as gravitational tessellations. The recent discovery of gravitational hum might have an explanation as gravitational diffraction in this kind of a tessellation. The unexpectedly large intensity of hum could be due to the concentration of the radiation intensity in discrete directions and due the fact that in diffraction the amplitude of the scattered field is proportional to the square N^2 of the number N of scatterers rather than N.

Icosa-tetrahedral tessellation relates to the TGD based view of the genetic code. The TGD inspired view of genetic code has evolved during decades.

- 1. The first model of the genetic code was based on the so-called Combinatorial Hierarchy [K60] [L159] and predicted what I called memetic code realized as sequences of 21 DNA codons. Surprisingly, this model made a comeback as I prepared this article.
- 2. After several stray paths I ended up from a model of music harmony [L16, L36] [L136, L103] based on Hamiltonian cycles at the icosahedron to a model of genetic code also involving the tetrahedral Hamiltonian cycle.

The basic observation was that the 12-note scale could correspond to a Hamiltonian cycle of icosahedron such that the steps of the cycle define a quint cycle. 12-note scale is obtained from the quint by octave equivalence. There are 3-types of icosahedral Hamiltonian cycles and each cycle defines 20 3-chords assignable to the triangular faces of the icosahedron and defines a musical harmony.

One obtains 20+20+20 chords for the 3 different harmonies with symmetry groups Z_6, Z_4 and Z_2 . The orbits of these groups define sets of 3-chords. The surprising finding was that if these sets are identified as amino acids, the numbers of the chords are the same as the numbers of DNAs coding for a given amino acid. By adding a tetrahedral Hamiltonian cycle one obtains 64 3-chords. At the level of molecules the music would be "music of light". Since music expresses and generates emotions, the idea that emotions appear already at the molecular level was natural. Different combinations of 3 Hamiltonian cycles with symmetries Z_6, Z_4 and Z_2 would correspond to different moods at bio-molecular level (why just 3?)

The model made almost correct predictions for the numbers of mRNA codons coding for amino-acids. I have discussed a considerable number of its variants during years and even considered the replacement of icosahedron and tetrahedron with some other geometric object.

The basic problem was that gluing the tetrahedron and icosahedron together looked ugly and would have allowed only 63 codons. At that time I did not yet realize that an icosahedron and tetrahedron could be parts of a bigger structure.

- 3. Second model was based on the realization of codons as dark proton triplets assumed to reside at the monopole flux tubes parallel to DNA strands [L36, L103]. Dark proton triplets would neutralize the constant negative charge of -3 units per codon. The model suggested that it might be possible to understand the numbers of DNA, RNA, tRNA and amino acids in terms of entangled states of dark proton triplets representing codons. The model had also problems: in particular, one had to assume an additional binary degree of freedom to get the number DNA and mRNA codons correctly and the proposed identifications of this new degree of freedom did not look quite realistic.
- 4. Icosa-tetrahedral realization [L159] of the code in terms of icosatetrahedral honeycomb of H^3 was the next step in the evolution of ideas. It was made possible only by the dramatic development of understanding of TGD itself, in particular of its number theoretical aspects related to $M^8 H$ duality [L127, L128].

The tessellations of the hyperbolic 3-space H^3 represented as possibly complex mass shell in $M_c^4 \subset M_c^8$ and as light-cone proper time = constant hyperboloids in $M^4 \subset M^4 \times CP_2$ are central in the the realization of holography in TGD. Icosa-tetrahedral honeycomb is a completely unique tessellation involving only Platonic solids and all possible platonic solids, tetrahedron, icosahedron, and octahedron are present. Kind of a quantum Platonic holy trinity is in question.

This led to a proposal of the genetic code in terms of icosa-tetrahedral honeycomb induced to the 3-surface by restriction. This realization could be assignable to the magnetic body of the system involving dark matter in the TGD sense. The realization would be universal and would not be restricted to mere biology. Counterparts of codons and genes can be realized also for higher-dimensional objects, say cell membrane and even brain.

Icosa-tetrahedral realization led to a proposal that the realizations of the code in terms of dark photon triplets and in terms of dark proton triplets are closely related. I did not however really understand the properties of the icosa-tetrahedral honeycomb when I published the first article about it [L159].

Sequences of N dark cyclotron photon triplets as representations of genes consisting of N dark proton triplets would make possible communications between dark genes by 3N-resonance. Genes would serve as addresses, much like in LISP, and the message would be coded by the modulation of the frequency scale. The details of this picture that were not discussed at that time create problems that are solved by the model based on icosahedral honeycomb.

In this article the properties of hyperbolic honeycombs are considered in detail and also a detailed view about the realization of DNA double strand in terms of the icosa-tetrahedral tessellation is considered. The emerging model is surprisingly quantitative and suggests a lot of new understanding about the dark realization of genetic code. Also a connection with the notion of memetic code [K60] [L38] and the realization of memetic codons in terms of 21 DNA codons are suggested by the model.

6.2 About honeycombs in hyperbolic 3-space

This section, written in 2023, represents some new understanding related to the tessellations of H^3 known as honeycombs.

6.2.1 Some preliminaries

Some preliminaries are needed in order to understand Wikipedia articles related to tessellations in general.

1. Schläfli symbol $\{p, r\}$ (rb.gy/j36tg) tells that the possibly existing Platonic solid $\{p, r\}$ has r p-polygons as faces meeting at each vertex. For instance, icosahedron $\{3, 5\}$ has 5 triangles as faces meeting at each vertex.

Schläfli symbol generalizes to higher dimensions. The analog of Platonic solid $\{p, r, q\}$ possibly in 4-dimensions and assignable to 3-sphere has q 3-faces which are Platonic solids $\{p, r\}$. This description is purely combinatorial and is recursive. For instance, one can start from 3-D dimensional Platonic solid $\{p, q\}$ with 3-D objects in dimension 4 by replacing p with p, r. One can also project this object to dimension 3. In this manner one obtains a projection of 4-cube (tesseract) $\{4, 3, 3\}$ for which 3 cubes $\{4, 3\}$ meet at each vertex ($2^4 = 16$ of them) and which has 8 3-cubes as faces as a 3-D object.

In the case of hyperbolic tessellations also strange looking Schläfli symbols $\{(p,q,r,s)\}$ are encountered: icosa-tetrahedral tessellation involving only Platonic solids has symbol $\{(3,3,5,3)\}$. My understanding is that this object corresponds to $\{3,3,5,3\}$ as an analogue of Platonic solid associate with 4-sphere in 5-D Euclidian space and that the fundamental region of this tessellation in H^3 is analogous to a 3-D projection of this object. At a given vertex 3 objects $\{3,3,5\}$ meet. For these objects 5 tetrahedrons meet at a given vertex.

- 2. Vertex figure is a further central notion. It represents a view of the fundamental region of tessellation from a given vertex. The vertices of the figure are connected to this vertex. It does not represent the entire fundamental region. For instance, for a cube (octahedron) it contains only the 3 (4) nearest vertices. For icosa-tetrahedral tessellation the vertex figure is icosidodecahedron (rb.gy/3u4pq). The interpretation of the vertex symbol of the hyperbolic icosa-tetrahedral honeycomb (htrb.gy/3u4pq) is a considerable challenge.
- 3. One cannot avoid Coxeter groups and Coxeter symbols (rb.gy/48qhg) in the context of tessellations. They code the structure of the symmetry group of say Platonic solid (tessellation of S^2). This symmetry group is generated by reflections with respect to some set of lines, usually going through origin. For regular polygons and Platonic solids is its discrete subgroup of rotation group.

The Coxeter group is characterized by the number of reflection hyperplanes H_i and the reflections satisfying $r_i^2 = 1$. The products $r_{ij} = r_i r_j$ define cyclic subgroups of order c_{ij} satisfying $r_{ij}^{c_{ij}} = 1$. Coxeter group is characterized by a diagram in which vertices are labelled by *i*. The orders of the cyclic subgroups satisfy $c_{ij} \ge 3$. For c_{ij} the generators r_i and r_{ij} commute. For $c_{ij} = 2$ the vertices are not connected, for $c_{ij} = 3$ there is a line and for $c_{ij} > 3$ the number c_{ij} is assigned with the line. For instance, hyperbolic tessellations are characterized by 4 reflection hyperplanes.

For instance, for p-polygon the Coxeter group has 2 generators and the cyclic group has order p. For Platonic solids the Coxter group has 3 generators and the orders of cyclic subgroups are 3, 4, or 5. For icosa-tetrahedral tessellation the order is 4.

6.2.2 The most interesting honeycombs in hyperbolic 3-space

 H^3 allows an infinite number of tessellations. There are 9 types of honeycombs. This makes 76 uniform hyperbolic honeycombs involving only a single polyhedron (hrb.gy/rs9h5).

4 of these honeycomes are *regular*, which means that they have identical regular faces (Platonic solids) and the same numbers of faces around vertices. The following list gives the regular uniform honeycombs and their Schläfli symbols $\{p, q, r\}$ telling that each edge has around it regular polygon $\{p, q\}$ for which each vertex is surrounded by q faces with p vertices.

- 1. H1: 2 regular forms with Schläfli symbol $\{5,3,4\}$ (dodecahedron) and $\{4,3,5\}$ (cube).
- 2. H2: 1 regular form with Schläfli symbol {3,5,3}(icosahedron)
- 3. H5: 1 regular form with Schläfli symbol $\{5,3,5\}$ (dodecahedron).

There is a large number of uniform honeycombs involving several cell types. There exists however a "multicellular" honeycomb, which is completely unique in the sense that for it all cells are Platonic solids. This icosa-tetrahedral (or more officially, tetrahedral-icosahedral) honeycomb has tetrahedrons, octahedrons, and icosahedrons as its cells. All faces are triangles. The icosa-tetrahedral honeycomb is of special interest since it might make possible the proposed icosa-tetrahedral realization of the genetic code (rb.gy/h8xx0).

From the Wikipedia article about icosa-tetrahedral honeycomb (htrb.gy/3u4pq) one learns the following.

- 1. The Schläfli symbol of icosa-tetrahedral honeycomb is $\{(3,3,5,3)\}$. This combinatorial symbol allows several geometric representations. The inner brackets would refer to the interpretation as an analogue of the Platonic solid assignable to a 4-sphere of Euclidian 5-space. At each vertex 3 objects of type $\{3,3,5\}$ would meet. At the vertex of $\{(3,3,5)\}$ in turn 5 tetrahedrons meet.
- 2. Icosa-tetrahedral honeycomb involves tetrahedron $\{(3,3)\}$, octahedron $\{(3,4)\}$, an icosahedron $\{(3,5)\}$ as cells. That there are no other honeycombs involving several Platonic solids and only them as cells makes this particular honeycomb especially interesting. Octahedron with Schläfli symbol $\{3,4\}$ can be also regarded as a rectified tetrahedron havig Schläfli symbol $r\{3,3\}$.
- 3. The vertex figure of icosa-tetrahedral honeycomb (htrb.gy/3u4pq), representing the vertices a lines connecting them is icosidodecahedron (rb.gy/q5w62), which is a "fusion" of icosahedron and dodecahedron having 30 vertices with 2 pentagons and 2 triangles meeting at each, and 60 identical edges, each separating a triangle from pentagon. From a given vertex VF=60 vertices connected to this vertex by an edge can be seen. In the case of cube, octahedron, and dodecahedron the total number of vertices in the polyhedron is 2(VF+1). It is true also now, one would have 122 vertices in the basic structural unit. The total number of vertices for the disjoint polyhedra is 6+4+12=22 and since vertices are shared, the number of polyhedra in the basic unit must be rather large.
- 4. The numbers called "cells by location" could correspond to numbers 30, 20, and 12 for octahedrons, tetrahedrons and icosahedrons respectively inside the fundamental region of the tessellation defining the honeycomb. That the number of icosahedrons is smallest, looks natural. These numbers are quite large. The counts around each vertex are given by (3.3.3.3), (3.3.3), resp. (3.3.3.3) for octahedra, tetrahedra, resp. icosahedra and tell the numbers of vertices of the faces meeting at a given vertex.
- 5. What looks intriguing is that the numbers 30, 20, and 12 for octahedrons (O), tetrahedrons (T) and icosahedrons (I) correspond to the numbers of vertices, faces, and edges for I. As if the fundamental region would be obtained by taking an icosahedron and replacing its 30 vertices with O, its 20 faces with T and its 12 edges with I, that is by using the rules vertex → octahedron; edge → I, face → T. These 3-D objects would be fitted together along their triangular faces.

Do the statements about the geometry and homology of I translate to the statements about the geometry and homology of the fundamental region? This would mean the following replacements:

(a) "2 faces meet at edge" \rightarrow "2 T:s share face with an I".

- (b) "5 faces meet at vertex" \rightarrow "5 T:s share face with an O".
- (c) "Edge has 2 vertices as ends" \rightarrow "I shares a face with 2 different O:s".
- (d) "Face has 3 vertices \rightarrow "T shares a face with 3 different O:s".
- (e) "Face has three edges" \rightarrow "T has a common face with 3 I:s".

6.2.3 An attempt to understand the hyperbolic honeycombs

The following general observations might help to gain some understanding of the honeycombs.

The tessellations of E^3 and H^3 are in many respects analogous to Platonic solids as 2-D objects. The non-compactness implies that there is an infinite number of cells for tessellations. It is important to notice that the radial coordinate r for H^3 corresponds very closely to the hyperbolic angle and its values are quantized for the vertices of tessellation just like the values of spherical coordinates are quantized for Platonic solids. The tessellations for E^3 are scale covariant. For a fixed radius of H^3 characterized by Lorentz invariance cosmic time this is not the case. One can however scale the value of a. What distinguishes between regular tessellations in E^3 and H^3 is that the metric of H^3 is non-flat and has negative curvature. H^3 is homogeneous space meaning that all points are metrically equivalent (this is the counterpart of cosmological principle in cosmology). Since both spaces have rotations as symmetries, this does not affect basic Platonic solids as 2-D structures assignable with 2-sphere if the edges are identified as geodesic lines of S^2 . Quite generally, isometries characterize the tessellations, whose fundamental region corresponds to coset space of H^3/Γ by a discrete group of the Lorentz group acting as isometries of H^3 . The modifications induced by the replacement $E^3 \to H^3$ relate to the 3-D aspects of the tessellation. This is because the metric is non-flat in the radial direction. The negative curvature implies that the geodesic lines diverge. One can use a counterpart of the standard spherical coordinates and in these coordinates the solid angles assignable to the vertices of Platonic solid are smaller than in E^3 . Also the hyperbolic planes H^2 emerging from edges of the tessellation of H^3 diverge in normal direction the angles involved are smaller.

It is useful to start from the description of the Platonic solids. They are characterized combinatorially by integers and geometrically by various kinds of angles. Denote by p the number of vertices/edges of the face and by q the number of faces meeting at vertex.

- **3.** Important constraints come from the topology and combinatorics. Basic equations for the numbers V ,E, and F for the number of vertices, edges and faces are purely topological equations VE + F = 2, and the equation pF = 2E = qV. Manipulation of these equations gives 1/r + 1/p = 1/2 + 1/E implying 1/r + 1/p > 1/2. Since p and q must be at least 3, the only possibilities for $\{p, q\}$ are $\{3, 3\}, \{4, 3\}, \{3, 4\}, \{5, 3\},$ and $\{3, 5\}$.
- 2. The angular positions of the vertices at S^2 are basic angle variables. In H^3 hyperbolic angle assignable to the radial coordinate is an additional variable of this kind analogous to the position of the unit cell in the E^3 tessellation. The cosmological interpretation is in terms of redshift.
- 3. There is the Euclidian angle ϕ associated with the vertex of the face given by π/p . Here there is no difference between E^3 and H^3 .
- 4. The angle deficit δ associated with the faces meeting at a given vertex due to the fact that the faces are not in plane in which case the total angle would be 2π . δ is largest for tetrahedron with 3 faces meeting at vertex and therefore with the sharpest vertex and smallest for icosahedron with 5 triangles meeting at vertex. This notion is essentially 3-dimensional, being defined using radial geodesics, so that the δ is not the same in H^3 . In $H^3 \ \delta$ is expected to be larger than in E^3 .

- 5. There is also the dihedral angle θ associated with the faces as planes of E^3 meeting at the edges of the Platonic solid. θ is smallest for a tetrahedron with 4 edges and largest for a dodecahedron with 20 edges so that the dodecahedron is not far from the flat plane and this angle is not far from π . The H^3 counterpart of θ is associated faces identified as hyperbolic planes H^2 and is therefore different.
- 6. There is also the vertex solid angle Ω associated with each vertex of the Platonic solid $\{p, q\}$ given by $\Omega = q\theta (q-2)\pi$. For tessellations in E^3 the sum of these angles is 4π . In H^3 its Euclidian counterpart is larger than 4π .
- 7. The face solid angle is the solid angle associated with the face when seen from the center of the Platonic solid. The sum of the face solid angles is 4π . For Platonic solid with *n* vertices, one has $\Omega = 4\pi/n$. The divergence of the geodesics of H^3 implies that this angle is smaller in H^3 : there is more volume in H^3 than in E^3 .

 E^3 allows only single regular tessellation having cube as a unit cell. H^3 allows cubic and icosahedral tessellations plus two tessellations having a dodecahedron as a unit cell. Why does E^3 not allow icosahedral and dodecahedral tessellations and how the curvature of H^3 makes them possible? Why is the purely Platonic tetra-icosahedral tessellation possible in H^3 ?

The first guess is that these tessellations are almost but not quite possible in E^3 by looking at the Euclidian constraints on various angles. In particular, the sum of dihedral angles θ between faces should be 2π in E^3 , the sum of the vertex solid angles Ω at the vertex should be 4π . Note that the scaling of the radial coordinate r decreases the dihedral angles θ and solid angles Ω . This flexibility is expected to make possible so many tessellations and honeycombs in H^3 . The larger the deviation of the almost allowed tessellation, the larger the size of the fundamental region for fixed a.

Consider now the constraints on the basic parameters of the Platonic solids (rb.gy/1cuav)in E^3 while keeping their H^3 counterparts in mind.

1. The values of didedral angle for tetrahedron, cube, octahedron, dodecahedron, and icosahedron are

$$[\theta(T), \theta(C), \theta(O), \theta(D), \theta(I)] \approx [70.3^{\circ}, 90^{\circ}, 109.47^{\circ}, 116.57^{\circ}, 138.19^{\circ}]$$
.

Note that r = 5 tetrahedra meeting at a single edge in E^3 would almost fill the space around the edge. In $E^3 r = 4$ cubes can meet at the edge. In $H^3 r$ should be larger. This is indeed the case for the cubic honeycomb $\{4,3,5\}$ having r = 5. For r = 3 icosahedrons the sum dihedral angles exceeds 2π which conforms with the that $\{3,5,3\}$ defines an icosahedral tessellation in H^3 . For the r = 4 dodecahedra meeting at the edge the total dihedral angle is larger than 360°: r = 4 is therefore a natural candidate in H^3 . There are indeed regular dodecahedral honeycombs with Schläffi symbol $\{5,3,r\}$, r = 4 and r = 5. Therefore it seems that the intuitive picture is correct.

2. The values of the vertex solid angle Ω for cube, dodecahedron, and icosahedron are given by the formula $\Omega = q\theta - (q-2)\pi$ giving

$$[\Omega(C), \Omega(D), \Omega(I)] \approx [1.57080, 2.96174, 2.63455].$$

The sum of these angles should be 4π for a tessellation in E^3 . In E^3 This is true only for 8 cubes per vertex ($\Omega = \pi/2$) so that the cubic honeycomb is the only Platonic honeycomb in E^3 . The minimal number of cubes per vertex is 9 in H^3 . It is convenient to write the values of the vertex solid angles for D and I as

$$[\Omega(D), \Omega(I)] = \ [0.108174, \ 0.209651] \times 4\pi \ .$$

The number of D:s resp. I:s must be at least 10 resp. 5 for dodecahedral resp. icosahedral honeycombs in H^3 .

3. The basic geometric scales of the Platonic solids are circumradius R, surface area A and volume V. The circumradius is given by $R = (a/2) \tan(\pi/q) \tan(\theta/2)$, where a denotes the edge length. The surface area A of the Platonic solid $\{p,q\}$ equals the area of face multiplied by the number F of faces: $A = (a/2)^2 Fpcot(\pi/p)$. The volume V of the Platonic time is F times the volume of the pyramid whose height is the length a of the face: that is V = FaA/3.

Choosing a/2 as the length unit, the circumradii R, total face areas A an the volumes V of the Platonic solids are given by

$$[R(T), R(C), R(O), R(D), R(I)] = [\sqrt{3}/2, \sqrt{3}, \sqrt{2}, \sqrt{3}\phi, \sqrt{3-\phi}\phi]$$

$$[A(T), A(C), A(O), A(D), A(I)] = [4\sqrt{3}, 24, 2\sqrt{3}, 12\sqrt{25} + 10\sqrt{5}, 20\sqrt{3}]$$

and

$$\begin{split} & [V(T), V(C), V(O), V(D), V(I)] \approx [\sqrt{8}/3, 8, \sqrt{128}/3, \ 20\phi^3/(3-\phi), 20\phi^2/3] \\ & \approx [.942809, 8, 3.771236, 61.304952, 17.453560] \ . \end{split}$$

What can one say about icosa-tetrahedral tessellation?

- 1. Consider first the dihedral angles θ . The values of dihedral angles associated T, O, and I in H^3 are reduced from that in E^3 so that their sum in E^2 scene must be larger than 2π . Therefore at least one of these cells must appear twice in H^3 . It could be T but also O can be considered. For 2T + O + I and T + 2O + I the sum would be 388.26° resp. 427.43° in E^3 . 2T + O + I resp. T + 2O + I could correspond to 4 cells ordered cyclically as ITOT resp. IOTO.
- 2. The values of the vertex solid angle Ω for tetrahedron, octahedron, and icosahedron are given by $[\Omega(T), \Omega(O), \Omega(I)] = [0.043870, 0.108174, 0.209651]4\pi$ If the numbers of T, O and I are [n(T), n(O), n(I)], one must have $[n(T)\Omega(T), +n(O)\Omega(O) + n(I)\Omega(I) > 4\pi$ in H^3 . If the number of the cells for the fundamental domain are really [N(T), N(O), N(I)] = [30, 20, 12], the first guess is that $[n(T), n(O), n(I)] \propto [N(T), N(O), N(I)]$ is approximately true. For [n(T), n(O), n(I)] = [2, 3, 1]n(I), one obtains $\Omega = n(T)\Omega(T) + n(O)\Omega(O) + n(I)\Omega(I) = n(I) \times .629 \times 4\pi$. This would suggest n(I) = 2 giving [n(T), n(O), n(I)] = [4, 6, 2]

6.3 New results about the relation of the icosa-tetrahedral tessellation to the dark genetic code

How could the icosa-tetrahedral tessellation relate to the proposed dark realizations of the genetic code [L136, L159]?

6.3.1 About the problems of the earlier view of the dark realizations of the genetic code

Consider first the problems of the earlier views of the realization of the dark genetic codes in terms of dark proton triplets at monopole flux tubes parallel to the ordinary DNA and to the realization in terms of dark photon triplets.

1. The TGD based inspired model of the dark photon genetic code [L16] [L103, L136] assumes that the dark realization of genetic code involves 3 icosahedral Hamiltonian cycles giving rise to 20+20+20 dark DNA codons and the unique tetrahedral Hamiltonian cycle giving the remaining 4 codons.

The obvious problem of icosa-tetrahedral picture is that one must assume that icosahedron and tetrahedron are disjoint. If they have a common face, the number of faces reduces to 63 and one DNA codon is missing. This raises the question whether icosahedron and tetrahedron could be disjoint pieces of a larger structure.

- 2. Icosahedron and tetrahedron should have a physical realization: what could it be? How the Hamiltonian cycles are realized physically? The cycles are defined only modulo the isometry group I of icosahedron having 60 elements and $Z_n n = 6, 4$ or 2 leaves the cycle and the orbits of this group (amino-acids) invariant. The Hamiltonian cycle has $\#(I/Z_n)$ isometric copies (the numbers of copies are 10, 15, and 32). Does this have a physical significance? How are the 12 frequencies associated with the edges of the cycle realized physically? What is the physical interpretation of octave equivalence: does it have something to do with 2-adicity?
- 3. In the dark proton realization a given codon would correspond to a selected triangular face of I or T carrying dark protons at the vertices of this face. The original view was that dark 3-proton states would correspond to 64 codons. The problem was that one obtains only 8 states for dark proton triplets from spin and antisymmetrization in spin degrees of freedom would not allow any states unless the spatial wave function is totally antisymmetric and spins are in the same direction.

In the original proposal also neutrons were assumed so that the codon corresponds to a sequence of 3 nucleons with both spins. 3 nucleons would give rise to 64 states as required. Dark protons can also be effectively neutrons as far as charge is considered. This might be possible if the bonds connecting the dark protons can be both neutral and negatively charged. Weak interactions are as strong as electromagnetic interactions in a given biological scale (such as DNA scale) if the dark Compton length proportional to h_{eff} is larger than this scale and the weak transitions change the dark protons to effective dark neutrons.

This option leads to a problem with the fact that DNA nucleotides have negative unit charge. One should have protons to neutralize this charge and stabilize DNA. Also variants of the proposal in which there are flux tube connections between dark protons having 2 different neutral states analogous to neutral pion and neutral ρ meson.

The simplest proposal, which is consistent with the idea that genetic codons correspond to cyclotron transitions of dark proton triplets assignable to the triangular faces of an icosahedron or tetrahedron is as follows. Besides 2 spin states, dark protons can also have 2 states with spin ± 1 corresponding to the analog of rotation in the discrete space defined by the vertices of the triangle. This would give $2^3 \times 2^3 = 64$ states.

The realizations of the genetic code in terms of dark photon triplets and dark proton triplets should correspond to each other. This requires that dark proton triplet realization should naturally correspond to the icosa-tetrahedral realization.

1. The codons identified as dark proton triplets assignable to one of the 20 triangular faces of icosahedron and tetrahedron have in quantum situations a wave function in the discrete space of the faces, which is in general delocalized. Could these wave functions in the set of faces give rise to states in 1-1 correspondence with the icosahedral and tetrahedral codons? There would be 20 wave functions for an icosahedron and 4 wave functions for a tetrahedron. The number of icosahedral states must be tripled to 60 corresponding to the 3 basic types of icosahedral Hamiltonian cycles with symmetries Z_n , n = 6, 4, 2.

The 3 dark protons also have spin degrees of freedom. The dark proton triplet in the ground state(s) would be naturally spontaneously magnetized so that all spins are in the same direction. Also the states in which some dark protons are excited are allowed by Fermi statistics and are needed since these excitations could correspond to the spatial wave functions in face degrees of freedom.

2. Dark photon triplets are needed for communications. The vision is that they correspond to the representation of codons as frequency triplets represented by the realization of icosahedral and tetrahedral Hamiltonian cycles as frequency triplets. The assumption has been that the 3 frequencies of dark 3-photon are associated with the cyclotron (or Larmor transitions if only spin is dynamical) of dark protons of a dark proton triplet.

Dark photon communications between identical codons would take place by 3-resonance. The de-excitation of the first codon would lead to the excitation of an identical codon: one would have a kind of flip-flop. Also dark genes as sequences of N dark codons could act as a single quantum coherent unit and 3-N resonances between identical dark genes would become possible. The mechanism is very similar to that used in the computer language LISP. The modulation of the frequency scale by modulating the thickness of the monopole flux tubes would make possible coding of the signal and it would be transformed to a sequence of resonance pulses at the receiving end.

Dark photon triplet states could correspond to wave functions in the space of icosahedral and tetrahedral faces.

3. Cyclotron transitions would be needed in order to generate dark photon triplets. This would require excitations of the dark protons of the spontaneously magnetized ground state(s). If only spin matters, the cyclotron transitions reduce to Larmor transitions. The correspondence with the icosahedral Hamiltonian cycles in terms of dark photon triplets would suggest that these excitations correspond to icosahedral genetic codons as wave functions in the set of faces. The cyclotron transition would provide the energy needed to excite the wave function in the set of faces. 64 transitions would be needed. It is important to notice that cyclotron transitions rather than cyclotron states of dark protons would correspond to codons of icosa-tetrahedral representation represented as wave functions in the set of faces.

There are however only 8 states per face if only Larmor transitions are allowed. This is much less than the number 20 20+20+4=64 for icosahedral and tetrahedral Hamiltonian cycles. An additional two-valued degree of freedom is needed. The simplest possibility is the assignment to each dark proton an analog of angular momentum eigenstate with spin ± 1 corresponding to a discrete rotation around the triangle. This would give $8 \times 8 = 64$ states per face. Could the excitations of these states correspond to 20+20+20 icosahedral states plus 4 tetrahedral states?

4. Hitherto the considerations have been implicitly classical in that a localization in the set of faces has been assumed. Quantum theory allows us to give up this assumption. Icosahedral realization suggests that dark proton triplet has a icosahedral wave function delocalized to the set of 20 faces with symmetry fixed by the Hamiltonian cycle to Z_n , n = 6, 4 or 2, and that the excitation of the dark proton triplet in the face degrees of freedom provides the energy changing the wave function in the set of faces. The same would apply to the tetrahedron with symmetry Z_4 allowing 4 wave functions.

The orbital and angular momentum degrees of freedom would be coupled. The transition from the ground state for dark proton triplet would excite wave function in the set of faces. This could imply the desired correspondence between the dark proton representations and dark photon realizations of the code.

5. There is a further problem. Spontaneously magnetized states of 3 dark protons would define ground states of codons. The ground state proton triplet cannot have lower energy states and cannot emit dark photon triplets and are therefore "mute" and unable to communicate, presumably necessary for processes like transcription and translation. Note that ground states are however not deaf.

The proposed general view is attractive but the details remain to be understood and problems solved. Here the notion of icosa-tetrahedral tessellation could help. The proposal of [L159] was that the icosa-tetrahedral honeycomb at the light-cone proper time a = constant surfaces identifiable as hyperbolic 3-space H^3 allows to realize the dark genetic code.

The icosa-tetrahedral honeycomb is the unique honeycomb, which involves only Platonic solids. This inspires the question whether genetic code could be universal and realized in all scales by induction, which means that the tessellation of H^3 induces tessellation of 3-surface $X^3 \subset H^3$ by restriction. Also the induction to $H^3(a)$ projection of X^4 makes sense.

The TGD view of holography indeed predicts the special role of hyperbolic 3-spaces. The space-time surfaces in $H = M^4 \times CP_2$ are analogs of Bohr orbits, which go through $H^3(a_n) \subset M^4 \subset H$, where a_n corresponds to a root of the polynomial with integer coefficients determining to a higher degree a given region of the space-time surface by $M^8 - H$ duality [L127, L128].

In the sequel the detailed realization of the genetic code in terms of the icosahedral honeycomb will be discussed with an emphasis on the problems noticed above.

6.3.2 The realization of the code in terms of icosa-tetrahedral tessellation

The fundamental region of the icosa-tetrahedral tessellation contains 30 octahedrons, 20 tetrahedrons, and 12 icosahedrons and the cautiously proposed interpretation is that the cells meeting at each *edge* of the tessellation have either the cyclic structure TOTI or OTOI, and each vertex involve 3 O:s, 2 T:s and 1 I. Could one interpret this in terms of the dark icosahedral realization of the genetic code?

Ideas related to the detailed realization of the genetic code

The detailed realization of the dark genetic code is far from completely understood and one might hope that icosa-tetrahedral realization could bring in the constraints allowing us to fill in the details. It is useful to proceed by considering basic requirements on the realization of the dark code.

1. There are 3 O:s per single I in vertex if 10 instead of 12 icosahedral cells are included. The reasons for this become clear from the proposed relation between DNA double strand and fundamental cell of icosahedral honeycomb. What could the role of O:S be?

Imagine that it is possible to arrange the polyhedrons for a given I to cycles as -I-O-T-O-T-O-T-O-: here cyclicity is assumed. The two tetrahedrons and I would be disjoint. This would solve the problem due to the common face of T and I (only 63 DNA codons) but give 60+4+4 faces and 68 dark DNA codons. There is however the problem posed by the mute codons. Could the presence of mute DNA codons reduce the number of DNA codons from 68 to 64. This would imply that their transcription allows only 64 dark mRNA codons. Could mute mRNA codons reduce the effective number of mRNA codons to 61 for the standard code (stop codons would be mute)? What about its variants with a smaller number of stop codons?

2. Bioharmony involves 3 icosahedral Hamiltonian cycles. All the combinations of the 3 -cycles with symmetries Z_6, Z_4 and Z_2 predict the same code. These bioharmonies are interpreted as correlates for emotional states appearing already at the basic bio-molecular level. The motivation comes from the fact that the icosa-tetrahedral harmony emerges as a geometric model for the music harmony and music indeed both creates and expresses emotions.

Could icosahedral honeycomb allow us to understand the realization of these 3 icosahedral Hamiltonian cycles in terms of cyclotron frequency triplets? One must have closed magnetic monopole loops in order to have cyclotron transitions. Could these loops form triangles of form I-T-O. This would be 6 different triangles and 3 different positions of I for given T. This kind of loop would be assigned with each vertex of the face. Could the magnetic field strengths depend on the loop and for a given T give rise cyclotron frequency triplets characterizing a given icosahedral Hamiltonian cycle.

3. One can criticize the assumption that there is only a single codon per single I and T. I:s could in principle carry several codons. This however gives a restriction that the codons inside given I and T are different and restricts the representative power of the code if it involves more than 2 strands. This restriction is however automatically satisfied for the base-paired codon and anticodon in the DNA double strand!

Dark photon realization of the icosahedral part of the code

Consider first the realization of the icosahedral part of the code in terms of dark photons.

1. The 3 icosahedral Hamiltonian cycles have symmetries. The 20 codons with Z_6 symmetry correspond to 3 6-plets and 1 doublet of Z_6 and for unbroken symmetry the codons inside these multiplets code for the same amino acid. This means 3+1=4 amino acids. Z_4 symmetry has 5 4-plets and in absence of symmetry breaking this corresponds to 5 amino-acids. Z_2 symmetry as 10 2-plets, and also this symmetry is also almost exact and corresponds to the almost exact symmetry with respect to the third letter of the codon analogous to isospin symmetry.

2. Icosahedral part of the icosa-tetrahedral realization involves 3 icosahedral Hamiltonian cycles characterized by different symmetries. For Z_6 symmetry, there are 6+6+6+2=20 codons codons. These sets of codons can be regarded as orbits of Z_6 and correspond to amino-acids. This if the Z_6 symmetry is not broken. This means 3+1 amino acids in absence of symmetry breaking.

 Z_4 symmetry has 5 4-plets and in absence of symmetry breaking this corresponds to 5 aminoacids coded by 4 codons each. Z_2 symmetry has 10 2-plets and this symmetry is also almost exact. This symmetry corresponds to the almost exact symmetry with respect to the third letter of the codon.

3. Dark photon codons are represented as cyclotron frequency triplets of dark photons created in 3-cyclotron transitions for dark proton triplets involving simultaneous emission of 3 dark photons made possible by quantum coherence. In the case of genes with N codons one has 3N-cyclotron transition and 3N dark proton-state represents a gene as a quantum coherent unit.

Dark proton realization of the icosahedral part of the code

Consider next the dark proton realization of the icosahedral part of the code.

1. The basic problem of the dark proton realization of the code is that there are only 8 dark proton spin states. If one assumes that each dark proton can have spin ± 1 this problem the number of dark proton states is 4 and one obtains 64 states.

If one allows the states with vanishing spin so that one would have 3 orbital states per dark proton, the number of cyclotron transitions per dark proton is 4. Since lowest energy states are mute and transitions define codons, this could be the correct identification.

- 2. Icosa-tetrahedral realization should give 20+20+20+4 = 64 dark proton triplets assignable to the faces of I and T. Suppose that the cells can be thought of as forming a cycle O-I-O-T-O-T with O and T ends connected. The two T:s have no common faces with O and without additional conditions give rise to 4+4 additional codons giving 68 codons. How can one reduce the number of dark DNA codons to 64?
- 3. Dark proton codons have a ground state, or possibly several of them, which by definition cannot decay to lower energy states by emission of dark photon cyclotron triplet. Ground state codon is mute since it cannot produce dark photon triplets as 3-chords.

The natural first guess is that the ground states correspond to the 6 combinations 3 icosahedral Hamiltonian cycles and 2 tetrahedral cycles assignable to $2 \times T$. The 3 stop codons are transcribed but not translated so that the interpretation of 3 DNA stop codons as icosahedral ground state dark codons unable to send 3-photon signals is not correct. For mRNA this interpretation could make sense if the mRNA images of DNA stop codons represent ground state codons.

4. Cyclotron excitations of ground state codons are induced by dark photon triplets. Conversely cyclotron de-excitatons generate dark proton triplets except for the ground state codons with minimum total energy. Suppose that there are 6 ground state codons as combinations of 3 dark codon ground states assignable to the 3 icosahedral Hamiltonian cycles and 2 dark proton ground states assignable to tetrahedral cycles of the two T:s. This would give 8 mute states. The total number of dark DNA codons is 60+8=68. Note that the mute states are not deaf: they can receive messages.

One would obtain only 60 DNA codons, which can be transcribed to mRNA codons if the transcription involving dark photon codons. How could one get 64 as an effective number of DNA codons?

One can imagine transitions between otherwise mute codons, which generate dark photon triplets coupling to mRNA associated with DNA. Let A, B and C the ground state codons with minimal total dark cyclotron energies in an increasing order for the 3 icosahedral Hamiltonian cycles. If for a given T (two options) the cyclotron transitions are possible only between

codons C and B and A one obtains 2 DNA-mRNA pairings for both T:s. One would have 60+2+2=64 mRNAs pairing with DNA and effectively 64 DNA codons.

Note that the transcription produces only 64 dark mRNA codons from 68 dark DNA codons.

For 64 mRNA codons it could happen that there are no transitions between the 3 icosahedral codons for both choices of T so that there are 6 mute mRNA codons. If there are transitions $C \rightarrow B$ and $B \rightarrow A$, the number of mute icosahedral codons is 4. If there are no transitions between tetrahedral ground state codons, one has effectively 60 mRNA codons since the translation stops due to the absene of dark 3-photon signals to tRNA. If there is a transition between the 2 ground state nRNA codons associated with the two T:s, one obtains 61 effective mRNA codons of the standard realization of the code. The transitions between tetrahedral codons can increase the effective number of mRNA codons.

5. What about tRNA appearing as a pair of amino-acid and single RNA codon. Could the RNA of tRNA and amino-acids correspond to the unique icosahedral honeycomb of H^3 and to icosahedral Hamiltonian cycles so that the number of dark codons in absence of tetrahedral degeneracy would reduce to 32, which is the minimal number of ordinary tRNA codons, which is increased by the non-uniqueness of the ordinary tRNA itself? Note that mute tRNA codons are not deaf: they can receive messages but cannot send them. Obviously, tRNA and amino-acids would correspond to the lowest evolutionary level.

The tentative conclusion would be that in the TGD framework DNA-mRNA transcription is not 1-to-1: information is lost and could say that RNA represents a lower level of evolutionary hierarchy. This would conform with the RNA world vision. The numbers of dark proton DNA and mRNA codons are 68 and 64 respectively. The unavoidable existence of mute codons gives effective DNA codon number 64 as the number of mRNA codons. 3 icosahedral codons can be mute and one obtains 3 stop codons unable to communicate with tRNA. The number of mute codons can also be smaller.

The dark DNA and RNA codons are dynamical and are not fixed to be the same as ordinary codons. This is required only during the communications with ordinary DNA possibly taking place by dark photons transforming to ordinary photons and inducing resonant transitions of ordinary DNA and other basic biomolecules. This strongly suggests that dark DNA and RNA act as kinds of R&D laboratories making it possible to test variants of the genes. Actually their ground states would correspond to 3 icosahedral representations and 2 tetrahedral representations and would correspond to aminoacids via transcription and translation.

Needless to say, this picture is highly speculative and one can probably imagine variants for it. The basic idea is however clear: icosa-tetrahedral tessellation could explain the details of the standard genetic code and its modifications.

Realization of the flux tube structures associated with dark codons

The following represents an attempt to make the above picture more concrete.

- 1. The selection of 1 O from 3 O:s could mean a selection of an icosahedral Hamiltonian cycle with symmetry group Z_6 , Z_4 , or Z_2 . This gives for icosahedral realization 20+20+20=60icosahedral codons. Tetrahedral Hamiltonian cycles associated with the two T:s should give the remaining 4 codons. One can however imagine several ways for how this could occur.
- 2. The selection of O should correspond to a choice of the icosahedral cycle. What does this mean geometrically? To each dark proton of the codon, one must assign a closed monopole flux tube. The strength of the magnetic field of the flux tube fixes the cyclotron frequency scale for each flux tube. The 20 dark-photon chords defining a given icosahedral bioharmony differ for different choices of O and T. The frequencies are fixed if the Hamiltonian cycle corresponds to a quint cycle such that the frequencies associated with the neighboring vertices of the Hamiltonian cycle differ by a scaling 3/2. This requires that the magnetic field strengths along the cycle differ by scaling 3/2.
- 3. How to concretely realize the correlation of the bioharmony with the choice of O and T for a given I? Suppose that for a given I, the closed flux tube connects I and the selected O and

T. There would be a closed I-O-T flux tube for each vertex of the face defining the codon. This kind of flux tube would define an analog of a string of a musical instrument.

These closed flux tubes would be hyperbolic analogies of closed circuits formed by Euclidian nearest neighbour lattice bonds. If makes sense to assign to each I a cycle O-I-O-T-O-T, with O and T at ends being connected, the cycle I-O-T would go through the either T, and this implies that tetrahedral codons correspond to the other face of T. One would obtain 64 dark proton codons with 3 mute dark proton codons identifiable as stop codons. In the transcription the signal as a dark photon triplet would not reach the dark RNA codon and the transcription would stop. Could this mean that dark RNA codon attaches first to dark DNA codon and the transcription of DNA to ordinary RNA occurs after that in the usual way.

4. The proposed transitions between ground state codons for icosahedral Hamiltonian cycles modify the cycle geometrically since the O in cycle I-O-T changes. If the transitions for given T are only of $C \rightarrow B$ and $B \rightarrow A$ with energies in increasing order, one can imagine that the O is replaced by a neighboring O in the transition in the O-I-O-T-O-T.

Several questions remain to be answered.

1. The symmetry breaking for the icosahedral codons with Z_n , m = 6, 4, 2 should be understood. This symmetry breaking can be assumed to occur at the level of dark mRNA and modify the frequency triplets from those for completely symmetric mRNA codons. The replacement $T \rightarrow U$ might relate to the symmetry breaking.

UUG, CUG, and the very common AUG appear as start codons. They correspond to symmetry breaking for 6-plet (Z_6) coding for leu and 4-plet (Z_4) coding for ile. All symmetry breakings occur for start codons UUG, CUG, and for codons UAA and UAG and UGA and UGG closely related to stop codons.

- 2. Can one understand the reduction of the number of mRNA stop codons to 2 or 1 occurring for some variants of the code? In these situations, the stop codon of mRNA can code for an exotic amino acid pyrrolysine and selenocysteine. Could the transition between stop codon of dark mRNA icosahedral Hamiltonian cycle to a stop codon of another Hamiltonian cycle take place such that the dark photon triplet generated couples to tRNA involving the exotic amino acid. Situation would be almost like in the case of DNA where only two ground state codons stop the transcription.
- 3. What can one say about the strength of the magnetic fields assignable with the monopole flux tubes? Nanometer length scale 1 nm, naturally assignable to the DNA double strand, corresponds from the formula $l_B = 26nm/\sqrt{B/Tesla}$ to 12.2 GHz. What is interesting is that the gravitational Compton frequency for Earth is 67 GHz and defines a lower bound for the gravitational quantum coherence time. If the strengths of the magnetic fields span 7 octaves, the thickness of the flux tube would vary by a factor 10 in the range about .1 nm 1 nm.
- 4. Note that the 12-note scale can be realized using powers $(3/2)^k$, k = 1, ..., 12, of the fundamental and by using octave equivalence to reduce the note to the basic octave. Since the monopole flux is quantized, the realization of the scale requires variation of flux tube thickness inducing variation of magnetic field strength and therefore of that cyclotron frequency scale.

There is nothing cherished in the rational quint cycle as the basis of the 12-note scale. For instance, the well-tempered scale actually replaces the Pythagorean scale with an algebraic scale coming in powers of $2^{1/12}$.

6.3.3 Description of the entire DNA double strand in terms of icosatetrahedral tessellation

The most ambitious model would describe the entire DNA double strand and relate the model bioharmony to the properties of the icosa-tetrahedral tessellation. There are however many questions remaining.

- 1. Single DNA and RNA strand would correspond to a "half realization" for which the T and I cells would contain only single codon. The splitting of DNA could have a geometric interpretation as an effective replication of the induced tessellation to two tessellations to RNA type tessellations.
- 2. There are 20 amino-acids and an icosahedron involves 20 faces. Is this a mere accident? Could icosahedral honeycomb describe amino-acid sequences geometrically. tRNA appears as a single unit. tRNA-amino-acid pairing would involve pairing of two icosahedral tessellations as also the pairing of RNA and tRNA in the translation. tRNA would naturally correspond to a single cell of icosahedral tessellation. This would also explain why the number of tRNA molecules is considerably smaller than RNA codons.
- 3. Does RNA correspond to icosahedral or icosa-tetrahedral tessellation? Tetrahedral Hamiltonian cycles are needed, in particular the dark proton triplets associated with the tetrahedral faces. Therefore icosa-tetrahedral tessellation is the natural option also for RNA.
- 4. It is thought that DNA and RNA nucleotides float freely in the cellular water and DNA and RNA codons are built from them in replication/transcription. This is probably the case at the biochemical level, whose dynamics is controlled by dark level (I have however considered the possibility that freely floating nucleotides could actually form loosely bound codons).

At the ark level both replication and transcription would involve replication of the induced icosa-tetrahedral tessellation: a similar process occurs for clay crystals, and is suggested to be a precursor of DNA replication. This process is a holistic quantum process occurring in a single quantum jump. This would explain the incredible accuracy of these processes, which is extremely difficult to understand in the chemical approach.

The replication would determine the outcome, be it a pair of DNA double strands or of DNA and RNA. After this the chemical processes leading to the formation of chemical codons from nucleotides and their pairing with dark codons of the induced icosa-tetrahedral tessellation would take place.

DNA has a helical structure. Helical tessellations are known to exist (rb.gy/5ova6). If icosa-tetrahedral tessellation is induced, the helical structure would most naturally reflect the dynamics of the corresponding space-time surface. This suggests that only a sequence of I:s is selected from the set of 12 I:s in a given fundamental region of the icosa-tetrahedral tessellation.

To see whether this hypothesis can make sense one must use geometrical facts about DNA double helix, which has A-, B-, and Z forms rb.gy/4kcrm).

- 1. B-form is believed to dominate in cells. From the table of the Wikipedia article one learns that for the B-form the rise per base pair (bp) is 3.32 Å, that full turn corresponds to 10.5 bps, and that the pitch of the helix per turn 33.2 Å, which corresponds to 10 bps per turn. The pitch/turn should be equal to $10.5 \times 3.32 = 34.52$ Å. There is obviously a mistake in the table.
- 2. The solution of the puzzle is that straight DNA in solution has 10.5 bps/turn and 10 bps/turn in solid state (rb.gy/wqjbh). If DNA double helix corresponds to solid state then 10 codons correspond to 3 full turns. Therefore my earlier assumption 10 bps/turn in the double helix is correct. 10 codons would correspond 3 full turns and to the length 99.6 $\mathring{A} \simeq 10$ nm, which in TGD framework corresponds to the p-adic length scale L(151).

Double DNA strands cannot pair with all 12 I:s associated with the dark DNA. The length L(151) should correspond to 10 I:s taking 80 per cent of the icosahedral volume. Is helical winding enough to achieve this?

1. The total volume of the fundamental region is V = 20V(T) + 30V(O) + 12V(I) = 341.44using 2*a* as length unit. Using the estimate $V_{real} = L(151)^3 = 10^6 \text{ Å}^3$, one obtains $a = L(151)/2V^{1/3} \simeq 0.07 \times L(151)$. The volume fraction of single icosahedron would be $17.45/V \simeq .05$ and 10 I:s would take 1/2 of the volume.

- 2. The circumradius of single icosahedron would be $R = \sqrt{3 \phi}\phi a/2 \simeq .1 \times L(151) = 1$ nm. This conforms with the assumption that there are 10 codons per length L(151)! The diameter of the B-type DNA strand is 20 Å is also consistent with the value of the circumradius. Maybe the proposed picture works!
- 3. Notice that if an icosahedral cell corresponds to 2 tetrahedral cells and 3 tetrahedral cells, then 10 codons is the maximum for the realizable DNA codon.

What can one say about the straight form of DNA?

- 1. For 10.5 bps/turn for a straight DNA in solution, the smallest portion of strand, which corresponds to integer numbers of turns and of codons is 6 full turns. This corresponds to 63 bps and 21 codons.
- 2. With an inspiration coming from the notion of Combinatorial Hierarchy [A33, A45] defined in terms of Mersenne primes $M_n = 2^n 1$ defined by the recursive formula $M(k) = M_{M(k-1)} = 2^{M(k-1)} 1$, I proposed decades ago that ordinary genetic code could correspond to Mersenne prime $M_7 = 2^7 1$ [K60] [L38]. The basic idea is that a system with $2^7 1$ states corresponds to a Boolean logic with 7 bits but with one state missing: this state would correspond to empty set in the set theoretic realization or fermionic vacuum state in the realization as a basis for fermionic Fock states. Only 6 full bits can be realized and the number of realizable statements is 64, the number of genetic codons.
- 3. Memetic code corresponds to the Mersenne prime $M_{127} = M_{M_7} 1 = 2^{127} 1$. Now the number of codons would be $2^{126} = 2^{6 \times 21}$ and is realizable as sequences of 21 DNA codons! Note that higher Mersenne numbers in the hierarchy were proposed by Hilbert to correspond to Mersenne primes but for obvious reasons this has not been proven.
- 4. Could 6 full turns of straight DNA define a memetic codon? During the transcription and replication, DNA double strand opens and becomes straight. Could memetic code be established during the transcription and replication periods? A further intriguing observation is that the cell membrane involves proteins consisting of 21 amino-acids.

6.3.4 Some questions

Many questions remain to be answered.

- 1. Hamiltonian cycles are fixed only modulo the 60-element isometry group I of icosahedron. Subgroups Z_n , n = 6, 4 or 2 as invariance groups of their orbits defining amino-acids coded by DNA codons assigned to them. Therefore the space I/Z_n corresponds to the space of orbits of Hamiltonian cycles having 10, 15, *resp.* 32 elements for n = 6, 4, *resp.* 2. Suppose that the Hamiltonian cycles for various icosahedrons of the fundamental region proposed to be associated with the sequence of 10 DNA codons differ by a non-trivial isometry assignable to I/Z_n . Does this have physical implications or is it mere gauge degeneracy?
- 2. The wave functions defining quantal variants of the genetic codons can be assumed to be products of wave functions for the position of the face and 3-proton states assignable to a given face should form an orthonormal set. The face wave functions associated with tetrahedra are trivially orthogonal with those of second tetrahedron and icosahedron. For a fixed choice of the icosahedral or tetrahedral Hamiltonian cycle orthogonality can be realized for the wave functions associated with the position of the face.

If the icosahedral face wave functions correspond to different Hamiltonian cycles then orthogonality of protonic states for a given face can guarantee the orthogonality. This is possible if the number of protonic states is larger than the number of icosahedral wave functions. This requires 20+20+20+20 protonic states so that four protonic 4 states are left if their number is 64.

3. Why Hamiltonian cycle and quint cycle? Without Hamiltonian cycles the number of frequencies defining 3-chords would be 30 and is reduced to 12 for Hamiltonian cycles. Hamiltonian cycles assigned to the genetic code define an additional symmetry as shifts along the cycle, which are represented as 3/2 scalings modulo octave equivalence. The quint cycle defines the 12 frequencies for a given magnetic field strength and the chords of different cycles consist of different combinations of frequencies.

What does the Hamiltonian cycle as a 1-D closed path correspond physically?

The proposal that the fundamental region of the icosa-tetrahedral honeycomb could have interpretation as a kind of super-icosahedron raises several interesting questions.

- 1. Assume that the sequence of 10 DNA (2 codons missing) to the super-icosahedron having icosahedrons as 12 super-edges, tetrahedrons as 20 super-faces, and 30 octahedrons as super-vertices. Combinatorial equivalence suggests that one cdefine icosahedral Hamiltonian cycles as sequences of 12 icosahedrons serving as superedges. Could one define higher level icosahedral genetic codes in terms of icosahedral Hamiltonian cycles. The orthogonality of the face wave functions for the different Hamiltonian cycles would require the assignment of the analogs of dark proton triplets to the super-faces.
- 2. What could the notion of a super-Hamiltonian cycle as a sequence of 12 dark DNAs mean? The proposed interpretation is that the collection of tetrahedral and 3 icosahedral Hamilton's cycles defines a correlate of a mood, emotional state. It is difficult to say whether the mood is the same for all cells of the entire organism, for the genome of a single cell, for the genes, for the sequences of 10 DNAs, or for codons.

Super-Hamiltonian cycle associated with the super-icosahedron would have as its edges icosahedrons with the associated 12 dark DNA codon. If the 12 icosahedrons can correspond to different Hamiltonian cycles, one would have a correlate for a sequence of moods. Hamiltonian cycle property allows only 60 sequences of this kind. Without this restriction one would have N^{12} mood sequences, where N is the number of Hamiltonian cycles.

3. One can of course ask whether super-octahedron and super-tetrahedron could make sense and whether they could combine to form a super-icosa-tetrahedron. Does one have any tessellation for which fundamental region would correspond to super-tetrahedron with tetrahedron as interior, 4 octahedrons as 4 super-vertices and 4 icosahedrons as super-edges. There is no mention of this kind of tessellation but it is known that hyperbolic tessellations constructible using the standard methods do exist.

One could even ask whether there could exist a fractal hierarchy of these super-structures constructible from the super-Platonic solids of the previous level and whether it could be realized as a hierarchy associated with dark DNA. This would mean a hierarchy of increasingly refined emotions emerging as the length of genes and DNA increases.

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Chapter 7

Homonymy of the Genetic Code from TGD Point of View

7.1 Introduction

This article was motivated by the article of Peter Gariaev [K118] about the linguistic notions of synonymy and homonymy applied to genetic code (for other works of Gariaev and collaborators on the linguistic aspects of DNA see [I112, I106]). In another article by Peter Gariaev and Ekaterina Leonova-Gariaeva to be published in Open Journal of Genetics the notion of synomy fusing these concepts is introduced. Homonymy is visible in mRNa-tRNA pairing and induced by the 1-to-many pairing of the third mRNA nucleotide with tRNA nucleotide. The homonymy in mRNA-AA (AA for amino-acid) pairing is also present albeit rare and might be explainable in terms of context dependence of this pairing.

The article summarizes much what is known about the theoretically poorly understood role of the third nucleotide of mRNA in the translation of mRNA to AAs. That many tRNAs correspond to same mRNA - synonymy - is not surprising since the number of tRNAs is smaller than that of mRNAs. There is however also homonymy present - the third nucleotide of mRNA can correspond to several tRNAs. If the AAs associated with homonymous tRNAs are same, the is no homonymy in mRNA-AA pairing. This is not quite always the case but the deviations are surprisingly small.

The article emphasizes the fact that the codons for the standard code can be divided to two classes. For 32 codons the first two letters fix AA completely. For the remaining 32 codons there is almost unbroken symmetry in that U and C *resp.* A and G code for the same AA. This symmetry is broken only for the three 4-columns of the code table containing Stop codon or Start codon coding also for met: this symmetry breaking is unavoidable given that the number of both start and Stop codons is odd. This symmetry breaking is minimal and applies only to A-G whereas T-C symmetry is exact. For the deviations of the code from the standard code the deviation as a rule breaks A-G or T-C symmetry or re-establishes it.

The notion of homonymy is extremely interesting from TGD point of view. TGD leads to two basic proposals predicting the numbers of DNA codons coding for given AA rather successfully.

1. The first proposal [L36] relies on TGD view about dark matter as $h_{eff}/h = n$ phases of ordinary matter [K50, ?, K85] [L67, L66] motivated by adelic physics extending physics to include also the correlates of cognition [L67] [L66]. The empirical motivation comes from several sources, in particular from the findings of Pollack [L20] discussed in [L20]. One can understand the formation of negatively charged regions - exclusion zones (EZs) - as being due to the transformation of part of protons to dark protons residing at magnetic flux tubes.

Dark genetic code would be realized in ters of dark proton sequences - to be denoted by DDNA, DmRNA, DtRNA, and DAA - would provide dark analogs of DNA, mRNA, tRNA, and AA. Biochemistry would emerge as a shadow of the much simpler dynamics of dark matter at flux tubes and genetic code would be induced by dark code code. The dark code would be sequence DDNA \rightarrow DmRNA \rightarrow DtRNA \rightarrow DAA of many-to-1 maps free of

homonymies.

2. Second model of genetic code emerged accidentally from a geometric model of music harmony [L16] (see http://tinyurl.com/yad4tqwl) involving icosahedral (12 vertices-12-note scale and 20 faces-number of AAs) and tetrahedral geometries leading to the proposal that DNA codons and possibly also AAs correspond to 3-chords defining the harmony and obtained as unions of 20+20+20 3-chords associated with icosahedral 20-chord harmonies with symmetries Z_6, Z_4, Z_2 plus tetrahedral 4-chord harmony. There is large number of these harmonies bringing in additional degrees of freedom.

Remark: This model has obviously analogies with the notion of wave genome introduced by Peter Gariaev [I74, I75, I113].

Since music both expresses and creates emotions the proposal is that these harmonies assigning additional hidden degrees of freedom to the magnetic bodies of DDNA, DRNA, etc... serve as correlates of emotions also at the molecular level. This emotional context could also give rise to context dependence of the code if several harmonies are realizable chemically. Taking seriously TGD inspired theory of consciousness [L69] and model of emotions [L84] (see http://tinyurl.com/ydhxen4g), one might say that the details of the code might depend slightly on the "emotional" state of DNA, RNA, and possibly other molecules.

In the sequel I will consider the following proposal for the various pairings of dark DNA and ordinary DNA visualizable as a 2×4 -matrix with two rows representing DDNA, DmRNA, DtRNA, DAA *resp.* DNA, mRNA, tRNA, AA.

- 1. The proposal is that genetic code at dark level extends to a sequence DDNA \rightarrow DmRNA \rightarrow DtRNA \rightarrow DAA of horizontal pairings analogous to projections is the fundamental one, and realized via dark photon triplet resonance expect for the coupling to DAA for which coupling is based on the sum $f_{XYZ} = f_1 + f_2 + f_3$ of 3-chord frequencies. One might perhaps say that AA sequence defines melody and mRNA sequence the accompaniment. The frequencies f_{XYZ} for codons coding same AA would be same modulo octave multiple. There is context dependence and homonymies already in DmRNA-DtRNA pairing and due the fact that DtRNA corresponds to a 2-harmony as sub-harmony of 3-harmony and can be chosen in 3 different way. Also this choice perhaps by state function reduction could correlate with emotional state.
- 2. There are also vertical mappings DDNA → DNA, DmRNA → mRNA, DtRNA → tRNA and DAA → AA. These pairings would induce the horizontal pairings DNA → mRNA → tRNA → AA at the chemical level. The homonymy at mRNA-tRNA level would have no effects on DNA-AA pairing.
- 3. Apart from mRNA-AA pairing all these pairings would be realized dynamically in terms of 3-chords (f_1, f_2, f_3) and giving rise to a resonant coupling between members of the pair connected by magnetic flux tubes to single dynamical unit carrying the dark photon triplets at the frequencies characterized by the 3-chord. The model for musical harmony [L16] leading also to a realization of genetic code suggests the existence of a large number of harmonies.

It is not however obvious whether these harmonies can be realized bio-chemically since the 3-chords must be resonance 3-chords for bio-molecules. For DNA-AA and mRNA-AA correspondence the constraints are the slightest ones since they couple to $f_{XYZ} = f_1 + f_2 + f_3$: AAs could have emerged in rather early stages of the prebiotic evolution. One cannot even exclude the possibility f_{XYZ} are same for different harmonies. Slight chemical modifications of DNA and mRNA and AA analogous to wobbling for tRNA might allow to realize the slightly different collections of 3-chords defining the harmonies.

4. The model leads to an explanation for the homonymy of mRNA \rightarrow tRNA pairing as being induced by the mRNA-tRNA homonymy realized already at dark level. The rather rare homonymies in DNA-AA pairing can be understood as accidental degeneracies. AA couples resonantly to the sum $f_{XYZ} = f_1 + f_2 + f_3$ of frequencies associated with codon XYZ, and one can have $f_{X_1Y_1Z_1} = f_{X_2Y_2Z_2}$ modulo octave multiple for two codons. DAA coded by DDNA codes for AA and tRNA serves only in the role of transferring DAA-AA pairs and attaching
them to DmRNA-mRNA pairs: the mRNA-AA pairing would be determined completely by dark molecules. It is actually advantageous to have tRNA homonymy since it can happen that the concentration of particular certain kind of tRNA is low.

- 5. What distinguishes between DNA and RNA and between codons and anti-codons is not obvious in the harmonic model. The most plausible identification for the map mapping codons to anti-codons is reflection symmetry of the icosahedron permuting opposite faces. An internal reflection changing the orientation of the scale could map DNA to RNA: this makes sense if the chords can be regarded as arpeggios.
- 6. The vision of biological evolution as chemical evolution in which dark variants of genetic code gradually find biological representations suggests a concrete model for RNA era. At that era AAs would have catalyzed mRNA replication possibly as non-faithful process. This era might have preceded tRNA era with mRNA replaced with tRNA analog corresponding to the fusion of two 20-chord representations. The era before this could have been era with single 20-chord representation and corresponding tRNAs and amino-acids.

7.2 Some background

In the following I will discuss briefly the basic facts about genetic code at Wikipedia level with emphasis on the poorly understood aspects of the code.

7.2.1 Variations of the genetic code

There exists also as many as 31 genetic codes (see http://tinyurl.com/ydeeyhjl) and an interesting question is whether this relates to the context dependence. Mitochondrial codes differs from the nuclear code and there are several of them. The codes for viruses, prokaryotes, mitochondria and chloroplasts deviate from the standard code. As a rule, the non-standard codes break U-C or A-G symmetries for the third code letter. Some examples are in order (see http://tinyurl.com/puw82x8).

- 1. UUU can code Leu instead of Phe and CUG can code Ser rather than Leu. In bacteria the GUG and UUG coding for Val and Leu normally can serve as Start codons.
- 2. UGA can code to Trp rather than Stop: in this case the broken symmetry is restored since also UGG codes for Trp.
- 3. There is variation even in human mitochondrial code (see http://tinyurl.com/puw82x8). In 2016, researchers studying the translation of malate dehydrogenase found that in about 4 per cent of the mRNAs encoding this enzyme the UAG Stop codon is naturally used to encode the AAs Trp and Arg. This phenomenon is known as Stop codon readthrough (see https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5133446/).
- 4. There is also a variant of genetic code in which there are 21st and 22nd AAs Sec and Pyl coded by Stop codons. UGA can code for Sec and Stop in the same organism. UAG can code for Pyl instead of Stop and introduces additional breaking of A-G symmetry for the third letter (UAA to Stop and UAG to Pyl).

7.2.2 Wobble base pairing

Wobble base pairing (see http://tinyurl.com/y73se8vs) emerges from the observation that the number of tRNAs pairing with mRNAs is smaller than 45 and considerably smaller than that of mRNAs. The needed minimum number of tRNAs is 32. Therefore the RNA-tRNA pairing cannot be 1-1 and some mRNA codons must correspond to several tRNA codons.

Remark: One could ask whether mRNAs code for tRNAs just like DNAs code for AAs. Homonymy for mRNA-tRNA pairing implies that the pairing can be many-to-1 only in given context.

- 1. According to the standard code, the first two bases of mRNA codon corresponds to two last bases of tRNA anti-codon and obey standard code. Wobble base pairing hypothesis applies to the pairing of the 3rd mRNA base to the 1st base in tRNA anticodon. At the level of chemistry the hypothesis is that the position of the first tRNA anticodon base pairing with the third mRNA base is variable and allows it to pair with several bases appearing as 3rd base in mRNA. This homonymy would be due to "wobbling" of the position of the first tRNA anticodon.
- 2. In the original model for wobble base pairing tRNA bases contain besides standard A, C, G, U also inosine I as a modification of G obtained by dropping NH₂ from the 6-cycle of G. It has turned out that there are actually variants of C and 5 variants of U (see http://tinyurl.com/y73se8vs). The large amount of homonymy for tRNAs forces to ask whether chemistry alone really dictates the genetic code.
- 3. The first tRNA letter is assumed to be spatially wobbling so that the association of tRNA with RNA is not unique and mRNA-tRNA pairing involves both synonymy and homonymy as the two tables for the pairing of the 1st 5' anticodon base of tRNA and 3rd 3' codon base of mRNA show. In the second column bold letters for mRN bases allow to read the standard pairing with tRNA codons in the first column and non-bold letters allow to deduce the non-standard behavior.
- 4. The first table (see http://tinyurl.com/y73se8vs) represents the original Watson-Crick proposal.
 - (a) The pairings of the 3rd letter of mRNA codon to the 1st letter of tRNA anti-codon are following.
 - $\bullet \ U \to G.$
 - $G \rightarrow U$
 - $\{A, C \text{ or } U\} \rightarrow I.$

The 2nd and 3rd tRNA letters A and C are paired with the 1st and 2nd mRNA letters in the canonical manner. There are only 3 tRNA letters, which implies that the number of tRNAs is smaller than maximal.

- (b) There is single 1-to-many pairing: $U \rightarrow \{G, I\}$ giving rise to 2-fold homonymy.
- 5. Revised pairing rules (see http://tinyurl.com/y73se8vs) are more complex since the number of tRNA bases is larger (U has 5 variants and C has 2 variants). All mRNA letters have 1-to-many pairing. Even if one counts the variants of U as single U there is 4-fold homonymy for U and homonymies for other codons. For A one has 9-fold homonymy.

These variations do not induce variation in DNA \rightarrow AA pairing if the AA associated with the homonyms of tRNA are identical. This seems to be the case almost always since the variation of the genetic code is surprisingly small. This raises the question whether there is some mechanism eliminating to high degree the expected effects of homonymy in mRNA \rightarrow tRNA pairing.

7.3 Two TGD based realizations of genetic code

During years I have considered several visions about genetic code. Two of them have allowed to build concrete contacts with the empirical reality. They are realized in terms of dark protons sequences [L36] and in terms of 3-chords of bio-harmony [L16].

7.3.1 Dark realization of genetic code

The first TGD view about this is based on the dark realization of the genetic code [L36] (see http://tinyurl.com/jgfjlbe). This relies on general vision that dark matter and magnetic flux tubes - magnetic body (MB) - controls the biochemistry and that biochemical realization need not be complete.

- TGD proposal is that dark proton sequences dark nuclei at magnetic flux tubes parallel to DNA strands provide the fundamental realization of the genetic code. Dark proton triplets would represent the analogs of DNA, mRNA, tRNA, and AAs. There would be 64 DDNAs, 64 DmRNAs, 40 DtRNAs and 20 DAAs. Dark codon cannot be separated to a product of letters but is an entangled state of 3 dark protons. There is a linguistic analogy: in primitive languages entire words are holistic basic units having no decomposition to letters.
- 2. DDNA, dmRNA, dtRNA, and DAA would control their biochemical variants and would be associated flux tubes carrying dark proton sequences. Dark code would dictate what happens at the chemical level. Chemistry would be a shadow of dark dynamics. Transcription and translation would take place at dark level.

One can argue that this assumption is too strong. It requires that also the Stop codon codes for DAA and this in turn requires at the level of chemistry to an analog of tRNA attaching to the Stop codon. For standard realization of the genetic code there are indeed 2 release factors RF1, RF2 which are proteins not involving RNA (see http://tinyurl.com/ydcgnlb3) attaching to Stop codons and stopping the translation. RF1 recognizes UAA and UAG. RF2 recognizes UAA and UGA.

There is also release factor RF3 binding to GTP (not appearing in RNA) and leading to a dissociation of RF1/RF2 after peptide release. Therefore RF3 does not play a role of tRNA. Note that both release factors recognize UAA so that the map from RNA codon to release factor is 1-to-2.

The 1-to-many character of mRNA-AA association requires hidden degrees of freedom for DDNA affecting the genetic code by changing DAA \rightarrow ordinary AA pairingat the level of chemistry.

3. If there is **no** homonymy at the dark level, one would have the following picture to start with.

Remark: One could of course ask whether the dark variants of the 3 codes unique - are there several dialects possible already at this level. The degeneracies of dark codons coding for dark codon at lower levels down the ladder DNA-mRNA-tRNAA-As are unique but how many codes satisfying this condition are possible? In the sequence dark code is however assumed to be universal.

- (a) Dark genetic code decomposes to a sequence of three many-to-one codes without context dependence/homonymy: DDNA \rightarrow DmRNA, which is 1-to-1, DmRNA \rightarrow DtRNA, which is 64-to-40 and DtRNA \rightarrow AA, which is 40 \rightarrow 20.
- (b) Chemical representation of dark variants of biomolecules is induced by the dark-chemical pairing, which can be context dependent to some degree. This in turn would induce context dependence of mRNA-tRNA pairing and possibly tRNAA-A pairing and as a consequence also that of mRNAA-A pairing. It is important to notice that the DX-X pairing involves transformation of dark photons to ordinary photons. The proposal is that the ordinary photons are bio-photons with much higher frequencies. The transition reducing the value of $h_{eff}/h = n$ would allow energy preserving transformation of extremely low frequency photons with large n and to bio-photons inducing molecular transitions.

Remark: mRNA-AA correspondence is basically induced by DAA \rightarrow AA correspondence.

(c) One could say that there are several dialects each free of homonymies in their own context. Even the genes or the two strands of DNA might speak different dialects. What could be the quantum physics behind these dialects? At which level one can find the contexts causing the dialects? In TGD framework magnetic body (MB) carrying dark matter suggest itself.

One can ask whether DDNA and DRNA, and maybe DtRNA and DAA could have a context defined by internal degrees of freedom, which varies in the situation when same DNA/RNA codes for 2 different AAs or AA and stopping sign. Magnetic body (MB) would naturally give rise to these new integral degrees of freedom.

7.3.2 The notion of magnetic body carrying dark matter and resonance as a mechanism of pairing

Pairing is the basic mechanism of molecular biology appearing in DNA replication, translation, and transcription. Pairing could be based on resonance coupling by dark photons propagating along magnetic flux tubes connecting the pairing systems.

The pairing between DDNA and DmRNA and DDNA and ordinary DNA would rely on resonance. More generally both dark and ordinary variants of the basic biomolecules would be characterized by collections of frequencies and if the frequencies are same the objects pair with each other. The 3-letter structure of the genetic codon suggests that resonance coupling occurs simultaneously for 3 frequencies defining the 3-chord. The pairing objects able to pair must be characterized by same the 3-chord.

- DDNA, mRNA, tRNA, and AAs would pair horizontally. These horizontal pairings together with vertical pairings of dark molecules to their ordinary counterparts (DDNA →DNA, Dm-RNA → mRNA- DtRNA → tRNA, DAA → AA would induce the horizontal pairings of DNA, mRNA, tRNA, and AAs.
- 2. All these pairings would rely on resonant coupling and the structure of codons suggests that 3-chords of frequencies are involved.
- 3. The first idea was that there is no context dependence at the level of horizontal pairings. It turned out that there are naturally 3 different DmRNA-DtRNA pairings for a given harmony for mRNA. This induces context dependence at the level of chemistry and would due to variation of the collection of 3-chords characterizing DtRNA.

7.3.3 The geometric model for music harmony and genetic code

For some years ago I developed a model of music harmony [L16] (see http://tinyurl.com/ yad4tqwl), which should define map of dark codons to 3-chords represented as dark photon triplets and defining allowed 3-chords of music harmony (music of light and perhaps also of sound). The Appendix provides the tables describing the details of the harmonies.

1. The model of music harmony is separate from the model of genetic code based on dark proton triplets and one of the challenges has been to demonstrate that they are equivalent. The model relies on the geometries of icosahedron and tetrahedron and representation of 12-note scale as so called Hamiltonian cycle at icosahedron going through all 12 vertices of icosahedron. The 20 faces correspond to allowed 3-chords for harmony defined by given Hamiltonian cycle. This brings in mind 20 AAs.

Single step of Hamiltonian cycle connecting vertices of a face of icosahedron (triangle) is assume to correspond to a scaling of the frequency by factor 3/2. This leads to a problem since 12 scalings of this kind does not quite given 7 octaves which reduced octave equivalence to the basic octave would give 12-note scale. The solution is to add single notice slightly differing from 7 octaves and represented as vertex P of a tetrahedron glued to icosahedron along face. The Hamilton cycles are deformed so that they begin and end from this vertex. This also gives the missing 4 DNA codons realized as 3-chords and also defines unique ground note for the scales.

2. It turns out that has three basic types of harmonies depending on whether the symmetries of icosahedron leaving the shape of the Hamiltonian cycle is Z_6 , Z_4 or Z_2 . For Z_2 there are two options: $Z_{2,rot}$ is generated by rotation of π and $Z_{2,refl}$ by reflection with respect to a median of equilateral triangle.

Combining together one harmony from each type one obtains union of 3 harmonies and if there are no common chords between the harmonies, one has 20+20+20 3-chords and a strong resemblance with the code table. To given AA one assigns the orbit of given face under icosahedral isometries so that codons correspond to the points of the orbit and orbit to the corresponding AA. 4 chords are however missing from 64. These one obtains by adding tetrahedron. One can glue it to icosahedron along chosen face or keep is disjoint. The model predicts a highly unique and realistic model for numbers of DNA codons coding for a given AA. The model in its original form predicts two codes and also explains the fact that there are two additional AAs Pyl and Sec that appear as end-products.

3. The model in its original form predicts 256 different harmonies with 64 3-chords defining the harmony. DNA codon sequences would be analogous to sequences of chords, pieces of music. Same applies to mRNA. Since music expresses emotions and produces them, the proposal is that these harmonies correspond to different molecular emotional states. The fundamental realization could be in terms of dark photon triplets replacing phonon triplets for ordinary music. Geometrically the two codes can be described as attachment of tetrahedron to icosahedron along face or as union of the two. Icosahedron corresponds to 60 DNAs and tetrahedron to 4 DNAs.

During writing of this article I learned that the number of harmonies could be different, probably larger. There is however the question of the chemical realizability of the harmony: it is not at all clear whether there exist biomolecules to which the 3-chords of several harmonies could couple resonantly.

4. As I developed the model of bio-harmony [L16] (see http://tinyurl.com/yad4tqwl) it did not occur to me that also the tRNA part of the dark code should have counterpart in the icosahedral model. AAs correspond to single 20-codon code, DNA and RNA to union of 3 20-codon codes with symmetries Z_6 , Z_4 or Z_2 : here Z_2 would correspond to $Z_{2,rot}$ or $Z_{2,refl}$ and this would give to two two different codes.

Could tRNA correspond to a union of 2 20-codon codes? Combining only 2 20-codon codes with 40 codons and tetrahedral code with 4 codons would give maximally 44-letter code and the upper bound for tRNAs is according to Wikipedia 45! Dark proton model predicts 40 DtRNAs suggesting that only the 40 isosahedral codons contribute to DtRNA code. The additional tRNAs could result from homonymy. The code sequences could be seen as a hierarchical sequence $3 \rightarrow 2 \rightarrow 1$ in this framework.

An important implication is that there are many realizations of DtRNA and tRNA harmony: (Z_6, Z_4) , (Z_6, Z_2) , (Z_4, Z_2) and Z_2 could be either $Z_{2,rot}$ or $Z_{2,refl}$. This could explain the homonymy of mRNA-tRNA pairing via difference in the chords in turn affecting biochemical counterparts. Note however that the chords for tRNA must be a subset of chords for mRNA so that RNA harmony determines tRNA harmony apart from the three choices (Z_6, Z_4) , (Z_6, Z_2) or (Z_4, Z_2) giving rise to 3 different contexts. If DAAs code by 3-chords the AAs then this choice does not affect AAs.

What conditions pairings pose on the frequency triplets?

The realization of DDNA-DtRNA and DDNA-DAA pairings in terms of frequencies must involve a loss of information since the correspondence is many-to-one.

- 1. For DNA-mRNA pairing information is not lost and the pairing must be of form $(f_1, f_2, f_3) \rightarrow (f_1, f_2, f_3)$. Note that the frequencies cannot be associated with the letters. It is however possible to consider the assignment of (f_1, f_2) to the first letter pair XY as a whole and f_3 to the third letter Z.
- 2. For DDNA-DAA and DmRNA-DAA pairing the natural hypothesis is $(f_1, f_2, f_3) \rightarrow f_1 + f_2 + f_3$. AA couples to the sum of the frequencies of the triplet. The simplest possibility is that the $f_1 + f_2 + f_3$ is same for all codons codin for given AA. One might say that AA sequence defines melody and mRNA sequence the accompaniment. If the sums for codons coding given AA are different they must couple resonantly to it. If there are several harmonies the sum must same for all realizable 3-harmonies or all chords of 3-chord harmonies coding for same AA couple to it resonantly. Since one has linear 1-D structures one might ask whether frequency differences coming as multiples of lattice frequencies are allowed. Second natural possibility is octave equivalence. mRNA-AA pairing would take place directly rather than with the mediation of of tRNA.

3. In the case of DmRNA-DtRNA pairing one one does not lose so much information since the number of dark DNAs is 40 (as also the 3-chords if tetrahedron does not contribute). One must remember that tRNAs are pairs of RNA like codons - call them RNA_t, and AAs. Therefore there pairing involves also the pairing mRNA-AA give by $(f_1, f_2, f_3) \rightarrow f_1 + f_2 + f_3$ and guaranteeing that the code is realized by this pairing alone irrespective of mRNA-RNA_t pairing. At chemical level the first to mRNA codons pair with tRNA anticodons according to the standard rules. Could RNA_t have completely passive role in carrying the AA? This cannot be the case since the last two letters of RNA_t couple in standard manner to the first two letters of mRNA.

Remark: tRNA is analogous to melody + accompaniment using one of the 3 possible 2-harmonies for a given 3-harmony.

Suppose that mRNA-RNA_t pairing corresponds to 3 possible choices of 2-harmonies as subharmonies of 3-harmony. This would suggest these different sub-harmonies define maps $(f_1, f_2, f_3) \rightarrow (f_1, f_2, f_3)$ such that RNA_t pairs only with two sub-harmonies. For each choice RNA_t would correspond effectively to 40 sub-codons of the entire code (forgetting the tetrahedral part giving 4 additional codons). The three different realizations of the projection would give rise to the homonymy. Also the AA-trNA coupling would come out correctly.

DAAs would be different in the sense that they couple only to the sum of the frequencies. This is in accordance with bio-harmony in which AAs correspond to orbits of 3-chords for DNA under isometries rather than single 20-chord harmony. The coupling to the sum of frequencies is in accordance with the quantal interpretation as 3-dark-photon state whose energy is $E = h_{eff}(f_1 + f_2 + f_3)$ and couples to AA chemically via the transition to ordinary photons with the same energy.

This leaves some questions.

- 1. Could one consider the possibility that the chords of one of the 20-chord harmonies corresponds to AAs? There would be 3 basic types of AAs. This does not look plausible and the association of AAs with the orbits of 20-note chords is more natural and fits nicely with $f = f_{XYZ}$ picture.
- 2. It would be nice to assign notes to the individual letters of codons. This is not possible since codons with 2 or 3 identical letters would reduce to 2-chords or 1-chords. It is also impossible to assign frequencies with letters at dark level since letter decomposition does not exist. Thus the 3-chord has resonant interaction with the entire codon.
- 3. The symmetries of the genetic code however suggest that it might make sense to treat the first two letters XY of the codon as a single unit and the third letter as separate single unit. Could one assign to XY a 2-chord not reducible to frequencies for the letters X and Y, and to letter Z its own frequency. The frequencies of A, G, T, C as third letter must be different. Four 32 codons of standard code the AA would not be sensitive to the frequency of Z: this is possible if these frequencies are resonance frequencies of the same AA. For the remaining 32 codons the AA would not distinguish between frequencies of T and C *resp.* A and G so that the two frequencies would be both resonance frequencies of the corresponding AA.

Probabilistic estimates for single 20-chord harmony

One can make first some naïve probabilistic estimates about single 20-chord harmony.

- 1. Given 20-chord harmony makes $20/220 = 1/11 \simeq 9$ per cent about al possible 3-chords. Three 20 chord harmonies would make $3 \times 9 = 27$ per cent about all possible 3-chords if there are no common chords so that the optimistic expectation might make sense. Of course, one cannot exclude the possibility that there are also triplets of 20-codon codes which gives smaller number of codons.
- 2. The total number of chords with different notes is $12 \times 11 \times /3! = 220$. Bio-harmony has 64 chords corresponding to faces of icosahedron: this is about 64/220 making 29 per cent of all possible 3-chords with different notes. Given bio-harmony thus throws out roughly 2/3 of

all possible codons. This should be easy to test. For instance, does given gene correspond to a fixed bioharmony? Or does even entire genome do so. If bio-harmony is realized for non-nuclear genomes, it must satisfy rather strong constraints.

3. Given 20-chord harmony corresponds to 12 edges. Each edge is shared by two adjacent triangles. If all 20 triangles would contain just single face, there would be 24 triangles altogether. Therefore there must be triangles containing two subsequent edges of the cycle. Each triangle of this kind reduces the number of 24 neighbours by 2 units. Hence it seems that one must have at least 2 triangles with 2 edges at the cycle (two quints in the 3-chord).

If there are more than 2 triangles of this kind, there must be triangles having no edges along the path. Each vertex of icosahedron is shared by 5 triangles and there are 5 edges starting from it.

4. The notion of Hamilton cycle generalizes to any graph and magnetic flux tube networks define such graphs as tensor networks. Why only icosahedron? Could one consider the possibility that any tensor network is characterized by harmonies characterize by Hamiltonian cycles and that one could assign some kind of codes with the combinations of these cycles? In the general case symmetries would be absent so that the notion of code in the proposed sense would fail: one could not identified codons as points at orbits of symmetry group. Rather, one can imagine that the notion of code could be defined quite generally in terms of orbits as AAs and points at them as DNAs coding them. For regular polygons in any dimension the symmetries are present and one could define the notion of code and also fuse the codes.

For arbitrary tensor network the faces need not be symmetry related and one can also have faces that can be interpreted as higher-dimensional polytopes.

One can also ask whether the icosahedron is realized physically. Icosahedral geometry is indeed very common in biology. Could the fusion of icosahedral and tetrahedral geometries have some concrete realization at molecular level?

Is the maximal number of codons for the fusion of 3 20-codon codes possible?

It has not earlier occurred to me to wonder whether the chords associated with the 3-different icosahedral harmonies giving 20 codons each correspond to 20+20+20=60 different chords as assumed. Could there be common 3-chords? This question could be answered by studying the Hamiltonian cycles at icosahedron.

Remark: Perhaps more important constraint than absence of common chords is the chemical realizability of the codes. If same mRNAs and DNAs realized different bio-harmonies then they must be able to respond resonantly to several 3-chords.

One can make naïve probability estimates for a pair of codes to allow the maximal number of 60 codons. It seems natural to assume that the isometries of icosahedron (or their subgroup) can be applied separately and only the isometries acting on both in similar manner are symmetries. The situation would be the same as in the case of many-particle system: only the translations acting on all particles simultaneously remain symmetries and relative translations cease to be symmetries.

With this assumption the icosahedral group gives a large number of code pairs. For the fusion of 3 20-codon codes giving DNA/RNA the number is even higher. By choosing suitably the relative isometries it might be possible to obtain the maximal number of 60 different codons for the icosahedral genetic code. On the other hand, by a suitably choice of relative isometries one might have undesired common 3-chords. In any case, the earlier estimate 256 for the number of bio-harmonies [L16] suggested to correlate with "emotional" states of the basic biomolecules is expected to change.

Before going to estimates one must consider some delicacies related to the notion of 12-note scale as Hamiltonian cycle.

1. One can regard the cycles as purely geometric objects without orientation or assign to them orientation. For two different orientations the scales would run in opposite directions as scalings by 3/2 along single edge of the cycle. If two codes have common edge, the scaling must be same along it. If the orientation of the second cycle is changed, the common edge ceases to be common.

2. The basic note of the 12-note scale at cycle can be chosen arbitrarily: this corresponds to the choice of the key in music (one could of course argue that the key does not make sense in 12-note scale if one has tempered scale with notes comes as powers of $2^{1/2}$ scaling of ground note rather than Pythagorean scale with rational ratios of notes).

The fusion of tetrahedron to icosahedron selects one particular triangular face and brings in one additional vertex outside the icosahedron, call it P. It would be natural to assign the ground note as P. The isometries not affecting P would correspond to those of icosahedron leaving the common face invariant and isometries of tetrahedron leaving P un-affected and continuable to icosahedral isometries. One would have subgroup of icosahedral group as allowed isometries acting on the cycles to be fused.

- 3. If one assigns note sequences to the cycle by quint rule, cycles C_1 and C_2 can have common triangle in geometric sense but if the distances of the vertices A, B, C of the triangles from P measured as the number of edges of cycle portion connecting them are not same along C_1 and C_2 , the triangles correspond to different chords and are thus orthogonal in the proposed description as many-fermion states.
- 4. To sum up, the states associated with triangles would be characterized by the position of triangle (20 values), by the notes of the triangle characterized by the distances from P, and the number 0, 1, 2 of the edges belonging to the cycle and should make easier to find ortogonal basis.

Again one can make probabilistic estimates: cycles are treated as purely geometric entities without orientation and without assignment of notes to the triangles.

- 1. Given cycles C_1 and C_2 what is the probability that they have at least one common edge as purely geometric entities without the sequence of notes? There are 30 edges so that given edge is shared with probability 1/30. If the edges of cycles were chosen randomly (certainly not true), the probability of having a common edge for two cycles would be P(1) = 12/30. The assumption of note sequence reduces this probability dramatically.
- 2. By the above estimate each cycle contains at least two triangles with 2 edges at the cycle with minimal angle between them. One can call these these edge pairs V-corners. Assume that for cycle C_1 one has V-corner ABC at vertex A, call it $V_{1,A}$. What is the probability that one one of the V-corners of C_2 is located at A co-incides with ABC. The probability of V-corner of C_2 to locate at A is 1/12 and the probability that the edge of C_2 from B is BC is is 1/4 so that the probability of having common V-corner is 1/48. If C_2 contains n V-edges the probability is naïvely n/48.

This estimate takes into account only geometry. The situation changes if one assumes that the cycles are oriented. In this case one can have common V-corner if the local orientations of C_1 and C_2 are opposite at the V-corner. If one assumes that the external vertex P of the tetrahedron defines the ground note then the number of edges connecting P to A defining distance d(P, A) must be same for C_1 and C_2 .

3. Given C_1 and C_2 (and vertices A with same distance d(P, A)) it might be possible to perform suitable isometry for C_2 that there is common V-corner. Therefore not all possible combinations of three code types allowing relative isometries need not maximal number of 3-chords.

Remark: An interesting question is whether these can be allowed meaning that some codons are missing in the chemical realization of the dark codons in terms of ordinary DNA codons. Also the 1-1 pairing between dark DNA and and dark RNA would not be 1-1 if mediated by 3-chord resonance and one would have homonymy. This suggests that only codes without common chords can be allowed.

4. What about chords having 1 edge at cycle for two cycles C_1 and C_2 ? Let the edge be AB. As found, the naïve probability for this is P(1) = 12/30. Both cycles must go through the third vertex C of the triangular face. The subsequent notes along cycle differ by a quint that is scaling of the frequency by factor 3/2. Notes are same if the numbers of the needed quints are same for C_1 and C_2 For C_1 the number $n_B > 1$ of quints is known. In the approximation that possible portions of C_1 represent *n*-step non-self-intersecting random walks from *B* to *C*, one must estimate the number of all non-self-intersecting *n*-step-paths from *B* to *C* and find what is the number of the paths leading to *C*. One can go from A to C with n_A steps and similar estimate applies.

5. The third possibility is that the one has 3 common vertices A, B, C forming a triangular face such that neither cycle contains any of its edges.

The cautious conclusion is that it is plausible that one can find 3 cycles having no common chords if one allows relative rotations of the cycles and that this condition is necessary for realizing the absence of homonymies at dark level. The automatic orthogonality of the Hamiltonian cycles cannot be excluded but would allow also codes with codons containing more than 3 letters so that one could have kind of super-DNA. Whether they can be realized chemically depends on whether there are biomolecules resonating with the the n frequency triplets involved. Octave equivalence for frequencies might give hopes about chemical realization of several harmonies. Therefore the evolution might be seen as gradual emergence of molecules able to pair with DDNA and one can even imagine artificial evolution by tailoring the frequencies involved (maybe cyclotron frequencies).

Could harmonies form a Hilbert space

The condition that there are no common 3-chords brings in mind orthogonality and suggests that harmonies as Hamiltonian cycles could be defined as quantum states in suitable Hilbert space.

- 1. One could define inner product for Hamiltonian cycles as the number of common chords suitably normalized so that the norm of cycle of cycle equals to one. The number of common chords in the norm squared is 20 in the icosahedral case and 24 for the fusion of icosahedral and tetrahedral codes. Could Hilbert space picture for cycles make sense? The fusion of 2 (tRNA) or 3 (DNA) codes does not however naturally correspond to quantum superposition but rather tensor product.
- 2. Could one think that each cycle correspond to a 20-fermion product state with 3-chord characterizing the state of given triangle created by fermionic oscillator operator so that product P of 20 fermionic oscillators assignable to the triangles would create the harmony? The fusion of cycles C_1 and C_2 would be obtained by product P_1P_2 . By fermionic statistics the resut would be zero if there are common cycles.

These considerations are purely formal and have no implications for what follows.

7.3.4 How the symmetries of the model of harmony could relate to those of the genetic code?

Genetic code has surprisingly strong symmetries. I have discussed a possible interpretation of these symmetries using analogies with particle physics and considered also a mechanism explaining their emergence earlier [K7, ?]. The proposal was that 3-letter code emerged as a fusion of 2-letter code with 16 codons and 1-letter coded with 4 codons. In the recent framework, a more natural option is that the third codon of 3-letter code was originally passive and became active via symmetry breaking distinguishing first between UC and AG pairs and later between U and C *resp.* A and G. Note that for the standard code the breaking is minimal and caused by odd number of Start and Stop codons.

- 1. For vertebrate code one half of codons has very high symmetry in the sense that the two first letters dictate the AA for 32 cases. Exception is UUU, which codes for Phe or Leu for some modifications of the standard code. UUU \rightarrow Leu means breaking of maximal symmetry.
- 2. There is also a second symmetry, which I have referred to as isospin symmetry. It is only slightly broken. For general codons XYU and XYC code for same AA as also XYA and ad XYG. For the standard code this symmetry is broken only in columns containing initiation codon or stop. The Start codon AUG codes also for met. UGA and UGG code for Stop and

Trp. For the remaining codons one has slightly broken "isospin symmetry". The breaking of isospin symmetry is minimal for vertebrate code. The modifications of the code tend to break the isospin symmetry and even the maximal symmetry of 32 codons. This must be important.

If the model of genetic code based on music harmony [L16] is correct, the symmetries for the model of music harmony must relate to those of genetic code.

1. How the symmetries of the genetic code relate to the symmetries of icosahedron (60-element group) and tetrahedron (permutation group S_4 with 24 elements) in the model of bioharmony? Icosahedral symmetry group has 60 elements and has sub-groups $Z_2, Z_4, Z_5, Z_6 = Z_2Z_3$. Note that there are two Z_2 :s having rotation by π and reflection as generators.

The gluing of tetrahedron to icosahedral along single face reduces its group of symmetries to S_3 leaving the point P not belonging to icosahedron invariant. S_3 has as subgroups reflection group $Z_{2,refl}$ and Z_4 consisting of rotations.

2. What is the counterpart for maximal symmetry in icosahedral and tetrahedral groups? Do the 3-chords for codon XYZ decompose to two-chord characterizing XY and a note characteriing Z= A,U,C,G, which can depend on XY. The symmetry relating UC pair and AC pair could correspond to $Z_{2,refl}$ reflection symmetry, which is shared by icosahedral and tetrahedral groups. For 32 icosahedral codons the action of $Z_{2,refl} \times Z_{2,rot}$ would be trivial so that AA would not depend on the third letter at all. For most of the remaining codons the action of the symmetry group on icosahedral codons would reduce to $Z_{2,rot}$ permuting the third letters U and C resp. A and G. At the level of frequencies the sums of frequencies for codons coding for the same AA sould be same modulo octave equivalence.

The addition of tetrahedron brings in 4 tetrahedral codons with one of them shared with icosahedron. Icosahedral $Z_{2,rot}$ does not make sense for these codons. Intriguingly, there are 4 codons in vertebrate code which break isospin symmetry AUA and AUG coding for I and Met/start and UGA and UGG coding for Stop and Trp. If these codons correspond to the tetrahedral codons which cannot have $Z_{2,rot}$ as isospin symmetry, the breaking of $Z_{2,rot}$ would follow from the breaking of symmetry induced by the attachment of tetrahedron to icosahedron.

7.3.5 What distinguishes between codons and anti-codons and between DNA and RNA?

The icosahedral model should provide answer to several questions not considered yet.

- 1. The model for the genetic code in terms of dark proton sequences both DNA and RNA are predicted. This should be the case also in the icosahedral model. The 3-chords for DNA and RNA should be the same but there should be some inherent distinction between the two realizations.
- 2. Besides the active DNA strand there is also the inactive DNA strand (no transcription to mRNA) consisting of anti-codons. What does anti-strand correspond in the representation consisting of 3-chords? The chords assignable to the anti-strand should exist but there should be some difference between chords and anti-chords. Why this strand is inactive? mRNA is produced only via the pairing of RNA codons with active DNA strand. Could RNA_t as part of tRNA and counterpart of anti-RNA be unable to form stable strands in the recent biological environment and could lonely RNA_t codons fail to exist stably so that the transcription of DNA anti-strand to RNA_t strands would be impossible.
- 3. What does anti-DNA anti-RNA and anti-tRNA mean at the level of dark proton sequences?

I have approached these problems from particle physics point of view by using analogies and they might be helpful in the attempts to answer these questions [?]. There are two mirror symmetries in the icosahedral harmony: 3-D reflection with respect to origin and change of the direction of the 12-note scale. Could these reflection symmetries help to understand the situation? 1. The symmetry mapping letters to antiletters $(T \leftrightarrow A, G \leftrightarrow C)$ is mirror symmetry like chargeparity symmetry CP of particle physics equivalent with time reversal T by CPT theorem. CP is mysteriously broken: we have matter but where is the antimatter?

The biological analogy with matter-antimatter asymmetry is that strand is active but antistrand is passive - no transcription to mRNA. This would be the case if anti-RNA does snot exist as stable sequences. This would also explain why RNA does not replicate and does not form stable double helices.

2. Codons and conjugate letters for DNA are related by the CP like transformation (T ↔ A, G ↔ C). There should exist an icosahedral symmetry realizing this symmetry. Icosahedron allows also 3-D reflection through the origin as a symmetry (see http://tinyurl.com/y8capjz7). It permutes the opposite faces of icosahedron and extends the icosahedral rotation group with 60 elements to a group with 120 elements. The extended symmetry should preserve the set of 3-chords: they should be identical for DNA codon and anticodon.

Harmony and anti-harmony for DNA would differ in that the attached tetrahedron would be at opposite face for the anti-codon representation since the reflection maps the tetrahedron to the opposite face. Could one see this as an analog of matter antimatter asymmetry? For double DNA strand anti-codons would correspond to icosahedron with tetrahedron attached to the opposite face. This symmetry should map the codons to their anticodons and there should be no fixed codon - this is indeed the case since there are no fixed faces.

Icosahedral reflection should however leave the chords invariant apart from transponation by some power of 3/2 in order to leave the harmony invariant: codons and anticodons would be in different key in order to resonate. Icosahedral reflection would be an additional symmetry of the Hamiltonian cycles. The tetrahedron attached to the opposite face in reflection would be shifted back in transponation.

mRNA should have icosahedral realization with same 3-chords as DNA. What distinguishes mRNA from DNA at icosahedral level?

Could only mRNA exists as stable sequences and anti-mRNA fails to exist in this manner? This would be analog of CP breaking and the codons RNA_t in tRNA would correspond to anti-RNA_t existing only as single codon attached to AA. Could also the 4 tetrahedral anticodons for RNA_t (anti-tRNA) fail to exist (this would give 40 tRNA codons as also dark proton model predicts). Otherwise one would have 44 RNA_t codons.

DNA and mRNA differ only in single aspect: the letter T is replaced with letter U. How the replacement of $U \rightarrow T$ (and the replacement of riboses with de-oxy-riboses) is visible in the icosahedral harmony if the set of chords remains the same - perhaps modulo transponation by some number of quints?

Could the order of notes along the Hamiltonian cycle distinguish between DNA and RNA? The chords would remain the same but the order of notes in the chord would change.

- 1. If the reversed scale proceeded downwards in quarts (quint backwards, say C-G to C-G), the 3-chords would be same for the scales and the two scales are identical. Could one imagine that 3-chords are "played" as arpeggios! The order of arpeggio (upwards downwards in scale) would be opposite for up-chord and down-chord. RNA_t would define down-chords for mRNA up-chords but they would not form stable sequences and 4 anti-chords might be even missing.
- 2. If it proceeds in quints, the chords for the harmonies would not be same in general (for instance C-G upwards quint is replaced with C-F downwards quint). The scalings $(3/2)^k$ are replaced by scalings $(3/2)^{12-k}$ and the cycle becomes mirror image retaining its shape so that it is still a cycle and since the shape is preserved the symmetries are preserved too. Chords are in reflected positions and related by the map $(k_1, k_2, k_3) \rightarrow (12 k_1, 12 k_2, 12 k_3)$. The chords are obviously different so that DNA and mRNA cannot differ in this manner.

The scale and its quint-reversed counterpart differ much like major and quint scales as one easily finds (consider only the upwards scale Cmajor scale CDEFG... in C major and the downwards Cminor scale $CB \flat A \flat G$...). They could therefore correspond to two different moods rather than mRNA-RNA.

3. TGD and TGD inspired theory of consciousness bringing observer part of physical system relies on zero energy ontology (ZEO). In ZEO the scale and its quint reversal could correspond to two different arrows of time for zero energy states. As self dies in state function reduction to the opposite boundary of causal diamond (CD), it is predicted to reincarnate with reversed arrow of time [L69]. Death is a sad event: could it be that the death of subself representing mental image is experienced by self as sad event and that in bio-harmony time reversal would change joy to sadness?

This relates in an interesting manner to the earlier speculations in TGD inspired view about pre-biotic life.

1. The proposal made in [?] is that during RNA era preceding DNA era RNA replicated and AAs associated with pre-tRNA served as catalyst and later stole the stage so that RNA replication became translation. The greatest betrayal in the history of life! At this moment also DNA had to emerge. Otherwise RNA and life would have disappeared.

Amusingly, also in cosmology CP symmetry was broken, when antimatter and matter annihilated and what remained was matter (there was slight imbalance originally).

2. Could one think that before the breaking of the analog of CP symmetry the tetrahedral part of the code was not present and the number of mRNA codons was 60. mRNA and antimRNA realized as mRNA_t had common chords related by icosahedral reflection symmetry. Also the 1st letter of mRNA_t was just like the other letters.

In the transition A and C as 1st letters disappeared and were replaced with G,U and I (in Watson-Crick scenario). The 4 tetrahedral codons containing Start and Stop codons emerged in the transition.

In the symmetry breaking DNA with opposite direction of the scale (the reversed scale proceeded downwards as quarts rather than quints) and arpeggios emerged. Perhaps this required the replacement of U with T and perhaps also of riboses with de-oxy-riboses.

- 3. Did the 4 additional tetrahedral codons responsible for the breaking of the analog of isospin symmetry (A \leftrightarrow G and T \leftrightarrow C) associated with the stop and Start codons emerge in this event so that 60-codon realization of the code was replaced with 64 codon realization. If Start and Stop emerged in this event the entire mRNA strand replicated before it.
- 4. Was the letter mRNA letter U replaced with DNA letter T in this transition. Did this make possible the existence DNA as double strands stable in the presence of nuclear or cell membrane but not stable as single strand. Did the 4 additional tetrahedral codons responsible for the breaking of the analog of isospin symmetry (A \leftrightarrow G and T \leftrightarrow C) associated with the stop and Start codons emerge in this transition. Before the transition the entire mRNA strand would have been able to replicate. mRNA-AA pairing was present and AA would have catalysed the replication.
- 5. Was the homonymy present in mRNA replication before the transition. The updated scenerio for mRNA-tRNA correspondence allows the replication albeit not in 1-1 manner (see http://tinyurl.com/y73se8vs). Was the letter I present at that period: was it part of both mRNA and rNA_t or of only RNA_t giving therefore rise to a leakage?

If RNA era in the proposed sense was realized, what happened before it?

1. One imagine that before RNA era the RNA_t - not necessary identical with its recent form - as a realization of 2-harmony (or perhaps of all 3 different types of 2-harmonies) with 40 codons was realized and was able to replicate with AAs serving as catalysts attached to RNA_t .

Only the complementary RNA_t was able to appear as sequences: tetrahedral codons were absent. In the transition from 2-harmony to 3-harmony both DNA and full RNA emerged. Replication of RNA_t transformed to translation of AAs. This vision would be more in spirit with the idea about the gradual emergence of biological representations of the dark variants of biomolecules. 2. One could go even further and ask whether this period was preceded by a period during which pre-tRNA identifiable as single 20-codon representation choosable in 3 ways. Pre-tRNA \leftrightarrow AA correspondence would have been 1-1. AAs would have decomposed to three types corresponding to these 3 choices. For instance for the code with Z_6 symmetry only 4 AAs would have been present. For the details of harmonies see the Appendix of [L16] (see http://tinyurl.com/yad4tqwl).

7.4 Context dependence from TGD point of view

The original idea was that context dependence and homonymy are absent at the level of dark variants of various codons and AAs and would result from the pairing with chemical counterparts of dark codons. More precisely: the horizontal dark DX-DY pairings would be context independent and would not depend on emotional state whereas the vertical DX-X pairings are induced by DX-DY pairings and induce X-Y pairings. This is obviously something new from the point of biology as chemistry paradigm.

It however turned out that the context dependence appears very naturally at the dark level. DtRNA bio-harmony allows naturally 3 different representations as 2-harmonies realized as sub-harmonies of 3-harmony associated with DNA and mRNA. One would have 3 basic context already at this level.

One can imagine at least 3-sources of context dependence and expression of emotions by gene expression.

1. Several bio-harmonies are possible and DX and X would couple by different resonant 3-chords for each harmony. It is of course possible that very few of these bioharmonies - perhaps only one - are realized at the level of DNA and mRNA. This would explain the uniqueness of DNA and mRNA codons in biological sense.

If several bioharmonies are realized for DNA then both mRNA, RNA_t and AA must have resonance couplings to all these bioharmonies. For AA this is satisfied if $f_{XYZ} = f_1 + f_2 + f_3$ is same (perhaps modulo octave equivalence) for all harmonies involved or if AA has all all the frequencies f_{XYZ} as resonance frequencies. For mRNA $(f_1, f_2, f_3) \rightarrow (f_1, f_2, f_3)$ pairing would require even larger spectrum of resonant 3-chords at the level of chemistry. Hence it is quite possible that only single 3-harmony is realized for DDNA, DmRNA, and DAA. If several harmonies are present, the evolution would have gradually invented the biomolecules having the needed spectrum and would still be in progress.

- 2. The situation with DtRNA is different. The DmRNA-DtRNA pairings would involve 3 different unions of 2 20-chord harmonies. This choice implies context dependence already at dark DNA level and could be the fundamental reason for mRNA-tRNA homonymy. What is however important that the decomposing of tRNA to (RNA_t,AA) pairs guarantees automatically genetic code via $f_{XYZ} = f_1 + f_2 + f_3$ coupling. AA dictates the pairing unlike usually thought.
- 3. If the frequencies are cyclotron frequencies determined by the magnetic fields at flux tubes, the variation of magnetic field strength due to the variation of flux tube thickness changes the frequency scale. This could be also seen as emotional expression (in analogy with membrane potential in biology inducing variation of Josephson frequencies and varying the degree of alertness in neurons).

The gradual variation of magnetic fields strengths during evolution could explain the slight differences in the genetic code. Evolution would be clearly in question in the sense that the symmetries of the code are maximal for the nuclear code. It will be found that also this mechanism is needed in order to understand all deviations of the code.

7.4.1 Context dependence as "emotional expression" at molecular level?

Using the attribute "emotional" certainly raises eyebrows and I will drop even the quotation marks in the following. Reader can freely add them.

Basic guide lines

Consider first the basicguidelines.

- 1. One plausible possibility is that genetic code as DNA-AA pairing is unique in given context whatever it is physically but there exist what one might call dialects just like slight modifications of vertebrate genetic code. There is homonymy, which however disappears when context is taken into account: same mRNA can correspond to two AAs or AA and stop. The homonymy is associated with mRNA-tRNA pairing for the third mRNA letter which is many-to-one and 1-to-many. Which the actual choice depends on context as in ordinary language.
- 2. Wobble base pairing is the model explaining both the many-to-1 and 1-to-many pairings. An interesting finding is that for 32 codons the pairing does not depend on third letter at all. I have proposed long time ago a model in which 2-letter code emerged first and then fused with 1-letter code to give 3-letter code. A more plausible interpretation is as activation of the 3rd letter in 3-letter code. The wobble base pairing and homonymy would have emerged in this fusion of codes.
- 3. From the tables of Wikipedia at article (see http://tinyurl.com/y73se8vs) for standard code one can read when the pairing of the third letter is many-to-one and 1-to-many. If it is 1-to-many and unless the resulting tRNA anticodons correspond to the same AA, the outcome can be several AAs.

This does not lead to 1-to-many mRNA \rightarrow AA if the RNAs associated with tRNAs in mRNA \rightarrow tRNA pairing couple with the same AA. The pairing between mRNA and AAs is 1-to-many rather rarely and could be accidental. It seems that there is a principle taking care that the deviations from the standard code get minimized.

4. The homonymy for mRNA-AA pairings is very rare. This suggests that it is accidental and disappeared during the evolution.

The origin of mRNA-tRNA homonymy and mRNA-AA homonymy

mRNA-tRNA homonymy is clearly exceptional and the proposal that tRNA bio-harmony corresponds to a fusion of 2 20-chord codes together with the fact that there are 3 basic types of these codes could explain this.

1. Suppose that DtRNA harmony corresponds to a sub-harmony of full bio-harmony for DDNA and DRNA as a fusion of two sub-cycles from the union of 3 cycles defining DDNA and DRNA harmony. One can make this choice in 3 ways corresponding to the choices (Z_6, Z_4) , (Z_6, Z_2) and Z_4, Z_2 . These 3 basic choices would naturally explain the DtRNA-tRNA homonymy without the dependence on emotional state. This would not however explain the deviations from the standard code.

In the case DtRNA- tRNA pairing it is enough that tRNA couples resonantly only to the 3chord representatives associated with one 2-harmony appearing as sub-harmony of 3-harmony that is selected and defines the context. This obviously allows larger number of tRNAs satisfying the resonance conditions. This could relate to the homonymy.

The function of tRNA as an agent transferring DAA-AA pair and attaching it to DmRNAmRNA pair. Hence tRNA homonymy is desirable - it can happen that the concentration of particular certain kind of tRNA is low so that second kind of tRNA coupling to same mRNA can handle the job.

2. tRNA homonyms for the first anticodon of tRNA would reflect the emotional state of DDNA/mRNA. Why only the third? This might relate to the idea about fusion of 2-letter codes and 1-letter codes. For 2-letter code there would be no "emotional expression" and no context dependence. The emergence or perhaps better, the activation of additional letter at the level of chemical expression, would have brought in the chemical emotional expression.

Consider now mRNA-AA homonymy. This homonymy is rather rare and could be accidental.

- 1. If AA couples to the sum $f_{XYZ} = f_1 + f_2 + f_3$ of the frequencies characterizing the codon $X_1Y_1Z_1$, it can happen that one has $f_{X_1Y_1Z_1} = f_{X_2Y_2Z_2}$ modulo octave multiple so that besides codon $X_1Y_1Z_1$ also the wrong codon $X_2Y_2Z_2$ codes for the same AA. Of course, this condition might hold true only approximately. This could explain mRNA-AA homonymies as accidental.
- 2. There is however an objection against the proposal. If the frequencies f_{XYZ} are identical in octave equivalence for all codons coding for AA, the accidental degeneracy would suggests that the entire mRNA multiplet containing $X_2Y_2Z_2$ codes for AA. Typically however only one member of the mRA multiplet codes for wrong AA.

Should one give up the idea that the members of mRNA multiplet satisfy $f_{X_1Y_1Z_1} = f_{X_2Y_2Z_2}$. If so, AA would have the frequencies f_{XYZ} of mRNA multiplet as distinct resonance frequencies. For instance, could one think that the A-G and T-C breakings at the level of frequencies are present although they are not large enough to make themselves visible in the mRNA-AA correspondence (say for the mRNA 4-plets coding for same AA). This is the case if AA has all these frequencies as resonance frequencies. Also the number of octaves distinguishing between $X_1Y_1Z_1$ and $X_2Y_2Z_2$ matters somewhat. In this case the accidental resonance condition for wrong AA could be satisfied for single member of mRNA multiplet only.

A concrete objection against the model

One can try to understand the possible dependence of code on the emotional state by looking the numbers of 3-harmonies obtained as fusion of Z_6 , Z_4 and Z_2 symmetries. One can find explicit tables for the codes in the Appendix of [L16] (see http://tinyurl.com/yad4tqwl).

1. A crucially important thing to notice is that Z_6 harmony is unique. This harmony allows 3 6-plets for which 6 DNAs code for single AA. There is also one doublet. Therefore the codons associated 3 6-plets and doublet should always code the same AA unless the magnetic fields at flux tubes determining the cyclotron frequencies van vary. It is easy to verify that this prediction is correct for the nuclear code.

For non-nuclear codes the situation is different. There are 3 6-plets and they code for Leu, Ser, and Arg. These 6-plets should be stable under the modifications of the standard code. This rule is however broken in at least two cases:

- (a) For CUG coding for Ser instead of Leu. Ser is coded usually by UCG. Both DAA and AA couple to the sum $f_{XYZ} = f_1 + f_2 + f_3$ of the 3-chord frequencies. The simplest explanation already discussed is that DSer and DLeu have accidentally $f_{CUG} = f_{UCG}$ modulo octave multiple. T
- (b) UUG coding for Stop rather than Leu. Stop is coded usually by UGG. Accidental degeneracy would be the explanation also now. Stop identified as release factor FR1 or FR2 playing the role of AA and possibly having also dark AA counterpart would have $f_{UGG} = f_{UUG}$.
- 2. All deviations from the standard code could be determined solely by the accidental degeneracies for the frequencies f_{XYZ} associated with two codons coding for different AAs or AA and stop. For standard code they would have been eliminated almost completely by evolution: as noticed earlier, even in human mitochondrial code there is this kind of homonymy.
- 3. For 3-chords with Z_4 as isometry group one has 2 different harmonies, which means nontrivial conditions on DNA and mRNA since the 3-chords of all these harmonies must act as resonance chords. In principle homonymy becomes possible for DDNA \rightarrow DNA and DmRNA \rightarrow mRNA pairings but is not realized. Either coupling to both harmonies is possible or there are no DNAs or mRNAs coupling resonantly to all 3-chords of either harmonies so that only 1 harmony is realized completely. This is important if one requires uniqueness of the genetic code.

4. For 3-chords having Z_{rot} isometries there are 3 harmonies and for Z_{refl} 5 harmonies. This gives increasingly stronger conditions on resonant couplings. The uniqueness of the code suggests that only a subset of possible harmonies is possible. Also the probability of homonymy for DAA-AA pairing increases and might explain 21st and 22nd AAs Pyl and Sec coupling to non-standard representation. Deviations typically occur for the doublets as indeed found.

What is interesting that if one loosens the conditions and allows different couplings and allows several 3-harmonies, it is in principle possible to have larger number of DNA and mRNA codons than usually. Also analogs of AAs can be considered. Frequency coding relates interestingly to extended genetic codes with 4 or 5 codons (see http://tinyurl.com/ycsfgu7n) and nucleic acid analogues (see http://tinyurl.com/y8tj8hsm).

7.4.2 Is the notion of reading frame consistent with the proposed realizations of the genetic code?

Reading frame (see http://tinyurl.com/yb6wr3d7) represents also a context dependence of the code. Reading frame begins with the Start codon and new reading frame can begin at second or third letter of codon. There must be also Stop after $3 \times n$ letters also in the new reading frame.

Shifting of reading frame by 1 or 2 units can take place for viral, prokaryote, and mitochondrial genomes but for some reason not in nuclear genome. Shift makes sense if the first codon is Start codon. For human genome MT-AOT8 and MT-ATP6 are examples of reading frames for mitochondrial genes coding for different proteins. The interesting question is why the shift occurs only at the level of viruses, prokaryotes, and mitochondria and chloroplasts.

Does the notion of reading frame make sense for the two models of genetic code? Consider first the representation of 64 codons as 3-chords. If all 64 codons are are realized as chords, shift does not produce chords not belonging to the harmony. Since the notes of chords cannot correspond to the letters the shift is highly non-trivial since it is not only shifted decomposition of notes to triplets but change also the notes.

Is this possible at the level of DmRNA? At the dark level code words do not have decomposition to letters. Dark proton triplets should re-organize in a new manner into triplets. If the dark protons inside proton triplet are connected by colored bonds to form color singlet, the shift would produce colored 3-proton states unless also the color structure of the states is re-organized so that it is consistent with the shift at the level of codons. Kind of phase transition would take place and induce the change of the reading frame.

Chapter 8

The Realization of Genetic Code in Terms of Dark Nucleon and Dark Photon Triplets

8.1 Introduction

I have worked for more than 10 years with a proposal for a realization of the genetic code in terms of dark proton or nucleon triplets forming closed or open strings. I have considered several variants of the code but the details have remained poorly understood and I have spent a considerable time on wrong tracks. Also the contents of this chapter reflect this wandering.

It however seems that the dust is finally settling (I am writing this in the beginning of 2022). One can see the model as a generalization of the quark model of nucleon and Δ baryons obtained by replacing u and d quarks with dark nucleons. The color group solving the statistic problem for Δ baryon is in the receint case solved by Galois confinement involving Galois group Z_3 assignable to the codons.

8.1.1 Basic notions and ideas

The basic notions behind the models of genetic code and of biomolecules rely on the notion of dark matter as $h_{eff} = nh_0$ phases of ordinary matter predicted by number theoretic vision. $n = h_e f f / h_0$ serves as a measure for algebraic complexity and as a kind of universal IQ.

Dark matter at the magnetic body (MB) has large h_{eff} so that it is quantum coherent in long scales and acts as a master controlling ordinary biomatter. The control dynamics at dark level is very simple as compared to the biochemical dynamics, which is a kind of shadow dynamics.

Galois confinement is an essential element of the picture. Physical states are singlets under the action of the Galois group associated with the real polynomial with rational coefficients permuting the roots of the polynomial defined a 4-surface in M_c^8 and mapped by $M^8 - H$ duality to $M^4 \times CP_2$. Among other things, this implies that the quark momenta, which are algebraic integers in an extension of rationals defined by the polynomial, sum up to an ordinary integer when the momentum scale corresponds to the largest ramified prime assignable to the extension.

Galois confinement provides a universal mechanism for the formation of bound states. Dark codons as dark nucleon- and dark photon triplets are Galois confined states behaving like a single quantum unit. Dark 3N-nucleons and dark 3N-photons define dark genes.

8.1.2 Two models of the genetic code based on dark particles

Both models are based on Galois confinement providing a universal mechanism for the formation of bound states in TGD Universe.

Bioharmony model

The faces of icosahedron and tetrahedron (and octahedron) are triangles. They would correspond to 3-chords made of dark photons, which in turn represent genetic codons. m

Communications are by dark 3N-photons representing genes and are based cyclotron 3Nresonance. Information coded in the frequency modulation of cyclotron frequencies. The chords serve as address and the message is coded to the frequency modulation. The outcome is sequence of resonances giving rise to pulses. Nerve pulse patterns could emerge by this mechanism.

Biophotons are ordinary photons resulting from the decay of dark N-photons to ordinary photons.

Codons as dark 3-nucleons

This work led to a more detailed model of the realization of the genetic code in terms of dark nucleon triplets forming a linear structure as the dark counterpart of linear biomolecule pairing and parallel with it.

The nucleons are connected by pionic flux tubes carring charge $0, \pm 1$ to form a closed stringlike entity carrying angular momentum 0,1, or 2. The dark variants DDNA, DRNA, DtRNA, DAA of DNA, RNA, tRNA, and and amino acids (AA) follow as a prediction. AAs correspond to nonrotating analogs of N (p,n) and Δ , DNA and RNA to rotating analog of Δ , and tRNA to rotating analog of N.

Also the pairings between dark information molecules can be understood to a high degree, and the chemical and functional differences between DNA and RNA could reflect the differences between DDNA and DRNA. The almost exact T-C and A-G symmetries of the third letter of the genetic codon could be seen as reflection of almost exact spin or isospin symmetry. The latter option was considered in [K60] but this work strongly favors spin symmetry. One can understand the numbers of DDNAs coding for given DAA and also the the breaking of spin symmetry. The number of DtRNAs is the minimal 32 and this predicts 1-to-many character of DtRNA-tRNA pairing which would induce wobble base pairing.

8.1.3 The relationship between the two models of genetic code?

The precise relation between the two models of genetic code remained poorly understood for a long time. The connection came from the realization of bioharmony model as so-called icosa-tetrahedral tessellation of hyperbolic 3-space H^3 , which corresponds to either mass shell in momentum space or light-cone proper time constant hyperboloid [L159]. H^3 allows an infinite number of tessellations as analogs of 3-D lattices in the Euclidean 3-space E^3 .

- 1. Basic biomolecules would correspond to linear sub-lattice-like structures of the icosahedral tessellation formed from triplets of icosahedron, tetrahedron and octahedron. One can say that DDNA codon X is associated with icosahedron-pair and corresponds to a face. This face represents X in the bioharmony model and also the entangled dark nucleons at its vertices represent X.
- 2. The cyclotron frequencies for the nucleons of X correspond to the frequencies of a dark 3-photon emitted by the dark 3-nucleon. This picture generalizes to genes represented as dark 3N-codons and dark 3N photons emitted in their communications involving 3N-resonance and frequency modulation yielding a series of resonance peaks at the end of the receiver as an analog of nerve pulse pattern.
- 3. Hamiltonian cycle must be physically realized at the icosa-tetrahedron which would serve as the basic structure for all dark counterparts of the information molecules. The simplest option is that the Hamiltonian cycle corresponds to a closed flux tube going through all vertices of the tetra-icosahedron. If the cyclotron frequencies, that is magnetic field strengths, are scaled by factor 3/2 (and scaled down to the same octave by octave equivalence) at each step along the cycle, the model of bioharmony is realized in terms of cyclotron frequencies. The codon realized as 3 dark nucleons associated with corresponds to the codon realized as dark photon triplet.

4. This picture generalizes to DtRNAs and DAAs. DtRNAs would have as active faces those DtRNA codons, which pair with DmRNA codons. DAAs would have at active faces those DtRNA codons which pair with them. Common dark codon would make pairing by dark 3-photon resonance possible. DtRNA could attach to correct DmRNA during translation and for DAA to correct DtRNA. Ordinary biomolecules would be paired with their dark variants so that dark variants of basic processes would induce their biochemical variants as a kind of shadow dynamics. The pairing by 3N-resonance could be a completely general mechanism involved with biocatalysis.

A concrete realization of bioharmony [?]n terms of the dark nucleon model for codons emerges. The small symmetry breaking effects - the members of doublet that should code for the same amino acid (or act as stop codons), code for different amino acid (or amino acid and stop), are understood. A crucial piece of the puzzle is that one particular chord CEG[#] has identical intervals between the notes in even tempered scale. Also the failure of the Pythagorean quint cycle (notes are obtained by scaling the basic frequency by power powers of (3/2) and using octave equivalence) to close, which bothered Pythagoras, is in an essential role. Also the differences between vertebrate and bacterial codes are understood.

8.2 Dark nucleon realization of the genetic code and basic information molecules

In this section I will represent the arguments leading to the recent (2022) view about dark nucleon realization of the genetic code and dark counterparts of basic information molecules DNA, RNA, tRNA, and amino acids.

8.2.1 The basic vision and the first guess

The basic vision is that dark matter and magnetic body (MB) serves as a master controlling the dynamics of the ordinary biomatter so that its dynamics is shadow dynamics, and the huge complexity of living matter could reduce to relatively simple control dynamics at the level of MB.

Biomolecules are information molecules and dark matter has a higher "IQ" than ordinary matter measured as the dimension $n = h_{eff}/h_0$ of the extension of rationals associated with the space-time regions characterizing the system measuring also the scale of quantum coherence. Therefore the natural expectation is that basic information molecules have dark counterparts and genetic code is realized at a darl level so that the chemical realization would be a secondary realization.

- 1. I started with a proposal [L1, K122, L77, K135] that dark codons could correspond to dark nucleons, that is dark quark triplets, assignable to open or closed string like objects (flux tubes). This led to the proposal for the basic group theoretical decomposition DDNA and DRNA codons in terms of group representations of $SU(2)_I \times SU(2)_R$ as $(4_I \otimes 4_s \oplus 2_I \otimes 2_s) \otimes (5_s \oplus 3_s) = [(3/2, -3/2)_I + (1/2, -1/2)_I] \otimes (4_s \oplus 2 \otimes 2) \otimes (5_s \oplus 3_s) = 64_{DNA} \oplus 64_{RNA}$. In the quark model, this corresponds in fermionic degrees of freedom to nucleon N and Δ assuming color degrees of freedom to get statistics right. $5 \oplus 3$ could be assigned to 2 *rho*-meson-like bonds for an open string-like object.
- 2. The realization of $4 \times 4 \oplus 2 \oplus 2$ in terms of quark color triplets is not physically plausible and the challenge is to realize $4 \times 4 \oplus 2 \oplus 2$ and $5 \oplus 3$ physically in terms of more plausible dark states. The natural guess is that this realization involves dark protons and neutrons. u and d would be replaced with p and n.
- 3. Color would be absent and since the Δ is completely symmetric, antisymmetry required by Fermi statistics must be realized by bringing in some new degrees of freedom. Galois confinement is suggestive in the TGD framework [L159, L169, L167, L175, L176]. Z_3 is a natural guess for the Galois group in the case of codons and one has 3 states in geometric degrees of freedom and 3-nucleon state, which is Z_3 singlet would be antisymmetric.

Since the induced spinors do not have color as spin-like quantum numbers, one must leave open the possibility that even ordinary color confinement has this kind of description as a description at space-time level (as opposed to the descriptions at embedding space and "world of classical worlds" (WCW) level).

8.2.2 The charge DNA as a guideline

A strong constraint comes from the observation that DDNA and DRNA codons have charge -3.

1. If DDNA and DNA form parallel string-like structures, this strongly suggests that there is a neutralizing charge +3 associated with the dark codon paired with the ordinary codon. This charge could be assigned either to 3 protons or 3 nucleons if there is some additional charge allowing to take care that the total charge is 3 units in the case of DDNA and DRNA.

If also the notions of DAA and DtRNA make sense, charge neutrality for them is a plausible option. Of course, the additional charges could be dynamical in the same way as the charges of corresponding bio-molecules.

2. The compensating charge could be assigned to meson-like states with charges $0, \pm 1$. They could be meson-like bonds connecting the dark nucleons to a string-like object. ρ mesons with spin 1 and charges $(0, \pm 1)$ and pions with spin 0 and charges $(0, \pm 1)$ are the natural candidates. For closed string-like objects one would have 3 bonds and for open string-like objects 2 bonds.

For ρ mesons associated with two bonds one would have spin representations $3 \otimes 3 = 5 \oplus 3 \oplus 1$. One should somehow get rid of the spin singlet if one assumes the proposal considered above. Spin-statistics represents the second problem: Bose-Einstein statistics does not allow 3.

For $3 \otimes 3 \otimes 3 = (7 \oplus 5 \oplus 3) \oplus (5 \oplus 3 \oplus 1) \oplus 3$ associated with closed string-like objects, the number of states is quite too high. The only completely symmetric representation is 7 whereas 1 is antisymmetric. Thus it seems that the ρ -meason option is not realistic so that only pionic realization remains.

This leaves open only the possibility that $5 \oplus 3(\oplus 1)$ corresponds to the rotational degrees of freedom of a closed or open string-like object.

8.2.3 Dark nucleons or dark protons?

Are both dark p and n needed or are dark protons enough as mildly suggested by the model [L20] of Pollack effect [I110, L20, I197, I162]? Could one build the needed states using only dark protons and suitably chosen bonds?

- 1. Could number theoretic Galois degrees of freedom [L157, L139, L127, L128, L169, L175, L176] come to rescue? The analog of isospin could be assigned with Galois degrees of freedom. For 3-D algebraic extension of rationals replacing color, the extension increases the algebraic dimension of the 3-space consisting of rational points by factor n = 3 to nd, d = 3. The dimension of number theoretic spinors would be $2^{n(d-1)}/2 = 2^3$, which is much larger than the dimension d = 2 of isospin spinors in 3-D space. One could speak of Galois-spin or G-spin. Nucleon isospin is therefore a more reasonable candidate.
- 2. The objection against the dark nucleon-triplet picture is that, in the standard nuclear physics, neutrons are not thought to be important in living matter. Note however that the dark electroweak length scale scaled by h_{eff}/h_0 could be much longer than the ordinary weak scale, even of the order of cell length scale.

Weak gauge bosons would be effectively massless below the dark weak scale and weak interactions associated with the dark pion-like bonds would be as strong as electromagnetic interactions. This could explain the mysterious large chirality breaking effects in living matter. 3. One can also ask whether the dark neutron is effectively a dark proton plus pionic bond so that dark protons would be the basic building bricks after all. One cannot exclude the possibility that this applies also to the neutrons of ordinary nuclei [K105, L1]. This does not however conform with charge +3 for DDNA codons . This would leave the option that the dark neutron is an ordinary proton plus dark π^- bond.

8.2.4 Dark variants of information molecules as analogs of nucleon and Δ obtained by replacing quarks with dark nucleons

Could the dark analogs of N and Δ with quarks replaced by nucleons give rise to the genetic code and dark analogs of the basic information molecules?

- 1. The analogs of N and Δ would give 2 spin doublets (counterparts of p and n as ppn and pnn) and 4 spin 4-plets as a counterpart of Δ (ppp,ppn,pnn,nnn): altogether 20 states, which brings into mind AAs. Note that pion bonds could modify the charges for ordinary nucleons.
- 2. The analogs of N and Δ can be tensored with $A = 5_s \oplus 3_s \oplus 1_s$ or $B = 5_s \oplus 3_s$. $\Delta \otimes B$ would give $[(3/2, -3/2)_I \oplus (1/2, -1/2)_I] \otimes (5_s \oplus 3_s)$: these two 64-plets could be identified as DDNA and DRNA.

 $N \otimes 1$ could give 20 AAs. For both options, $N \otimes B = (2_I \oplus 2_s) \otimes (5_s \oplus 3_s)$ would give 20+12=32 states, which is the minimal number of tRNA codons. The number of chemical tRNA codons is larger than 40 so that DtRNA-tRNA pairing would be 1-to-many. This could induce the wobble base pairing [I40].

3. DDNA and DRNA would correspond to the analogs of Δ nucleons with rotation. For instance, ppp and ppn as counterparts of Δ^{++} and Δ^{+} could correspond to DDNA and pnn and nnn as counterparts of Δ^{-} and Δ^{0} could correspond to DRNA. This implies charge asymmetry which should relate to the differences between DNA and RNA. DtRNA would correspond to N with rotation. DAA would correspond to Δ and N without rotation, which should relate to the different functions between AAs and molecules DNA, RNA, and tRNA.

Remark: Note that pionic bonds would guarantee that the total charge of DDNA and DRNA codons is 3 units.

8.2.5 Angular momentum of the nuclear string as origin of $5 \oplus 3 \oplus 1$

One must understand the origin of $5 \oplus 3 \oplus 1$ or of $5 \oplus 3$. There are 3 scenarios to consider. Closed string scenario favors $5 \oplus 3$ but does not predict AAs. Open string scenario favors $5 \oplus 3 \oplus 1$ and allows the identification of dark counterparts of all basic biomolecules. If ρ mesons do *not* give rise to $5 \oplus 3 \oplus 1$, both closed and open strings can be considered.

1. What came first into mind was that the bonds between protons are analogous to ρ mesons. This would allow only an open string option. There is however a problem with statistics: 3 is antisymmetric (analogous to the cross product of 3-vectors).

This suggests that the bonds are pionic and do not contribute to the spin but allow to obtain desired total charges for 3 proton states. Charge neutrality is attractive for AAs and would require maximum neutralizing charge -3 so that only the closed string option with ordinary nucleons plus dark pionic bonds remains. Even dynamical charges would be possible also at the level of dark bio-molecules and one can consider the possibility that the MB controls the charge state of the basic biomolecules.

2. Concerning the identification of $5 \oplus 3(\oplus 1)$, the rotational degrees of freedom of string seem to be the only reasonable option. 1 and 5 could correspond to spin 0 and spin 2 states of the Regge trajectory and 3 to spin 1 state of a possibly exchange degenerate trajectory. What is encouraging is that only the bosonic spins 0, 1, and 2 and fermionic spins 1/2 and 3/2, which are in a very special role physically would be needed.

To sum up, closed strings with dark nucleon triplets and stringy rotational degrees of freedom allow us to predict the dark counterparts of all basic information molecules as analogs of nucleon and Δ states with pionic bonds. The number of dark tRNA codons is predicted to be minimal and equal to 32, and the considerably larger number of the chemical tRNA codons implying that dark tRNA-tRNA pairing is 1-to-many. This would explain wobble base pairing.

8.2.6 Various pairings of the information molecules

The basic vision is that the dynamics of the MB induces the dynamics of the biological body and the observed chemical pairings are induced by dark pairings. One should therefore understand the DDNA-DRNA, DRNA-DtRNA, and DtRNA-DAA pairings.

- 1. DDNA-DRNA pairing is obtained trivially. DDNA-DAA pairing is induced by DRNA-DtrNA pairing and DtRNA-AA pairing.
- 2. The decomposition 2 × (20 ⊕ 12) for DRNA suggests a natural pairing with tRNA identified as 20 ⊕ 12. The spin contents of the codons are however different and the situation is more complex. This leads to a model for the breaking of the (A,G) symmetry of the third codon in RNA-AA pairing. The pairing of DtRNA with DAA requires pairing of 20 ⊕ 12 with 20. 20 → 20 is a natural pairing but how to realize 12 → 20?
- 3. Could icosa-tetrahedral realization of the genetic code in terms of dark photon triplets (bioharmony) [L16] [L136, L159] help here? In this realization the faces of icosahedron and tetrahedron identifiable as 3-chords correspond to codons and 3 isohedral Hamiltonian cycles providing a model for 12-note scale and the unique tetrahedral Hamiltonian cycle are needed for the realization of bioharmony as genetic code.

Icosahedron has 20 faces and 12 vertices defining Hamiltonian cycles essential for the realization in terms of bioharmony. Hamiltonian cycles have Z_6 , Z^4 or Z^2 as a symmetry group: Z_2 can correspond to reflection of rotation by π . Z_6 has 3 orbits with 6 faces and 1 orbit with 2 faces. Z_4 has 5 orbits with 4 faces. Z_2 has 10 orbits with 2 faces.

Could the missing faces correspond to the missing orbits for one of these symmetry groups: a) to 6-orbit and 2-orbit for Z_6 or b) 2 4-orbits for Z_4 or c) 4 2-orbits for Z_2 . Z_6 and Z_4 Hamiltonian cycles are unique and part of any realization. Option b) is more symmetric than option a) and is a more promising candidate.

Consider now the pairings of type DX-X.

- 1. All dark pairings as a bound state formation by Galois confinement [L175, L176] would involve formation of a composite $P_n \circ P_{n-1} \circ ... \circ P_1$ of the polynomials P_i determining at M^8 level the 4-surfaces of systems participating in the interaction. This implies that Galois groups extend to a larger group having the Galois groups of composites as normal subgroups.
- 2. The already mentioned charge asymmetry reflecting the violation of the weak isospin symmetry between DDNA and DRNA could explain why DNA *resp.* RNA involves deoxyribose *resp.* ribose molecule and the nucleotide T is replaced with U in RNA. The instability of RNA molecules and the rarity and short life-time of double RNA strands could derive from the properties of DRNA.

The almost exact T-C and A-G symmetries of the third letter of genetic codon could also reflect almost exact isospin symmetry as proposed in [K60]. The number of DtRNAs is the minimal 32 and this predicts 1-to-many character of DtRNA-tRNA pairing which would induced wobble base pairing.

Dark base pairing could involve an extension of Galois group Z_3 of codon to Z_6 of codon pair. This could make DDNA double strand stable and perhaps induce the stability of DNA double strand. DDNA double strand would permanently be in the bound state with Z_6 as the Galois group of the dark base pair. This would support the view that DDNA is above DRNA in the dark master-slave hierarchy. Also the functional differences between DNA and RNA could relate to the differences of their dark counterparts. The DDNA double strand with larger h_{eff} would represent a higher evolutionary level than the DRNA strand.

3. The number of DtRNA molecules is 32, and minimal one, so that DtRNA-tRNA pairing is not unique. This explains the wobbling of RNA-tRNA pairing [I40]. Does the wobble phenomenon have some biological function or does it signal that dark tRNA-tRNA pairing has not yet evolved to its final form?

That tRNA as such does not represent information storage but plays a role of servant in the translation process, supports the first view. The basic function of dark tRNA in the translation is unique but it is less risky to have several ways to perform this function: hence the large number of ordinary tRNAs.

8.2.7 A model for the symmetry breaking of the genetic code

The model predicts that the numbers of DRNA and DtRNAs are 64 and 32 respectively. This condition does not force DRNA-DtRNA correspondence to be 2-1 in a codon-wise way. This is however true in an excellent approximation as becomes clear by looking at the code table.

For the third letter, RNA-AA correspondence has an exact U-C symmetry and almost exact A-G symmetry. There are only 2 exceptions. TTX 4-plet decomposes to $3 \times \text{ile} + 1$ met: (A,G) doublet for the third codon splits to (ile,met). The (A,G) doublet in TGX splits to (stop,trp). Both stop codons and met as a start codon are therefore very special.

In bacterial genetic codes also the (A,G) doublet in TGX, which usually corresponds to (stop,stop), corresponds sometimes to (stop,pyl) doublet so that CG symmetry is broken. Also the (A,G) doublet usually mapped to (stop,trp) can be mapped to (sec,trp). The interpretation would be that a stop codon is obtained if DtRNA corresponding to UAG or UGA does not pair at all with tRNA. If it pairs, UAG codes for pyl and UGA codes for sec.

One should understand this symmetry breaking.

- 1. Since iso-spin and spin are involved, either isospin or spin symmetry breaking is suggestive. In the nucleon sector the situation is completely symmetric between spin and isospin. In the string sector, the situation is different for DDNA, DRNA and DtRNA.
- 2. The earlier interpretation for (U,C) and (A,G) doublets was as isospin doublets and isospin symmetry breaking. The conjugations $G \leftrightarrow C$ and $U \leftrightarrow A$ were interpreted as an analog of particle-antiparticle conjugation.

The following model leads to the proposal that dark (T,C) doublet corresponds to spin (rather than isospin-) doublet $2_s = (1/2, -1/2)$ and (A,G) doublet to pseudo-spin doublet (3/2, -3/2). As if rotational symmetry would have reduced to axial symmetry (this would conform with the linear structure of DNA). Letter and its conjugate would correspond to different spin doublets. Interestingly, the repetive purine (A, and G) sequences for intronic portions of active DNA strandd would correspond to dark (3/2, -3/2) doublet for which the breaking of rotational symmetry is larger for the active strands in the transcribed portion of DNA.

At the level of DNA, DRNA and DtRNA, the natural possibility is that (T,C) doublet corresponds to 2_s and (A,G) doublet to the spin symmetry violating $(3/2, -3/2)_s$. (T,C) and (A,G) could form an isospin doublet.

3. An important point to note is that (3× ile,met) and (stop,stop), (stop,trp) dot correspond to identical situations since 2 iles correspond to (T,C) for which there is no symmetry breaking. Actually one has 3 (A,G) symmetry breakings.

Consider now the identification of spin- and isospin contents of various dark information molecules.

1. Suppose that the spin symmetry is not broken at DDNA and DRNA level but isospin 4plet $4_I = (3/2, 1/2, -1/2, -3/2)$ splits into pseudo-doublets $2_{I_1} = (1/2, -1/2)$ and $2_{I_2} =$ (3/2, -3/2). If DDNA were maximally symmetric it would correspond to $2_{I_1} = (1/2, -1/2)$. Which option one chooses, does not matter in the sequel so that this option is selected. This would give

$$DDNA = 2_{I_1} \otimes [4_s \otimes (5_s \oplus 3_s)]$$

$$DRNA = 2_{I_2} \otimes [4_s \otimes (5_s \oplus 3_s)]$$

2. DtRNA and DAA correspond to

$$DtRNA = 2_I \otimes [2s \otimes (5_s \oplus 3_s)]$$

$$DAA = 4_I \otimes 4_s \oplus 2_I \otimes 2_s$$

3. One would expect that the pairing minimizes the breaking of rotational symmetry meaning that spins are the same for paired dark molecules if possible and the spin difference is minimized otherwise. To get some idea about the symmetry breaking, one can decompose the tensor products for the spin representations

$$DRNA = 2_{I_2} \otimes (8_s \oplus 2 \times 6_s \oplus 2 \times 4_s \oplus 2 \times 2_s)$$

$$DtRNA = 2_I \otimes (6_s \oplus 2 \times 4_s \oplus 2_s) \quad .$$

The representation contents are different and the number of spin states for DRNA is twice that for DtRNA so that the symmetry breaking relates to spin pairing rather than isospin pairing.

The first thing to notice is that $2 \times 2_s$ for DRNA naturally projects to 2_s for DtRNA. Also $2 \times 6_s$ projects to 6_s . Bothe decomposis however have $2 \times 4_s$:s so that 8_s must pair with $2 \times 4_s$. Symmetry breaking must localize to this pairing.

 8_s is not present in DtRNA and forces a pairing between different spins. This should cause the violation of spin symmetry for dark (A,G) doublets in the sense that they couple to different DAAs, which in turn requires that they couple to different DtRNAs.

1. One can decompose 8_s as

$$8_s = (7/2, -7/2)_s \oplus (5/2, -5/2)_s \oplus 4_{s_1}$$
.

 8_s should correspond to $2 \times 4_s$ in DtRNA. The pseudo 4-plet 4_{s_1} pairs with 4_s in a spin conserving manner.

- 2. What is left is $2_{I_2} \otimes [(7/2, -7/2)_s \oplus (5/2, -5/2)_s]$, which should pair $2_I \times 4_s$. This pairing cannot conserve spin and the 2-1 symmetry must be violated in the sense that the DRNAs paired with $(3/2)_s$ and $-(3/2)_s$ are different. One can ask whether the change of the magnitude of the spin component is minimal in the DRNA-DtRNA pairing.
- 3. At the level of DAA and DtRNA, ile could correspond to the first DtRNA doublet $((3/2)_I \otimes (1/2, -1/2)_s$ and $(3/2)_I \otimes (3/2)_s$ as a singlet and met to $(3/2)_I \otimes (-3/2)_s$ as a singlet. (stop, stop) and (stop, trp) could correspond to $(3/2)_I \otimes (3/2, -3/2)_s$ and $(-3/2)_I \otimes (3/2, -3/2)_s$. Spin symmetry breaking would therefore mean that different DRNAs pair with DtRNAs in the doublet $(3/2, -3/2)_s$.

How do DRNAs and DtRNAs correspond to each other in the (A,G) symmetry violating sector? In the absence of symmetry breaking DRNA-DtRNA pairing is 2-1 in a codon-wise way if DRNA with opposite values 3/2 and -3/2 of isospin pair with the same DtRNA. Symmetry breaking would mean that some DRNAs with spins 3/2 and -3/2 pair with different DtRNAs and therefore with different DAAs for some (A,G) doublets $(3/2, -3/2)_s$. For the (T,C) doublets $(1/2, -1/2)_s$ this would not occur.

1. There are 8 spin symmetry violating DRNAs and 8 DtRNAs corresponding to UA(A, G) and UG(A, G) and UA(T, C) and UA(A, G) (3× ile+ met). UA(T, C) is strictly speaking not spin symmetry violating but ile corresponds to DRNA triplet instead of doublet. As if the DRNA doublet paired with 2 DtRNAs pairing with met would pair with DtRNAs coding for ile and met.

There are 2 $[(7/2, -7/2)_s \oplus (5/2, -5/2)_s]$ multiplets at the DRNA side. At the DtRNA side one has pseudo doublets $(3/2, -3/2) \oplus 2_{s_1}$, $s_1 = (1/2, -1/2)$. There are two of these corresponding isospin doublet 2_{I_1} .

- 2. Since there are 3 UCAG 4-plets with symmetry breaking, the symmetry violation is not independent of the value of isospin for $(3/2, -3/2)_I$ for DRNA and $(1/2, -1/2)_I$ for DtRNA. Symmetry breaking for isospin should localize to the DRNA side. There are several options (3,0), (0,3), (2,1) (1,2) for the numbers of symmetry breakings for DRNA multiplets. One can restrict in the sequel to a single value of isospin, say 3/2.
- 3. One should find symmetry violating pairing between these 8 DRNAs and 8 DtRNAs. $[(7/2, -7/2)_s \oplus (5/2, -5/2)_s]$ should be mapped to $(3/2, -3/2)_s \oplus 2_{s_1}$. Assume that the spin difference between paired DRNA and DtRNA is as small as possible.
 - (a) (T,C) doublet without symmetry breaking would correspond to the pairing

$$(5/2, -5/2)_s \to (1/2, -1/2)_s$$

(T,C) symmetry is not violated if the both doublets correspond to the same DAA and DtRNA.

(b) (A,G) doublet could correspond to the pairing

$$(7/2, -7/2)_s \rightarrow (3/2, -3/2)_s$$

Now the members of the doublets would correspond to different DAA.

(c) For instance, the DRNA corresponding to the second met in (met,met) in absence of symmetry breaking, would pair with DtRNA, which pairs with ile. The symmetry present at the DRNA level would be broken by the pairing.

In the case of (stop,trp) doublet, the same would occur. This would also happen in the replacements (stop,stop) \rightarrow (stop,pyl) and (stop,trp) \rightarrow (sec,trp). Now the DtRNA in question would not pair at all with tRNA and AA or it would be with exotic tRNA pairing with an exotic AA.

8.2.8 Chemical bonds as flux tube links and a realization of dark codons using only dark protons

In the proposed model of dark DNA, one must assume that the dark codon is formed by a triplet of dark nucleons (proton and neutron). In the TGD framework one could justify the presence of neutrons by the large value of Planck constant increasing the weak scale to at least atomic length scale so that weak bosons would behave like massless particles in atomic scales at the MB. Therefore the dark protons could transform to dark neutrons easily. Neutron would be connected to either neighbor by a meson-like flux tube bond which is positively charged so that each codon would have a charge of 3 units neutralized by an opposite charge of 3 phosphates.

The sign of the magnetic flux as bit?

The introduction of neutrons brings in an additional bit. Therefore one could use only dark protons, if one could bring in this additional bit in some way. An obvious candidate would be the direction of a monopole magnetic flux assignable to the letter of the codon as a closed flux tube with respect to reference direction defined by the DNA sequence. If the letters of codon are closed linked flux tubes containing dark protons forming dark DNA as a chain, this kind of option might work.

Consider first the topology of the monopole flux tubes.

- 1. Magnetic monopole flux tubes correspond to closed 3-surfaces in the TGD framework. They are closed because the boundary conditions do not allow boundaries with a monopole charge nor boundaries at all. In dimension 3, these flux tubes can become knotted and closed flux tubes can get linked.
- 2. If one has a braiding of N flux tubes, one can connect the ends of the N flux tubes. There are many ways to connect the ends, and one obtains at most N linked closed flux tubes, which are knots. The simplest option is that the ends of each braid strand are connected so that one has N linked flux tubes. This corresponds to the "upper" ends as a trivial permutation of the "lower" ends.
- 3. Any permutation in the permutation group S_N is possible. A given permutation can be expressed as a product of permutations such that each permutation leaves invariant a subset. Permutations are therefore characterized by a partition of N objects to subsets such that the given set consist of N_i objects with $\sum N_i = N$ and that these sets do not decompose to smaller subsets. The allowed permutations for N_i objects correspond to elements of the cyclic group Z_{N_i} . These cyclic permutations give rise to a single closed tube when the ends of the braid ends and permuted braid ends are connected. The number of closed flux tubes is therefore the number of summands in $\sum N_i = N$.

These permutations are obtained by reconnections from the permutation corresponding to N closed loops so that there are two levels: the level of braiding and the level of reconnections behind the stages not visible in the properties of the braiding.

Linking is a metaphor for bonding. One speaks of the chain of generations, of a weak link in the chain, etc.

- 1. Chemical bonds are classified into ionic bonds, valence bonds involving delocalization of electrons, and hydrogen bonds involving delocalization of protons. Chemical bonds are not well-understood in the framework of standard chemistry. TGD suggests that they involve space-time topology: monopole flux tube pairs would be associated with the bonds and the splitting of the bond would correspond to a reconnection splitting the pair to two U-shaped flux tubes. Flux tubes and connecting molecules as nodes are proposed to form a network.
- 2. I have not considered in detail how the U-shaped flux tubes are associated with the nodes. Bonding=linking metaphor encourages a crazy question. The members of the flux tube pairs, which are proposed to connect molecules, which serve as nodes of a network. These flux tubes must close and could be linked with shorter closed flux tubes assignable to molecules.
- 3. Could this linking bind the molecules and atoms to a single topological structure. If so, both chemistry and topological quantum computation (TQC) in the TGD framework would involve linking, braiding, and reconnections as new topological elements. Biomatter at molecular level would consist of chains of closed flux tubes which can be also stretched and give rise to braids.

Note that 2 U-shaped flux tubes can reconnect and this transition can lead to a pair of flux tubes or to a linked pair of U-shaped flux tubes so that 3 different states are possible.

4. I have proposed that the pairing of molecules by a pair of monopole flux tubes serves as a correlate for entanglement. If dark protons are associated with closed flux tubes, they must entangle. Could also the linking of the U-shaped flux tubes give rise to entanglement? Stable linking correlates the positions of the flux tubes but this need not mean entanglement since wave function can be a product of wave functions in cm coordinates and relative coordinates.

Linking as an additional topological element inspires some quantum chemical and -biological speculations.

1. Could the presence of valence-/hydrogen bonds involve a closed flux tube at which the electron (pair)/proton is delocalized and that this flux tube is linked with another such flux tube. This picture is consistent with the proposed role of quantum gravitation in metabolism [L178] and generation of the predecessor of the nervous system [L183] based on very long variants of

hydrogen bonds characterized by gravitational Planck constant. In this view, living matter would be an extremely highly organized structure whereas in the standard chemistry organism would be a soup of biomolecules.

2. What comes to mind as an example, is the secondary structure of proteins (https://cutt. ly/sZ5rRiQ) involving α - helices, β -strands and β -sheets. Tertiary structure refers to 3-D structure created by a single protein molecule. It can have several domains. There are also quaternary structures formed by several polypeptide chains. Proteins consist of relatively few substructures known as domains, motives and folds. Could these structures involve braided and linked flux tube structures with dynamical reconnections?

Dark codons as triplets of dark protons at linked closed flux tubes?

Consider now a possible model of dark DNA involving only dark protons.

- 1. One can imagine that dark protons are associated with closed flux tubes acting as hydrogen bonds, such that 3 closed flux tubes as letters are linked to form a dark codon. The dark codons could in turn be linked to form genes as sequences of codons. The direction of the magnetic flux can be opposite or parallel to that of the chain so that each closed flux tube represents a bit of topological information. The chains of links would define sequences of bits and even qubits. Could this define the predecessor of the genetic code for which letter represents a single bit?
- 2. If one has only dark protons, one obtains only 32 dark codons. An additional bit is required to get 64 codons. Could the direction of the closed flux tube in the chain provide the missing bit and thus represent strong isospin distinguishing between p and n?

What implications could this identification have?

1. It is known that the genetic code has a slightly broken symmetry with respect to the last letter of the codon. For almost all RNA codons U and C resp. A and G define code for the same amino-acid. A possible interpretation of the symmetry is that this symmetry is that U-C pair and A-G pair correspond to the bit defined by magnetic flux so that the sign of magnetic flux would not matter much at the level of proteins. For this interpretation, the additional bit would not mean much at the level of proteins.

Dark DNA and presumably also RNA codons are linked chains of 3 closed flux tubes serving as bits. Could this chain in the case of dark amino acids be replaced with a single closed flux tube obtained by two reconnections so that amino-acid becomes a basic unit?

- 2. Could the breaking of A-G symmetry (stop-trp pair and ile-met pair) have a topological meaning? Could the direction of the magnetic flux for the third flux tube of the dark codon coding for these pairs matter (this is not the only possibility that one can imagine)? Note that the 4 tetrahedral dark codons in the bioharmony model [L196, L136] correspond to stop-stop and stop-trp pairs.
- 3. What could topologically distinguish met as a starting codon and stop codons from the other codons? Could it be that met is not linked to the codons preceding it so that transcription would naturally start at it.

Could stop codons be unlinked to the codons following them so that the transcription would naturally stop at them? Or could the stop codons correspond to a single closed flux tube so that no RNA codon could be assigned to them?

4. Genes contain intronic parts and the splicing of RNA eliminates these parts after the transcription. Could the topology of DNA and RNA isolate intronic portions from those to be translated. Could the intronic portions correspond to a single flux tube linked to the rest of the gene both at the level of DNA and RNA. If so, the information about the decomposition of intron to RNA codons would be missing and the assignment of tRNA codons to the intronic portion would not be possible.

8.2.9 Could dark genes be dynamical?

In [L188] it was found that the earlier 1-1 correspondence between dark codons and ordinary genetic codons is unnecessarily strict and a modification of the earlier picture of the relation between dark and chemical genetic code and of the function of dark genetic code was considered.

1. Dark DNA (DDNA) strand is dynamical and has the ordinary DNA strand associated with it and dark gene state can be in resonant interaction with ordinary gene only when it corresponds to the ordinary gene. This applies also to DRNA, DtRNA and DAA (AA is for amino acids).

This would allow DDNA, DRNA, DtRNA and DAA to perform all kinds of information processing such as TQC by applying dark-dark resonance in quantum communications. The control of fundamental biomolecules by their dark counterparts by energy resonance would be only one particular function.

- 2. Most importantly, flux tubes magnetization direction could define qubit. If the additional qubit corresponds to nucleon isospin, it is not clear whether this is the case. One can also allow superpositions of the dark genes representing 6-qubit units. A generalization of quantum computation so that it would use 6-qubits units instead of a single qubit as a unit, is highly suggestive.
- 3. Genetic code could be also interpreted as an error code in which dark proteins correspond to logical 6-qubits and the DNA codons coding for the protein correspond to the physical qubits associated with the logical qubit.
- 4. The teleportation mechanism discussed in [L188] could make possible remote replication and remote transcription of DNA by sending the information about the ordinary DNA strand to the corresponding dark DNA strand by energy resonance. After that, the information would be teleported to a DNA strand in a ferromagnetic ground state at the receiver. After this, ordinary replication or transcription, which would also use the resonance mechanism, would take place.

8.3 Connection between dark nucleon code and bioharmony

The model of genetic code based on bioharmony has evolved through many sidetracks [L16] but the version discussed in [L103, L136, L159] is roughly consistent with the original model and also gives a connection with the model of dark nucleon code.

8.3.1 Bioharmony and resonance mechanism for dark photon communications

The faces of icosahedron and tetrahedron (and also octahedron appearing in the model of genetic code as icosa-tetrahedral tessellation of hyperbolic space H^3 [L159]) are triangles. The proposal is that they somehow correspond to 3-chords made of dark photons, which in turn represent genetic codons.

Communications by dark 3-photons represent codons. 3N-photons represent in turn genes. The communications rely on cyclotron 3N-resonance so that the vertices of the faces of icosa-tetrahedron must contain charged particles coupling to a magnetic field. The magnetic field strengths at flux tubes associated with charged particles would determine the cyclotron frequencies.

Information is encoded to the frequency modulation of cyclotron frequencies. The chords serve as addresses much like in computer language LISP. If the modulations of 3N frequencies are identical and in synchrony, the outcome of the receiver consisting of 3N charged particles is a sequence of 3N-resonances giving rise to an 3N-pulse sequence. Nerve pulse patterns could emerge by this mechanism.

One can also consider 3N-signals for which only M < 3N modulations are identical and in synchrony. In this manner communications to subsets of the receiver are possible. For instance, some subset of codons of dark gene or dark protein can be selected as a receiver, possibly controlled. This selection could de-entangled the receiver to de-entangled coherent pieces. There is a direct connection with empiria. Biophotons, whose origin remains poorly understood, can be identified as ordinary photons resulting from the decay of dark 3N-photons to ordinary photons.

The realization in terms of dark nucleons looks more plausible if also DtRNA and DAAs are realized in terms of icosa-tetrahedral picture. This is because the amino acids (AAs) are often neutral unlike DNA nucleotides, which are negatively charged. The dark charge assignable to the dark codon can be controlled by pion-like bonds with charges $0, \pm 1$ so that it can be 3 units for DDNA and vanish for AAs. A natural proposal is that the pionic charge of the codon compensates the charge of the AA and tRNA but the dark charge could be also dynamical and control the ionization of the biomolecule.

Large value of h_{eff} would make possible dark nuclear interactions in the scale of the dark codons (about codon size) allowing the transformation of dark protons to neutrons by dark variant of strong interactions (dark nuclear interactions are central in the TGD based model of "cold fusion" [L56, L133] having implications also for the stellar evolution [L116]). Dark codons would be analogous to dark nuclei tritium (pnn), ³He (ppn), and also ppp and nnn not realized as ordinary nuclei).

There are pairings of type DX-DY. The pairings DDNA-DRNA, DRNA- DtRNA and DtRNA-DAA induce the biochemical dynamics of transcription and translation. There are also pairings DX-X involving the transformation of dark 3-photon to ordinary 3-photon and occurring via energyresonance but involving downwards scaling of wave-length. DDNA-DNA and DRNA-RNA unique DtRNA-tRNA pairing is 1-to-many and relates to the wobble phenomenon. The pairings between dark nucleon variants of biomolecules and corresponding dark 3N-photons make possible biocommunications and control.

8.3.2 Details of the bioharmony model

Consider now a more detailed bioharmony model of the genetic code based on the geometries of icosahedron and tetrahedron.

- 1. Icosahedron has 12 vertices and 20 faces, which are triangles. The idea is that the 12 vertices correspond to the notes of 12-note scale. Tetrahedron has 4 vertices and 4 faces and is self-dual whereas the dual of icosahedron is dodecahedron having 20 faces and 12 faces.
- 2. 12-note scale can be represented as a Hamiltonian cycle at an icosahedron going once through all vertices. The frequencies at the neighboring points as edges of a face in cycle relate by a frequency scaling of 3/2: this gives rise to the Pythorean variant of quint cycle.

Octave equivalence means the identification of frequencies differing by a multiple of octaves. Octave equivalence can be used to reduce all frequencies to a single octave. If the scaling is exactly 3/2 at all steps there is a slight-breaking of octave equivalence since $(3/2)^{12}$ does not quite correspond to an integer number (7) of octaves. Pythagoras was well aware of this.

Given cycle assigns to faces 3-chords defining a harmony with 20 chords assignable to the faces of the icosahedron. For dodecahedron there is only single harmony with 12 chords and 20-note scale which could correspond to Eastern scales. For the tetrahedron the Hamiltonian cycle is unique.

3. Icosahedral Hamiltonian cycles can be classified by symmetries. The group Z_6 , Z_4 , or Z_2 (rotation by π or reflection) as a group of symmetries

The connection with the genetic code emerges in the following manner.

- 1. The natural idea is that the faces of the icosa-tetrahedron correspond to both 3-chords and genetic DNA/RNA codons. If the orbits of faces could correspond to AAs (AAs), the DNA codon would code for AA AA if the corresponding face is at the orbit corresponding to AA.
- 2. One wants 64 DNAs: Z_6, Z_4 ja Z_2 cycle give rise to 20+20+20=60 DNa codons. Tetrahedron gives the remaining 4 codons.
- 3. Does one obtain a correct number of AAs? Do the numbers of faces at the orbits correspond to numbers of DNAs coding for the corresponding AA?

- (a) Z_6 decomposes to 3 6-orbits and 1 2-orbit ()3 × 6 + 2 = 20). There are 3 AAs coded by 6 DNAs. 2-orbit corresponds to AA coded by two DNAs.
- (b) Z_4 decomposes to 5 4-orbits. There are 5 AAs coded by 4 codons.

breaking one would have 11 doublets as predicted.

- (c) Z₂ corresponds to 10 2-orbits predicting 10 AAs coded by 2 codons. There would be 11 2-orbits altogether. There are 9 AAs coded by 2 codons.
 Some kind of symmetry breaking is present as in the case of dark nucleon code. 2 AA doublets must split to singlets. If (ile,ile,ile,met) coded by UAX could correspond to (ile,ile) and (met,met) such that (met,met) is split to (ile,met). In absence of symmetry
- 4. There are also 4 tetrahedral codons.

There is (stop,stop) doublet (UAA, UAG) and (stop,trp) doublet (UGA,UGG). These doublets could correspond to the faces of the tetrahedron. Only one face would code for AA in the vertebrate code. Other faces would not have corresponding tRNA?

For bacterial codes, the situation can be different. Pyl and sec appear as exotic AAs. Could (UAA,UAG) for code for (stop,pyl) and (UGA,UGG) for (sec,trp) instead of (stop,trp)? Orientation preserving rotations form a 12-element group having Z_2 and Z_3 as subgroups. For Z_2 the orbits consist of 2 vertices and for Z_3 of 3 vertices (face) and 1 vertex. Z_3 symmetry could correspond to trp as singlet and vertebrate stop codons as triplet. For bacterial pyl and sec Z_2 with symmetry breaking is suggestive.

8.3.3 Bioharmony, dark nucleon code, and icosa-tetrahedral code as a tessellation of H^3

Bioharmony model involves icosahedron and tetrahedron. This looks ugly unless there is some really deep reason for their emergence. One can also ask why not also octahedron having triangular faces.

Hyperbolic 3-space H^3 has interpretations as a mass shell of Minkowski space M^4 at the level of M^8 and as light-cone proper-time constant surface at the level of H. The 4-surface X^4 in M^8 contains mass shells of M^4 corresponding to the roots of the polynomial P defining X^4 . Hence one expects that H^3 plays a key role in quantum TGD both discretized momentum as defining a cognitive representation with momenta, which are algebraic integers associated with extension of rationals defined by P. H^3 has infinite discrete subgroups of the Lorentz group analogous to discrete groups of translations in E^3 as isometries and H^3 allows an infinite number of tessellations (lattices). Perhaps the simplest tessellation is icosa-tetrahedral tessellation involving also octahedrons and thus all triangular Platonic solids. This tessellation could give rise to genetic code by induction of tessellation to 3-surfaces or lower-D objects such as linear biomolecules, and cell membranes [L159]. I do not however understand the mathematical details well enough but the following discussion is general.

Consider first the model for DDNA and DRNA allowing us to understand the connection between dark nucleon and dark photon realization of the genetic code physically.

- 1. The realization of DDNA/DRNA/DtRNA/DAA could correspond to a sequence of icosahedrontetrahedron pairs at H^3 contained by the 4-surface $X^4 \subset M^8$ and its H images which is also H^3 .
- 2. Each icosa-tetrahedron would contain a dark codon realized both as a face and dark nucleon triplet associated with it. The dark photon chord associated with the face must be the same as the codon defined by dark nucleon triplet. The dark nucleon triplets correspond to cyclotron frequency triplets, which in turn correspond to dark photon 3-chords associated with the Hamiltonian cycles.
- 3. The cyclotron frequencies are determined by magnetic fields at flux tubes so that Hamilton cycles must correspond to flux tube patterns. The simplest hypothesis is that the Hamilton cycle is a closed flux tube connecting all vertices of the icosahedron. Dark codon triplet corresponds to a face. It does have 1 or 2 flux tube edges if the corresponding chord contains

1 or two quints and otherwise no flux tube edges. Therefore cyclotron frequencies cannot be always associated with the edges of the triangle.

The simplest option is that the Hamiltonian flux tube following the vertex at the cycle defines the cyclotron frequency associated with the vertex. The harmony depends on the orientation of the cycle and for 8-note scale roughly corresponds the transformation from major to minor. The variation of flux tube thickness implies frequency modulation crucial for communications.

The realization of the Hamilton cycle requires that the magnetic field strength along the cycle is scaled by factor 3/2 to give a Pythagorean quint cycle. For an evenly tempered quint scale the scaling is $2^{5/12}$.

4. An interesting question relates to the relation of DDNA strand and its conjugate. The change of the orientation of the Hamiltonian cycle changes the chord of the harmony. For the ordinary 8-note scale one can roughly say that major and minor chords are transformed to each other. The orientation reversal could correspond to time reversal. The fact that the orientations of two DNA strands are opposite suggests that DNA and conjugate DNA are related by the orientation reversal of the Hamiltonian cycle inducing the map $G \to C$, $U \to A$ a the level of DNA letters. The conjugation does not imply any obvious symmetry for the corresponding AAs as the inspection of the code table demonstrates.

How could the Hamiltonian cycle determine the DtRNA codons?

- 1. DRNA codons pair with 32 DtRNA codons and DtRNA codons pair with trNA codons in 1-to-many manner. Therefore DRNA-DtRNA pairing could be universal and 2-1, although not in a codon-wise manner. This pairing should be the same for both bioharmony and dark nucleont triplets.
- 2. The pairing by 3-resonances requires that DtRNA icosa-tetrahedron contains the DRNA codons, which pair with DtRNA codon. There would be 2 DRNA codons in DtRNA icosa-hedron for most DtrNA codons and 1 codon for DtRNA pairing with DAA corresponding to met and trp. The number 32 of DtRNA implies in the case of icosa-tetrahedral code that there are 10+10-10=30 icosahedral DtRNAs and only 2 tetrahedral DtRNAs so that two faces of tetrahedron cannot correspond to DtRNA codon so that corresponding DRNAs must serve as stop codons.

One of the DtRNAs could correspond to trp. The second one would correspond to a stop codon in the vertebrate code: either the DtRNA codon is not present at all or or it does not pair with tRNA. TAG and TGA can code for pyl and sec in some bacterial versions of the code and in this case the corresponding dark DRNA codon would be represented at the DtRNA tetrahedron.

3. For bioharmony DDNA-DAA correspondence means that AAs correspond to orbits of the faces of icosahedron under the subgroup Z_6, Z_4 , or Z_2 which could correspond to reflection or to a rotation by π .

Since DRNA-DtRNA correspondence is 2-1 although not codon-wise, the natural first guess is that Z_2 orbits of the faces define the DRNA codons at the DtRNA icosahedron so that it would contain 2 codons for most DtRNAs. At the DtRNA tetrahedron the only option is Z_1 so there is a symmetry breaking.

If Z_2 corresponds to a reflection, the orbit always contains 2 codons. If Z_2 corresponds to a rotation by π , it might happen that the face invariant under π rotation and the orbit would consist of a single point. Could this explain why one has (ile,ile,ile,inet) instead of (ile,ile) and (met,met)? The rotation axis should go through the invariant face and since the face is a triangle, π rotations lead out of the icosahedron. Therefore the answer is negative.

Ile-met problem deserves a separate discussion.

1. The pairing of Z_2 related DDRNA faces with two different DtRNAs coding for ile and met rather than two mets means Z_2 symmetry breaking at the level of bioharmony. Could the fact that AUG acts as a start codon relate to this? Could it be that both AUG and AUA cannot act as start codons? It is difficult to invent any reason for this.

- 2. The symmetry breaking could occur in DtRNA-DAA pairing and replace Dmet with Dile. Is it possible that the 3-chords for coding for ile and second met are nearly identical so that the resonance mechanism selects ile instead of met? Could the situation be similar for the codons coding for (stop,stop) and (stop,trp) and cause the coding of pyl or sec in some situations? The scale for the quint cycle model with octave equivalence does not quite close. Could this have some role in the problem?
- 3. Since similar ambivalence occurs for stop codons assigned to the tetrahedral Hamiltonian cycle, one can look at the tetrahedral Hamiltonian cycle. In this case one has 3-quint cycle and a given edge of the cycle corresponds to a scaling by $(3/2)^3$ so that 4 steps gives $(3/2)^{12}$, which is slightly more than 7 octaves. For the quint scale in Pythagorean sense, one obtains 4 notes in the same octave.

Exact octave equivalence corresponding to equally tempered scale in which half-note corresponds to frequency scaling $2^{1/12}$, implies that there is only one 3-chord $CEG\sharp$: this would explain why there are 3 stop codons in the vertebrate code!

The original guiding idea in the attempts to understand the fusion of icosahedral and tetrahedral codes was that the tetrahedron is effectively glued to the icosahedron along one face. This is consistent with the icosahedral quint cycle only if the common face contains no edges of the icosahedral cycle but contains tetrahedral flux edges with $(3/2)^3$ scaling. This would give strong constraints on the common face.

If bacterial codes correspond to Pythagorean scale, there would be two different 3-chords since CEG^{\sharp} and $EG^{\sharp}C$ are not quite the same. The reason is that the frequency ratios of chords are powers of 3/2)¹². This situation is completely exceptional.

In the quint scale there are small differences between the 4 chords. Could this explain why only one of these 3-chords codes for AA (trp) in vertebrate code and pyl or sec is coded instead of stop in bacterial codes? Amusingly, the chord $CEG\sharp$ ends many finnish tangos and therefore acts like a stop codon!

Could bacteria have a perfect pitch and live in a Pythagorean world? Could the transition to multicellulars mean the emergence of an algebraic extension of rationals containing $2^{1/12} \simeq 1.059$ (, which is considerably larger than to $(3/2)^{12}/2^7 \simeq 1.0136$)! Could people with perfect pitch have in their dark genome parts using Pythagorean scale or can they tune the magnetic flux tube radii to realize Pythagorean scale?

4. Could the ile-met problem have a similar solution? The chords associated with ile and met would differ by ascaling with $(3/2)^3$ or $(3/2)^6$ using octave equivalence. These chords are not quite the same: could it happen that the 3-chord associated with the second met is nearer to that for ile? These 3-chords do not contain quint scaling and should correspond to the special chords for which no edge belongs to a Hamiltonian cycle.

Also DtRNA-DAA pairing is based on the 3-resonance.

- 1. DAA icosahedron must contain the DtRNA codons pairing with DAA. This raises the question whether DDNAs could have a direct resonant coupling to DAAs. Could this pairing occur in DDNA-DAA occurring in transcription (https://cutt.ly/QPP46St) so that pieces of DDNA and DAA associated with an enzyme involved could pair with each other by 3N-resonance at DDA-DAA level? At the chemical level the base-AA interactions are extremely complex involving stereochemistry and formation of hydrogen bonds (https://cutt.ly/RPP7plM) so that the reduction of these interactions to 3N-resonance would mean a huge simplification.
- 2. Could this resonance pairing serve as a universal mechanism of bio-catalysis and take place for various enzymes and ribozymes? One example are promoters and enhancers involved with the transcription. Enhancers and promoters induce a highly non-local process generating a chromosome loop in which two portions of DNA become parallel and near to each other and dark 3N-photons could explain the non-locality as an outcome of quantum coherence in long scales.

3. Why would DDNA-DAA pairing not occur? 3N-resonance relies on cyclotron frequencies and therefore on the magnetic field strength determined by the radii of the monopole flux tubes. One explanation would be that the frequency scales of DAA and DDNA are slightly different. Could the attachment of DRNA to translation machinery scale the magnetic field strengths of the flux tubes and their cyclotron frequencies so that only dRNA-DtRNA and DtRNA-DAA couplings are possible.

8.4 Pythagorean number mysticism, music harmony, and genetic code

The discussion with Marko Manninen renewed my interest in the ideas of Pythagoras related to mystics and mathematics and its role in music.

8.4.1 Rational Platonia

Pythagoras believed that rationals are all that is needed for a Universe and for him the discovery of $\sqrt{2}$ represented geometrically by the diagonal of a unit square was probably a shock.

It is interesting that in the TGD framework the rationals appear naturally. In its simplest form, Galois confinement [L175, L176] states that the total 4-momenta of physical states are Galois singlets invariant under Galois group permuting roots of a given polynomial (the notion generalizes if one considers functions in momentum space). This would allow only momenta with components, which are integers when a physical natural momentum unit is used. Platon would have been right in a certain sense!

However, Galois singlets would at fundamental level consist of quarks (in particular leptons and bosons would do so) having 4-momenta with components, which are algebraic integers in the extension of rationals defined by the polynomial defining the space-time region considered [L127, L128]. One could regard the algebraic integer valued momenta as virtual momenta characterizing the building bricks of physical states.

8.4.2 Special role of primes 2, 3 and 5

The number mysticism of Pythagoras involves the idea that the numbers 2 and 3 are very special. Using the language of modern number theory, one could say numbers 2 and 3 span a group with respect to multiplication consisting of numbers $2^m 3^n$, where m and n are integers. One could call this group B(2,3). If m and n are restricted to non-negative integers, the inverses do not exist and only a semigroup is obtained. This object could be called A(2,3).

If Pythagoras identified rational numbers as a kind of Platonia, this group might be said to define an important province of Platonia. A more general object would be ideal consisting of all integers proportional to, say, $6 = 2 \times 3$ closed with respect to multiplication by any integer.

It should be noticed that any set $(p_1, ..., p_n)$ of primes and even integers defines a group with respect to multiplication as the group $B(m_1, m_2, ..., m_n)$ of integers. Especially interesting example is the group B(2, 3, 5) containing B(2, 3) and B(3/2).

p-Adic length scale hypothesis states that powers of small primes near to prime define important p-adic length scales. Powers of 2 are of special importance in p-adic mass calculations [K78] but there exists also evidence for powers of 3 [I127, I128].

Decimal system is the decimal system used in everyday life and very often numerologists freely change the position of a decimal number and get results, which make sense only if the decimal system is in a special role. Could this be the case? If so, then the decimal system would not reflect only the fact that we have 10 fingers, and also the algebras B(2,5) and B(10) could be special.

There are some indications that this might be the case.

- 1. The faces of icosahedron *resp.* dodecahedron are triangles *resp.* pentagons so that numbers of 3 and 5 are natural.
- 2. DNA is a helical structure with a twist angle $2\pi/10$ between to codons so that 10 codons make a 6π twist and define length scale 10 nm which is the p-adic length scale associated

with Gaussian Mersenne prime $M_{G,151} = (1+i)^{151} - 1$, one of the 4 Gaussian Mersennes defining p-adic length scales in the range 10 nm, 2.5 μ m. These scales are a number theoretic miracle. Numbers 2,3, and 5 relate to the geometry of DNA.

8.4.3 Pythagorean scale

Pythagoras also studied music and introduced the notion of Pythagorean scale for which the frequencies of notes are in rational ratios. A standard manner to realized this scale is by quint cycle, which means that one forms the multiples $(3/2)^n f_0$ of fundamental frequency f_0 and identifies them by octave equivalence with a frequency in the basic octave $[f_0, 2f_0]$. The quint cycle appears very often in jazz.

For n = 12 the frequency obtained is almost a full number of octaves but quite not. This imperfectness of Platonia troubled Pythagoras a lot. In an equal tempered scale one introduces powers $2^{m/2n} f_0$ and avoids this problem. This means replacement of rationals by its algebraic extension generated by $2^{1/12}$.

Obviously, the Pythagorean scale is very natural in the framework of group B(3/2). Pythagoras also had ideas about the relationship of music scale and Platonic solids.

8.4.4 Pythagorean scale and genetic code

In the TGD framework, the idea about a possible connection between music and Platonic solids inspired the proposal about realization of the 12-note scale as a Hamiltonian cycle at icosahedron. The Hamiltonian cycle is a closed curve connecting only neighboring points of the icosahedron and going through all its 12 vertices. There are quite a large number of icosahedral cycles and they assign to the 20 triangles of icosahedron 3-chords proposed to define icosahedral harmony with 20 chords. The non-chaotic icosahedral cycles have symmetry groups Z_6, Z_4 , and Z_2 , which can act as a rotation or reflection.

The big surprise was that the model of icosahedral harmony leads to a model of genetic code. The code would involve a fusion of 3 different icosahedral harmonies with symmetry groups Z_6, Z_4 , and Z_2 giving 60 codons plus tetrahedral code giving 4 codons. The counterparts of amino-acids would correspond to the orbits of these symmetry groups: 3 orbits with 6 triangles and 1 with 2 triangles as orbits for Z_6 , 4 orbits with 4 triangles for Z_4 and 10 orbits with 2 triangles for Z_2 . The number of triangles at the orbit is the number of DNA codons. Tetrahedron would give the missing 4 codons and stop codons and one missing amino acid.

For a given choice of the 3 Hamiltonian cycles, the realization would be in terms of 3chords of light defining harmony for a music of light (and possibly also sound). Since music expresses and generates emotions, the proposal was that this realization of the genetic code expresses emotions already at the molecular level and that emotional intelligence corresponds to this realization whereas bit intelligence would correspond to the interpretation of codons as 6-bit sequences.

It should be mentioned that Hamiltonian cycles are solutions to the travelling salesman problem at the icosahedron: cities would correspond to the vertices. In the case of dodecahedron, which is dual of icosahedron, there is only one Hamiltonian cycle so that the harmony is now unique. If this corresponds to harmony, the first guess is that there would be a 20-note scale and 12 5-chords.

8.4.5 What about dodecahedral harmony and analog of genetic code?

Could also dodecahedron define a bioharmony and an analog of genetic code?

- The first guess is that dodecahedral harmony has 20 notes per octave and perhaps corresponds to the scale defined by micro-octaves used in Eastern music. There would be 12 5-chords and the harmony would be unique. There would exist only a single emotional mood, a kind of enlightened state.
- 2. Since the harmony is unique, and there are no other Platonic solids with pentagons as faces. The analog of genetic code should correspond to dodecahedral harmony. The 5-chords would define 12 analogs of DNA codons.

The dodecahedral cycle Z_3 acts as a symmetry group (https://jrh794.wordpress.com/ 2021/04/01/the-original-hamiltonian-cycle-continued/). This means that there are 4 orbits of Z_3 with 3 codons at each and they would correspond to 4 different analogs of amino-acids.

3. Could one consider instead of an icosahedral quint cycle with scaling 3/2 replaced with scaling 5/2? The tempered system would use powers of $2^{1/20}$ to generate a 20-note scale. A single step along Hamilton's cycle connecting neighboring vertices of dodecahedron would correspond to a scaling $f \rightarrow 5/2f$ plus octave equivalence.

By octave equivalence the scaling b y 5/2 would correspond to a transition from say C to a note between E_b and E. The microintervals between this note and either Eb or E appears in blues, jazz etc as a blue note. This interval is between minor and major.

4. One can test this. The cold shower is that $(5/2)^{20}$ is not near to a power of 2. However, one has $(5/2)^{19}/2^{25} = 1.084$ (for the quint cycle in the icosahedral case the deviation that Platon was worried of, is about 1 percent). As if one had a 19-note scale. A completely analogous situation is encountered with bio-harmony. The scales assigned to Z_6, Z_4 , and Z_2 give rise to 19 amino-acids as orbits of these groups. One amino-acid is missing and the tetrahedral code gives this amino-acid plus 3 stop codons [L196].

The icosa-dodecahedral duality suggests that the scale should consist of 19 notes only. Note however that for an equal tempered variant of the scale one does not have this problem.

5. Dodecahedral code predicts 4 analogs of amino acids. Could these "amino acids" correspond to the 4 DNA codons? 3 dodecahedral codons would be needed to code for a single genetic codon.

Could he dodecahedral codons, which correspond to 5-chords, be realized as dark 5-photons and sequences of dark 5-protons. One should check whether the states of 5 dark protons could give rise to 12 dark dodecahedral codons and whether something analogous to 12 dark RNA codons, dark tRNA codons, and 4 dark amino acids could emerge.

For the dodecahedral bioharmony, 5-chords would label the codons and they would serve as addresses based on communications relying on cyclotron resonance. Icosahedral harmony would control codons and dodecahedral harmony would code for their letters so that the codes would appear in different scales.

This speculation raises some questions. One can argue that in the transcription and replication the control of both codons and individual letters is important. This suggests that both realizations are needed for both DNA strands and correspond to different control scales. This would be true for the transcribed DNA, at least.

One can however consider alternatives. For instance, could the passive DNA strand correspond to a dodecahedral realization at the level of letters and the active strand to the icosahedral realization at the level of codons. Or could "junk" DNA and introns in promoter regions correspond to the dodecahedral realization with dark dodecahedral DNA controlling single letters.

Chapter 9

TGD View about Water Memory and the Notion of Morphogenetic Field

9.1 Introduction

This article was inspired by the proposal of Savelev *et al* published since 2019 that there exists what they call DNA resonance code [I178, I176, I177]. (see https://cutt.ly/KAe6BOd, https://cutt.ly/rArqdlA, and https://cutt.ly/EArqzSL).

9.1.1 Motivations for the introduction of morphogenetic field

Morphogenesis is one of the very poorly understood problems of biology. The mystery is how the genes can encode for the shape of the organism and guide the morphogenesis. It is extremely difficult to understand the coherence of living organisms in terms of mere biochemistry alone and the basic mechanisms of bio-catalysis are still poorly understood. Even taking into account electromagnetic fields, it is very difficult to understand how stochastic dynamics, which seems unavoidable in the standard physics, could explain morphogenesis.

This has motivated the introduction of the notion of morphogenetic field. Support for its existence and hints about its nature come from several unexplained findings made already by Gurwitch. Beloussov, Burkalov and many others continued the work of Gurwitch [I67] and produced evidence for the existence of the morphogenetic field.

Water memory is a strange phenomenon, which still induces highly emotional responses in the mainstream community although the basic objection has long ago become obsolete: if water forms representations of molecules the extreme dilution produces no problems. Benveniste and Montagnier [I92] involving the basic procedure used to produced homeopathic remedies have produced evidence that the morphogenetic field is electromagnetic and generated by DNA and interacting with it: the low frequency spectrum of the bio-active molecules can be even recorded and it creates same biological effects as the real substance. The experiments also produce support for water memory and the basic method of homeopathy involving repeated dilutions and agitation plays a central role in the experiments. Montagnier has also produced evidence for the remote replication of DNA.

Also Peter Gariaev belongs to the pioneers and phantom DNA could have interpretation as a morphogenetic field: Gariaev talks about wave DNA [I73, I75, I113, I74]. I have written with Peter Gariaev an article about remote replication of DNA [K136].

Fröhlich condensates [J26, I107, I119] [J26] are analogous morphogenetic fields and would be generated by electric dipoles. They would explain the coherence of biosystems, which is very difficult to understand in the standard physics framework. No direct support for these fields has been found hitherto.

Miller and Webb [I148] proposed 2012 that the morphogenetic field is holographic and would be generated by DNA.
The authors of the articles [I178, I176, I177] that motivated this work, propose that morphogenetic field could be generated by DNA and might realize genetic code electromagnetically making it possible to transform the genetic information in terms of shape and form of the organism in morphogenesis.

9.1.2 The counterpart of morphogenetic field in the TGD framework

Quantum TGD brings in new physics elements crucial for TGD inspired quantum biology. The idea about p-adic physics as a description of correlates of cognition emerged around 1993. The systematic work with quantum biology and consciousness started around 1995 when I made also the first p-adic mass calculations. The first publication "Biological systems as quantum coherent systems" related to quantum biology appeared in CASYS2000 conference proceedings in 2020. During the first years of milleniums several ideas emerged, mention only the hierarchy of Planck constants as a possible explanation of dark matter, its number theoretical interpretation, and the notion of $M^8 - H$ duality.

This led gradually to what I call adelic physics. Adelic physics includes not only real numbers but also p-adic number fields and their extensions and was published 2017 [L66, L67] in a book by Springer. The notion of p-adic physics was originally inspired by the p-adic mass calculations and by the idea that p-adic number fields provide the correct language for the description of cognition. The requirement of number theoretical universality led to the realization that the hierarchy formed by extensions of rationals defines an evolutionary hierarchy behind the biological and other evolutionary hierarchies.

The articles published in the Journal of Non-locality and Remote Mental Interactions (2002-) and in Journal of Non-locality (2012-), both founded by Lian Sidoroff, give an idea about the evolution of TGD and TGD inspired quantum biology and consciousness theory. The articles published in journals founded by Huping Hu (2010-) give a view about the detailed evolution of ideas since 2010. In this article, as in all my articles and books about TGD, the references to TGD are to the updated versions of articles and books at my homepage.

Besides general problems, which might be regarded as philosophical, the anomalies of the physicalistic world view have served as the source of inspiration. Several poorly understood phenomena have played a central role in the "Poiroting-like" process leading to the development of TGD based views about quantum biology. Mention only the effects of ELF em fields on vertebrate brain [J7], biophotons [I155, I98], water memory [I193, I91, I93], Pollack effect [I110, I111, L20, I162, ?], and Comorosan effect [I170, I56]. The notion of syntropy by Fantappie [J33], which challenges the belief that the arrow of time is not always the same in living systems, has been also inspiring. Also the work of Rupert Sheldrake relating to morphic resonance [I164, I165] has been inspiring

In this article I will discuss the TGD based vision and the above listed phenomena, which are often forgotten. I have written during years several articles about morphogenesis from TGD point of view [L18, L43, L90, L49, L5] and I will compare the TGD based view with the proposed interpretation of morphogenetic field as em field generated by DNA and realizing genetic code discussed in the articles of Savelev *et al* [I178, I176, I177], and compare it with the TGD based models of genetic code realized in terms of dark nucleons and dark photons. The findings described in these articles and in the articles of Yolene Thomas [I193, I194] about water memory also provide new tests for the TGD based view. As always, this kind of process led to some new ideas and insights.

9.2 Basic ideas of TGD

In this sector I will describe briefly the basic ideas of TGD relevant to quantum biology, cognition and consciousness.

9.2.1 TGD view about space-time

1. The background comes from the new physics predicted by Topological GeometroDynamics (TGD). TGD emerged as a proposal for the unification of fundamental interactions [K5] and

was based on the proposal that space-times are representable as 4-D surfaces in the 8-D space $H = M^4 \times CP_2$, the product of Minkowski space and complex projective space CP_2 . TGD can be also regarded as a generalization of string models obtained by replacing 1-D strings in 10-D space with 3-surfaces in H and identifying the orbit of 3-surface as a space-time region.

- 2. The new view of space-time and 3-space brings the shape of 3-surface as a new degree of freedom. This also implies new topological degrees of freedom not possible in general relativity, where the condition that space-time is a small deformation of M^4 does not allow them. Even Euclidean signature of the induced metric is possible and realized for the space-time surfaces representing elementary particles. Geometrization of classical fields of standard model and quantum numbers emerges. The notion of field body (magnetic body) is of key importance in TGD inspired quantum biology.
- 3. Holography is one of the key notions of TGD and also central in the TGD based model of living matter. Holography in the sense that 3-D data determine the space-time surface as a preferred extremal analogous to Bohr orbit follows from general coordinate invariance in the TGD framework [K64, K97] [L169].

One aspect of holography is the hologram like character of the space-time surface. Space-time as a conscious hologram is indeed the basic idea of TGD inspired theory of consciousness [K24]. Space-time sheets of the many-sheeted space-time located inside causal diamonds (CDs) form a hierarchy defining cognitive representations with a varying degree of accuracy and abstraction level. In the TGD framework, this translates to the p-adic length scale hierarchy and $h_{eff} = nh_0$ hierarchy of phases of ordinary matter behaving like dark matter and follows as a prediction of adelic physics [L66, L67].

9.2.2 Number theoretical vision

The concrete realization of adelic physics involves $M^8 - H$ duality as a basic building brick. $M^8 - H$ duality [L127, L128, L134] realizes evolutionary hierarchy number theoretically, justifies the hierarchy of dark matter as $h_{eff} = nh_0$ phases of ordinary matter, provides a detailed understanding of p-adic length scale hypothesis, and predicts Galois confinement as a universal mechanism for the formation of bound states. All these notions are central in the TGD inspired quantum biology.

$M^8 - H$ duality

One of the key discoveries was $M^8 - H$ duality, which states that geometrization of physics has as dual its number-theoretization.

- 1. The details of M^8H duality have developed slowly during years via several side tracks. In this view, space-times correspond to both 4-surfaces in H and in the complexification of M^8 . At the level of M^8 they correspond to "roots" of polynomials P of real argument having rational coefficients and continued to polynomials with octonionic argument. Associativity as is the dynamical principle determining the 4-surfaces in M^8 and requires associative (quaternionic) normal space.
- 2. It took a long time to realize, or rather to admit, that the "roots" correspond to 3-D mass shells of $M^4 \subset M^8$ rather than 4-surfaces as the naive expectation was. 4-D surfaced X^4 in M^8 are defined by holography, which provides an alternative explicit definition of $M^8 H$ duality, which associates with $X^4 \subset M^8$ a 4-D space-time surface in H. The image of X^4 is a minimal surface [L174] H with singularities, which is analogous to soap film with frames.

The space-time surface in H is a preferred extremal analogous to Bohr orbit, which means that, apart from singularities, it is a simultaneous extremal of both volume action and so called Kähler actio analogous to Maxwell action. This picture has a twistorial generalization and implies the twistor lift of TGD.

3. M^8 is analog of momentum space so that $M^8 - H$ duality, which maps the 4-surface in M^8 to space-time surfaces in H, can be seen as a generalization of momentum position duality of wave mechanics motivated by the replaced of point-like particles with 3-D surfaces. Cognitive

representations as points of X^4 for which the momentum components are algebraic integers define a unique discretization of X^4 . In the generic case their number is finite. At the mass shells $H^3 \subset M^4$ corresponding to the roots of P defining 3-D cross sections of X^4 the cognitive representation explode and can contain momenta with components which are algebraic integers and even rationals. One can say that intelligence as algebraic complexity is concentrated at 3-D mass shells and their images in H under $M^8 - H$ duality. This also explains why the world is experienced as 3-D.

- 4. Polynomial P with rational coefficients defines an extension of rationals partially characterized by its Galois group and by ramified primes appearing as divisors of the discriminant of the polynomial. The largests ramified prime is identified as the p-adic prime assignable to the space-time region. This notion emerged already around 1995 via p-adic mass calculations and the recent view gives justification for the p-adic thermodynamics and generalizes it to the level of scattering amplitudes. The functional composition of polynomials is an attractive general way to build many-particle states at the level of M^8 and leads to very detailed proposal for the transition matrix [L175, L176]. It is also analogous to composition of functions, which plays a key role in computationalism. Nature would be a computationalist in a number-theoretically universal sense.
- 5. Number theoretical universality requires that the momenta of fundamental particles (actually quarks) as points of mass shells in $M^4 \subset M^8$ are algebraic integers. Periodic boundary conditions however imply Galois confinement as an analog of quark confinement. The conditions require that the physical states are Galois singlets: in particular, the momentum components are ordinary integers in the scale defined by the p-adic prime. This gives a a universal mechanism for the formation of bound states [L167, L169].

Dark matter as $h_{eff} = nh_0$ phases

Number theoretical vision provides a justification for several key notions of TGD based quantum biology and introduced before the recent understanding of $M^8 - H$ duality [L127, L128, L169, L175, L176].

- 1. Number theoretical vision leads to an identification of dark matter as phases of ordinary matter with Planck constant $h_{eff} = nh_0$, where n is the dimension of extension of rationals defined by P. h_{eff} can be much larger than h. This proposal emerged considerably earlier (around 2007) and was motivated by the strange effects of ELF radiation on the behavior and physiology of vertebrates [J7].
- 2. h_{eff} hierarchy makes quantum coherence possible in arbitrarily long scales and magnetic bodies (MBs) of the systems would carry dark matter in this sense. MB has an onion-like structure with layers labelled by h_{eff} and layers would form a master-slave hierarchy with ordinary biomatter at the bottom.
- 3. The value of h_{eff} depends on the character of interactions mediated by the flux tube. $h_{eff}/h < 100$ could be associated with valence bonds and hydrogen bonds [L62] and more generally to flux tubes mediating electromagnetic interactions.

Nottale hypothesis [E1] introduces gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where $v_0 < c$ has dimensions of velocity. In the TGD framework \hbar_{gr} is interpreted as a genuine Planck constant and reflects dark matter, which corresponds to a high-dimensional extension of rationals [K101, K84]. Note that the dimension of extension can be exponentially larger than the degree of the polynomial P: if the Galois group is the permutation group for roots, the dimension is n!.

The large value of h_{gr} conforms with the long range of gravitational interactions and predicts quantum gravity in arbitrarily long scales. The gravitational Compton length $\Lambda_{gr} = GM/v_0$ for a particle with mass m is independent of m and of the order of the Schwartzschild radius for mass M. Also cyclotron energy $E_c = \hbar_{gr} ZeB/m = GMZeB$ is independent of m. Both these features conform with the Equivalence Principle and are expected to play a crucial role in quantum biology [K85] [L78, L171].

9.2.3 Zero energy ontology

Zero energy ontology (ZEO) [K132] [L118, L165] is a further key notion of TGD and of TGD inspired biology and consciousness theory.

1. In ZEO quantum states as time= constant snapshot are replaced with a superposition of space-time surfaces as preferred extremals analogous to Bohr orbits.

In biology and neuroscience functions and behaviors as precise time sequences are typical and have preferred extremals realized as a minimal 4-surface with singularities as space-time correlates. Genes would not code only 3-D structures but also their time evolutions, which would be dictated by 3-D initial values (3-surface) by Bohr orbit property.

The motivation for the notion of morphogenetic field indeed is that biological processes look like computer programs or even better sequences of planned actions, rather than stochastic processes.

2. ZEO leads also to a new view about state function reduction (SFR) solving the basic problem of the standard quantum measurement theory. The basic prediction is that time reversal occurs in ordinary ("big") SFRs (BSFRs) but not in "small" SFRs (SSFRs) which replace the repeated measurement giving rise to the Zeno effect. The sequence of SSFRs correspond to the flow of consciousness for self as a conscious entity. Any un-entangled system can be regarded as self whose life corresponds to a sequence of SSFRs ending with BSFR changing the arrow of time and meaning reincarnation of self [L140, L154].

The basic implication of ZEO is that BSFRs in even macroscopic scales for subsystems look like deterministic classical time evolutions for the observer with opposite arrow of time [L104] and Minev *et al* indeed observed this in atomic scales [L104]. No transition zone from quantum to classical is needed. For instance, there is evidence that earthquakes could be regarded as macroscopic BSFRs.

This has also implications for the dynamics of DNA, in which time reversals might play a key role [L222, L224]. Quite generally, the phenomenon of quantum tunnelling could involve two sub-sequent BSFRs and tunnelling would correspond to a temporary change of the arrow of time [L169, L165].

- 3. The possibility of time reversal forces to generalize thermodynamics and leads to a generalization of second law. Time reversed subsystem obeys second law in reversed time directions and from the point of view of the system breaks it. This suggests a new mechanism of selforganization (in particular biological) as time reversed dissipation taking place spontaneously rather than as a result of intricate programming as in a computationalistic framework. This suggests a new view about homeosatasis [L225].
- 4. ZEO based theory of consciousness can be regarded as a generalization of quantum measurement theory based Negentropy Maximization Principle (NMP) [K73] [L162], which involves, besides ordinary entropy with matter, the p-adic entropies assigned with cognition which can be negative and tend to be so by NMP. The theory is consistent with the second law and explains the paradoxical looking findings of Jeremy England that biosystems seem to be maximal entropy producers.

9.2.4 Quantum criticality of TGD Universe

The notion of quantum criticality of TGD Universe was originally inspired by the question about how to make TGD unique if Kähler function $K(X^3)$ in WCW is defined by the Kähler action for a preferred extremal $X^4(X^3)$ assignable to a given 3-surface. Vacuum functional defined by the exponent of Kähler function is analogous to thermodynamical weight and the obvious idea with Kähler coupling strength taking the role of temperature. The obvious idea was that the value of Kähler coupling strength α_K is analogous to critical temperature so that TGD would be more or less uniquely defined. α_K is expected to have several values.

The precise meaning of quantum criticality is far from obvious. The recent progress in understanding the number theoretical aspects has however led to a considerable progress in this respect [L182].

- 1. The exponent exp(-K) of Kähler function K is the action for the preferred extremal (PE) as a space-time surface in H. PE has 3-surfaces X^3 and Y^3 as its ends at the boundaries of causal diamond (CD= cd × CP₂) of H.
- 2. Ideal holography would mean that Y^3 is fixed once Y^3 is known. PEs are however not completely deterministic but analogous to soap films with frames, which are known to allow non-determinism in the sense that frame does not define the soap film uniquely [L174, L182]. Hence X^3 does not fix Y^3 completely but there is a finite number of alternatives for given X^3 .
- 3. X^3 at the passive boundary of CD corresponds to a maximum of K under variations of X^3 in accordance with its passive character. Note that the WCW metric has zero modes not appearing in the metric of WCW so that the maxima could correspond to different values of zero modes. These could define the analog of spin glass energy landscape. Also transitions transforming zero modes to non-zero modes and vice versa are possible.
- 4. Y^3 at the active boundary of CD corresponds to a more general extremum of K with respect to variations of Y^3 , a saddle point. This means criticality. The criticality corresponds to the classical non-determinism of preferred extremals. This leads to a vision about WCW homology as a generalization of Floer homology and characterizing the non-determism of the action [L182].
- 5. The sequence of SSFRs can be seen as a process leading from a saddle point towards maximum of K, somewhat analogous to the thermodynamical process leading to a thermal equilibrium as maximum of entropy. The non-determinism of SSFRs has as a correlate the classical determinism of preferred extremals.

It is now clear that the values of α_K is determined by the extension of rationals determined by polynomial P [L127, L128, L175, L176, L182].

- 1. Space-time region $X^4 \subset H$ is the image of a 4-surface of M^8 under $M^8 H$ duality. The 4-surface in M^8 is determined by a polynomial P and by holography which actually defines the $M^8 H$ duality explicitly.
- 2. The vacuum functional exp(-K) for a maximum of K must be equal to number theoretical quantity associated with P. The most natural candidate is the discriminant D of P which is the product of squares of root differences for P: exp(-K) = 1/D. This condition predicts a spectrum of α_K appearing in K. p-Adic prime corresponds to the large primed dividing D.

9.3 Basic ideas of TGD inspired quantum biology and theory of consciousness

This section summarizes in more detail the ideas and concepts relevant for TGD inspired theory of consciousness and quantum biology.

9.3.1 Quantum criticality in biology

Quantum criticality [?] has become key concept of quantum TGD and TGD inspired biology. Quantum criticality allows to understand the hierarchy of Planck constants and also its relationship to p-adic length scale hypothesis, whose origin reduces to number theoretic vision about TGD [K126]. Dark matter phases characterized by $h_{eff} = n \times h$ accompany any quantum critical system, maybe even thermodynamically critical systems. The challenge is to find concrete realizations of quantum criticality in various scales. In biology biochemical realization is of special interest.

The basic aspect of quantum criticality is that the increase of h_{eff} occurs *spontaneously* since the process corresponds to increase of negentropy and NMP states that negentropic entanglement resources of the Universe are increasing as kind of Akashic records or cosmic library. At the level of selves this means that self "dies" and re-incarnates as its time reversal. Selves fight for survival and try to grow their negentropic resources to satisfy the requirements of NMP. This leads to metabolism and homeostasis characterizing living systems. The emergence of life would not be extremely rare accident but doomed to occur spontaneously sooner or later by basic law telling what happens in state function reduction in TGD Universe obeying Zero Energy Ontology (ZEO). Hence the process should occur spontaneously and increase h_{eff} .

- 1. The basic question is how quantum criticality is realized biochemically. Are the molecules excited near to a critical energy at which a dark ion at magnetic flux tube is generated and a phase transition analogous to that leading from ordinary to fourth phase of water occurs? Or are large systems near criticality to a generation of dark phase as the general vision about quantum criticality of TGD Universe suggests.
- 2. A natural assumption is that metabolic energy quantum should be able to induce the phase transition producing dark particles at criticality. Could dark photons in visible and UV range accompany criticality at the level of single molecule? Are cell membrane and neuronal membrane quantum critical systems and how they differ?
- 3. Dark variants of biologically important ions residing at magnetic flux tubes are in fundamental role in TGD inspired quantum biology. In particular, dark proton states are proposed to give rise to the dark analogs of DNA, RNA, amino-acids, and tRNA. The pairing of ordinary DNA/RNA/amino-acids with their dark analogs is expected to be fundamental in biology and transcription and translation are proposed to take place at dark level as the recent experimental findings indicate. How is this pairing realized? How ordinary DNA becomes paired with dark DNA or is it already paired with it?

9.3.2 MB carrying dark matter as controller of ordinary biomatter

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L127, L128], and interpreted as a universal IQ. The scales of quantum coherence increase with h_{eff} . The layers of MB characterized by the value of n naturally form a master-slave hierarchy in which ordinary matter with the smallest Planck constant is at the bottom, and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, an energy feed is needed to preserve the distribution of h_{eff} : the interpretation is as an analog of a metabolic energy feed.

MB acts as a "boss" controlling ordinary matter and induces self-organization [L113].

Anatomy of MB

MB has, as its body parts, magnetic flux quanta: flux tubes and flux sheets. There are two kinds of flux quanta. Flux can be vanishing, which corresponds to a Maxwellian regime. Flux can also be non-vanishing and quantized corresponding to a monopole flux. In the monopole case, the magnetic field requires no current for its creation. This option is not possible in the Maxwellian world. By fractality of the TGD Universe, these flux tubes play a key role at all scales [L105].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part (see Fig. ??) corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss and explains the strange effects of ELF EM radiation on the physiology and behavior of vertebrates [J7].

The presence of this part explains the stability of the Earth's magnetic field. This field should have decayed long ago in a Maxwellian world since it is generated by currents which disappear. The contribution of the molten iron in the Earth's core to B_E decays but the changes of the orientation of B_{end} regenerate it [L30]. Also, magnetic fields that penetrate super-conductors as quantized fluxes and even those of permanent magnets (as opposed to electromagnets) may have a monopole part consisting of flux quanta.

2. The interaction of MB with the gravitational field of Earth is discussed in [L172]. Intriguingly, the metabolic energy currency with the nominal value of .5 eV is rather close to the energy for the escape velocity of a proton. Could the transfer of ions from the surface of the Earth to MB be a standard process?

Evidence for dark charged particles

The notion of dark matter as a controller of biomatter preceded its justification based on number theory [L67, L66].

- 1. The values of $h_{eff} = nh_0$ must be so large that the energies $E = h_{eff} f$ of dark photons with EEG frequencies are in the biophoton energy range (visible and UV) assignable to molecular transitions [K20, K31].
- 2. What makes the large values of h_{eff} possible? Nottale's hypothesis [E1] introduces the notion of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$, whose form is fixed by an Equivalence Principle (EP). In the TGD framework, $h_{eff} = h_{gr}$ is assigned to gravitational flux tubes [L78]. There are non-trivial implications that reflect EP.
 - (a) The cyclotron energy spectrum $E_c = n\hbar_{gr}eB/m = nGMeB/v_0$ does not depend on the mass *m* of the charged particle and is thus universal. The energies involved are proposed to be in the range of biophoton energies (at least) suitable for control of the transitions of the bio-molecule. One cannot exclude lower energies above thermal energy for physiological temperature.
 - (b) The gravitational binding energies of a mass m for Bohr orbits around M do not depend on M at all [L172].

Also relatively small values of h_{eff} are possible.

1. Electrons can also have dark phases, but now the value of h_{eff} would be much smaller and satisfy the generalized Nottale hypothesis $h_{eff} = h_{em}$, where h_{em} is the electromagnetic analogue of h_{gr} assignable to flux tubes accompanying valence bonds. This inspires a model of valence bonds [L62] predicting that the value of $h_{eff}/h_0 = n = h_{em}$ increases along the rows of the Periodic Table.

This picture can explain why molecules such as proteins containing atoms towards the right end of the rows of the Periodic Table are ideal carriers of metabolic energy. It also explains why ions, such as Ca⁺⁺ involved with the control and communications of the cell membrane with the "large" part of MB and having very large $h_{eff} = h_{gr}$, are towards the left end of the rows.

2. The energy scale of dark variants of valence electrons is proportional to $1/h_{eff}^2$ so that the orbital radii are scaled up and the identification as a Rydberg atom provides the only possibility in the standard physics model. Could dark valence electrons be in question? There is empirical evidence, known for decades, for the mysterious disappearance of valence electrons of some rare earth metals in heating. An article by Chatterjee *et al* [L64] discusses this phenomenon for Yb.

The finding [D6] about "misbehaving" Ruthenium atoms also supports the view that covalent bonds involve dark valence electrons. Pairs of Ru atoms were expected to transform to Ru dimers in thermo-dynamic equilibrium but this did not happen. This suggests that valence electrons associated with the valence bond of Ru dimers are dark in the TGD sense and the valence bonded Ru dimer has a higher energy than a pair of free Ru atoms.

TGD based explanation [L64] could be justified by a resonant coupling of dark electron with an ordinary Rydberg state of the valence electron. In the lowest approximation, dark valence electrons have energies in the spectrum of ordinary valence electrons so that a resonant coupling with Rydberg states can be considered. The evidence found by Randell Mill [D7] for atoms with an abnormally large scale of binding energy suggests the formula $h = 6h_0$ [L41]. Atomic binding energies are proportional to $1/h_{eff}^2$ and Mills reports that the binding energy scale can be 4 times larger than for ordinary atoms. This would correspond to $h_{eff} = h/2$.

Pollack effect

In the Pollack effect (PE) [I162] negatively charged exclusion zones (EZs) are induced at the boundary between the gel phase and water by an energy feed such as IR radiation. The negative charge of EZ is explained as a formation of flux tubes carrying dark protons, which are interpreted as dark nuclei. Every 4^{th} proton should transform to a dark proton transferred to the flux tubes to explain the observations.

A simple model for linear dark proton triplets predicts their states to be in a 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be the same as for the vertebrate genetic code [L77, L103]. This suggests deep connections between nuclear physics and condensed matter physics, chemistry, and biology, which, in the reductionistic spirit, are considered separate disciplines.

EZs are able to remove impurities from their interior in conflict with the second law of thermodynamics (SL). The TGD based explanation is that the time reversal by BSFR at the level of MB [L118] also induces an effective time reversal in long time scales at the level of ordinary bio-matter.

PE explains the occurrence of a charge separation in living matter. DNA has one negative charge per nucleotide, microtubules are negatively charged, the cell is negatively charged, and ATP carries 3 units of negative charge. Therefore ZEO suggests that PE plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

Basic differences between organic and in-organic matter

One of the basic differences between organic and in-organic matter would be the presence of dark protons and electrons.

- 1. The notions of acids and bases would reduce to the presence of dark protons: pH would characterize the fraction of dark protons. Reduction and oxidation (the REDOX reaction) could be understood in terms of a transfer of dark electrons associated with valence bonds [L228].
- In biochemistry the density of dark protons would be much higher in PE [I110, I111, L20, I162, I197]. Dark ions could play a key role in TGD based view of biochemistry as the findings of Blackman and others suggest [J7].

Biocatalysis and water memory

Bio-catalysis and water memory [I186] remain mysteries in the bio-chemical approach. MB carrying dark matter could provide the needed mechanisms. Reconnection of flux tubes would be the basic mechanism of bio-catalysis and also explain water memory, which in the TGD framework forms the basis of the immune system [K62].

- 1. According to the TGD view of catalysis, tentacle-like U-shaped flux tubes associated with MBs of reactants reconnect to a pair of flux tubes connecting the molecules [L88]. This happens if there is a cyclotron resonance for dark cyclotron radiation assignable to massless extremals (MEs) associated with these "tentacles". This requires that the flux tubes have identical magnetic field strengths and by flux quantization the same thickness. The same value of h_{eff} guarantees resonance. The next step is the shortening of the "tentacles" by a reduction of h_{eff} and the liberation of energy which "kicks" the reactants over the potential wall making an otherwise extremely slow process possible.
- 2. The physics of water is plagued by anomalies [I186]. TGD suggests an explanation [L71] in terms of flux tubes assignable to hydrogen bonds [L71, L89]. These flux tubes could have $h_{eff} > h$ so that these flux tube could be long and give rise to long range quantal correlations. Water could be seen as a many-phase system. MBs assignable to water molecule clusters could mimic the cyclotron frequency spectrum of the invader molecule and make possible water memory and a primitive immune system based on reconnections of the "tentacles" of a water cluster and invader molecule [L137]. In this framework water would represent a primitive life form.

Comorosan effect

Comorosan effect [I170, I56] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546 \ nm$, which corresponds to photon energy 2.27 eV. As a result of irradiation molecules seem to undergo a transition $S \rightarrow S^*$. S^* state has anomalously long lifetime and stability in solution. $S \rightarrow S^*$ transition has been detected through the interaction of S^* molecules with different biological macromolecules, like enzymes and cellular receptors. I have discussed Comorosan effect in [K131] but the discussion reflect the state of TGD for decades ago.

The typical result in the enzyme-substrate interaction is represented by the enhancement of the enzymic rate, when the respective enzyme substrate is previously irradiated for certain sharply defined times. These *efficient (irradiation) times* are enzyme dependent and can also depend on the biological origin of the enzyme.

The *intensity of laser light does not matter*. What is needed is that the intensity is above certain threshold. The original explanation in terms of saturation of effect (for large intensities of laser light the effect of laser light on organic molecules does not depend on the intensity) has turned to be unsatisfactory.

The effective times are always of the following type $t_i = i * 5$ sec, where i is certain integer. The general formula for the effective times is $t_k = t_m + (k-1)\tau_n$, k = 1, 2, ..., 6, where t_m is the minimum radiation time inducing the first effect and τ_n is the period between two consecutive effects [I170, I56]. $t_m = m_E t_1$ and $\tau_n = n_E t_1$ are multiples of the basic time scale $t_1 = 5$ sec: $t_k = (m_E + (k-1)n_E)t_1$. The integers m_E and n_E can be regarded as enzyme characteristics, depending however on the biological origin of the enzyme.

Consider the specific enzymic interaction $E + S \leftrightarrow ES \leftrightarrow E + P$, where E stands for enzyme, S for substrate and P interaction product. Assume that substrate S is subject to a sequence of distinct irradiations lasting for times t_a, t_b, \dots The following rules are found to hold true.

- 1. The irradiations of the substrate performed after an irradiation with efficient time have no effect on the enzyme-substrate interaction.
- 2. Any arbitrary irradiation of the substrate with irradiation time less than sixth efficient time t_6 performed prior to any other efficient time, is irrelevant for the enzyme-substrate interaction.
- 3. Any arbitrary irradiation of the substrate lasting more than the sixth efficient time t_6 and performed prior to an efficient time precludes all other subsequent effects in enzyme-substrate interaction.
- 4. Note that the time scales 5,10, 20 seconds have been observed in the clustering of RNA polymerase molecules [I69] discussed from TGD view point in [L80].

The work of Comorosan demonstrates that all irradiation times have nontrivial effect on organic molecules but that for effective times something very special must occur. One should understand what this "very special" is, derive Comorosan formula from a physical model and find a physical interpretation for the integers m_E and n_E appearing in the formula as well as explain the special role of $t > t_6$ irradiation times.

Comorosan effect suggests that communications to MB could take place even at the level of relatively simple biomolecules. One can get some grasp about the situation by considering simplest possible picture that one can imagine.

- 1. It seems that laser light keep care that a connection from the system MB is generated and preserved a critical time for the phase transition to take place. The phase transition itself could correspond to increase of h_{eff} . The problem is to understand why the intensity of laser light does not manner. This suggests that the flux tube can receive the energy of the laser light energy with some fixed rate depending on the enzyme. The receiver could be the MB of enzyme and that it has a dead time after the receival of quantum of laser light.
- 2. The proposal is that Josephson junctions are involved and the Josephson frequency $f_J = ZeV/h_{eff}$ defines the time scales in question.

- 3. The assumption $\hbar_{eff}/\hbar = \hbar_{gr}/\hbar = GMm/v_0 = 2r_s(E)m/v_0$, where $M = M_E$ is the mass of Earth, $r_s(E) = .09$ m and $m = 2m_e$ as mass of electron Cooper pair, m_e is electron mass, allows to estimate the parameter $\beta = v_0/c$ assuming $f_J = E_J/h_{gr}$ is equal to Comorosan frequency $f_C = 1/T_C = .2$ Hz. For Josephson energy $E_J = 2eV \simeq .1$ eV of electron Cooper pair, this gives the estimate $h_{gr}/\hbar \simeq 5 \times 10^{13}$. The value of β_0 would be $\beta_0 \simeq .93$ near its maximal value. This estimate is consistent with the estimate of [L168].
- 4. There are two especially important cyclotron frequencies in endoenous magnetic field B_{end} with nominal value .2 Gauss.
 - (a) The cyclotron energy $E_c = \hbar_{gr} ZeB_{end}/m$ of a charged particle does not depend on its mass. For Fe^{++} ion f_c in the endogenous magnetic field $B_{end} = 2B_E/5 = .2$ Gauss equals alpha frequency $f_c(Fe^{++}) = f_{\alpha} = 10$ Hz. Cyclotron energy $E_c(Fe^{++}) = h_{gr}f_c = 2.5$ eV. Note that this energy is not far from the energy 2.27 eV of photons in the experiments of Comorosan suggesting that they were in energy resonance with dark Josephson photons or were in energy resonance with them. For $\beta_0 = 1$, one would have $E_c(10Hz) = 2.44$ eV. For $E_c = 2.24$ eV one would obtain $\beta_0 = 1.024 \ge 1$. Scaling of 10 Hz alpha frequency to 9.3 Hz would allow $\beta_0 = 1$ and E = 2.27 eV.
 - (b) DNA cyclotron frequency $f_J(DNA)$ is another probably very important frequency. It depends only weakly on DNA length and the base-pair it has has average value 1 Hz which corresponds to energy .244 eV. This is roughly 1/2 of the metabolic energy quantum.
 - (c) To sum up, for $\beta_0 = 1$, one can relate to each other f_C , $f_J(Fe^{++}, B_{end})$ and $f_J(DNA, B_{end})$, and the corresponding cycltron energies and the value of the membrane potential.

This model alone does not explain much. What happens looks like an outcome of a control action and should take place at the level of MB: the irradiation affects the MB of the E+S complex, which responds at times t_k . One can also assume the TGD inspired view about biocatalysis and look at what this gives.

- 1. The time $t_1 = 5$ s need not correspond to dark Josephson time for a given enzyme for which has 6 special irradiation times $t_k = t_m + (k_1)\tau_n$, k = 1, ..., 6, which are multiples $n_k t_1$ of t_1 . This would scale up h_{gr} by n_k and v_0 would be scaled to v_0/n_k . Therefore one would have a spectrum of $v_0 = 1/n$, with each enzyme allowing 6 different values of n. t_1 would be minimal Josepson time corresponding to maximal $v_0 = c$.
- 2. What could happen in the transition at t_k ? Why certain multiples $n_k t_1$ would define thresholds at which enzyme activity increases? Could one interpret this in terms of MB controlling the E+S complex?

At these specific moments enzyme action would be affected. If enzymatic action involves a reduction of h_{eff} for flux tubes connecting E and S, one might think that the Δh_{eff} increases and more energy is provided to overcome the potential wall slowing down the reaction. Reaction becomes faster.

- 3. Could the irradiation induce phase transitions increasing the h_{eff} for these flux tubes. Could these flux tubes be the flux tubes with $h_{eff} = h_{gr}$ and could the phase transition change the value of $v_0 = 1/n$ to new subharmonic and scale h_{gr} by n. The length of flux tubes would increase and the energy liberated in the shortening would be proportional to $\Delta h_{gr} \propto \Delta n$. The irradiation corresponds to $f_c(Fe^{++} = 2.27 \text{ eV})$ all the time. If an increasing value of h_{gr} is associated with catalyst flux tubes, alpha frequency must be changed to is sub-harmonic $f_c(Fe^{++}/n)$ in each phase transition bringing in longer length scales.
- 4. Why the transitions should take at such precise values t_k of time characterizing the enzyme? h_{gr} has a number theoretic origin that reflects the polynomial deterministic dynamics at the level of M^8 analogous to Bohr orbit dynamics at the level of H. If quantum non-determinacy has the failure of string determinism for the space-time surface as 4-D soap films with frames

as a correlate, one would expect that these phase transitions occur deterministically. One can also ask whether quantum jumps replace polynomial P with a new one.

Could the times t_k correspond to SSFRs or to the pairs of BSFRs giving rise to quantum tunnelling between the different phases at MB?

Why should t_k be some integer multiples of t_1 . What comes to mind is time crystal structure associated with the 4-D soap film with frames.

- 5. Threshold effect could be in question. The irradiation could play the role of metabolic energy feed. This might help to understand why the phase transitions occur at times t_k . For instance, the irradiation could transfer dark electrons at flux tubes as in the Pollack effect. It could also induce a phase transition of Bose-Einstein (BE) condensate at the magnetic body of the enzyme (phase transition of a spin glass-like structure analogous to spontaneous magnetization). The obvious possibility is the BE condensate of electron Cooper pairs. The increase of h_{eff} requires energy and when some minimum energy is feeded, the transition occurs.
- 6. Could laser photons be transfered to the flux tube photons with a rate determined by the flux tube alone as a slow step of the process, where it forms an dark N-photon state. N would increase steadily and when the energy of this state exceeds a threshold defined by the Josephson energy $E_J = 2ZeV$ a Cooper pair is created, which means that MB sends an ordinary photon with this energy to the aromatic ring and kicks out a Cooper pair. The number of laser photons would be such that the energy exceeds the binding energy of p^2 electron pair in the aromatic ring. A rough estimate for this energy as $E \simeq 2(Z^2/n^2)E_H$, $E_H = 13.6$ eV would be about 122.3 eV and gives $N \geq E/22.7 \geq 54$.
- 7. Why the number of transitions is 6? Could this relate to aromatic 6-ring as a basic object? The electron configuration of C is $[He]2s^22p^2$. There is one p^2 state as an candidate of the Cooper pair for each Carbon atom. Could the 6 steps correspond to a sequence of transitions in which one p^2 state becomes a dark Cooper pair.

Could base pairs act as Josephson junctions?

The basic idea is that each system has a "biological body" (BB) and MB and that BB sends sensory data to MB which in turn controls it. The idea about nuclear membrane as a communicator of sensory data to MB using dark Josephson radiation looks attractive. Is it enough to send the sensory data from the nuclear membrane only? Or could the sensory data from DNA be sent along flux tubes to the nuclear membrane to MB? Or could it be sent directly from DNA? The idea of base pairs as Josephson junctions need not be realistic but deserves to be shown wrong, if not anything else.

- 1. The sensory communication from DNA using a series of base pair Josephson junctions should utilize dark genetic code based on 3N-photons fused by Galois confinement to longer units like genes. The frequency triplet, 3-chord, must be different for codons, which differ only by the order of letters. This is impossible if one assumes that the letters are independent. The process of adding letters to codon and codons to DNA sequence must be non-commutative and one can speak of a well-defined order. This order naturally corresponds to the orientation of DNA strands.
- 2. In the number theoretic vision, many particle systems correspond to space-time sheets, which are obtained by $M^8 H$ duality from a 4-surface of M^8 obtained by holography from the roots of an octonionic continuation of a real polynomial P with rational coefficients. P is obtained as a non-commutative functional composition of real polynomials.

The spectrum of the roots has an interpretation as quantized virtual mass squared values specifying the mass shells $H^3 \subset M^4 \subset M^8$, which define holographic data. The root spectrum of a composite depends on the order of polynomials in the composite.

The letters A,T,C,G of codon could correspond to 4 different polynomials P_i , i = 1, ..., 4and codons would be composites of form $P_i \circ P_j \circ P_k$. If the order of functional composition corresponds to the orientation of the strand, it would be opposite for strand and conjugate strand and the 4-surfaces corresponding to strand and conjugate strand would not be simply the same surface but with opposite direction. Only for palindromes, the base pairs A-T and T-A (C-G and G-C) at the opposite ends of the double strand are equivalent if the picture based on polynomial composition is correct. This could explain the different biological roles of strands. Also the halves of many binary structures of biology, such as brain hemispheres could have a similar relationship.

- 3. Base pair would give rise to a basic Josephson junction between aromatic rings acting as superconductors. These elementary Josephson currents would integrate to to 3N-Josephson junction as a quantum coherent unit. The emitted Josephson photons would be dark 3Nphotons analogous to BE condensates.
- 4. The delocalization of protons in the hydrogen bonds of base pairs A-T and C-G would take place. In the delocalization the proton tends to shift to the direction of the atom to which hydrogen bonding takes place. Protons generate a polarization creating an electric field in which electron Cooper pairs move but at different space-time sheets than protons. This would produce oscillatory Josephson current emitting Josephson photons [K92]. The dark electron Cooper pair currents would originate from the aromatic rings. Note that the Josephson voltage would be the same along all space-time sheets.
- 5. The pairing of aromatic rings by hydrogen bonds need not be the only way to create dark Josephson junctions. Also Josephson junctions between hydrogen bonded molecules without any aromatic rings can be considered. Pollack effect creates negatively charged exclusion zones (EZs) in water. The protons would be transferred to dark proton sequences at the flux tubes whereas the electrons of EZ would form dark electron Cooper pair condensates generating Josephson currents and Josephson radiation perhaps making possible communications between these systems.
- 6. An estimate for the Josephson voltage is obtained by assuming that the Josephson voltage scales as the inverse of the size scale of the basic object. For neuron membrane of thickness D=10 nm (for cell membrane the thickness is nearer to 5 nm) is replaced with A-T or C-G pair with thickness of d=.34 nm. This gives an estimate for the energy $E_J = 2eV$ of Cooper the estimate $E_J = (D/d) \times .01 \text{ eV} = 3.3 \text{ eV} (1.75 \text{ nm})$. This energy looks rather reasonable. Interestingly, this is not too far from the energy 2.27 eV associated with the laser photons inducing the Comorosan effect already discussed.

In Comorosan effect [I170, I56], the irradiation with a laser beam with a photon energy $E_J = 2.27$ eV would generate the BE condensate of dark Cooper pairs. This might be true also for the base pairs. This should be testable.

Biosystem as a spin glass like system

Spin glasses represent an exotic phenomenon, which remains poorly understood in the standard theoretical framework of condensed matter physics. Actually, spin glasses provide a prototype of complex systems and methods used for spin glasses can be applied in widely different complex systems. Biology is certainly one the most interesting applications.

In [L166] a TGD inspired view about spin glasses is discussed.

- 1. TGD view about space-time leads to the notion of magnetic flux tubes and magnetic body. Besides spins also long closed magnetic flux tubes would contribute to magnetization. The basic support for this assumption is the observation that the sum of the NFC magnetization and the FC remanence is equal to the NFC magnetization. Magnetic field assignable to spin glass would correspond to a kind of flux tube spaghetti and the couplings J_{ij} between spins would relate to magnetic flux tubes connecting them.
- 2. Quantum TGD leads to the notion of "world of classical worlds" (WCW) and to the view about quantum theory as a "complex square root" of thermodynamics (of partition function). The probability distribution for $\{J_{ij}\}$ would correspond to ground state functional in the space of space-time surfaces analogous to Bohr orbits.

3. Spin glass is a prototype of a complex system. In the TGD framework, the complexity reduces to adelic physics fusing real physics with various p-adic physics serving as correlates of cognition. Space-time surfaces in $H = M^4 \times CP_2$ correspond to images of 4-surfaces $X^4 \subset M_c^8$ mapped to H by $M^8 - H$ duality. X^4 is identified as 4-surface having as holographic boundaries 3-D mass shells for which the mass squared values are roots of an octonionic polynomial P obtained as an algebraic continuation of a real polynomial with rational coefficients. The higher the degree of P, the larger the dimension of the extension of rationals induced by its roots, and the higher the complexity: this gives rise to an evolutionary hierarchy. The dimension of the extension is identifiable as an effective Planck constant so that high complexity involves a long quantum coherence scale.

The TGD Universe can be quantum critical in all scales, and the assumption that the spin glass transition is quantum critical, explains the temperature dependence of NFC magnetization in terms of long range large h_{eff} quantum fluctuations and quantum coherence at critical temperature.

- 4. Zero energy ontology predicts that there are two kinds of state function reductions (SFRs). "Small" SFR would be preceded by a unitary time evolution which is scaling and generated by the scaling generator L_0 . This conforms with the fact that relaxation rates for magnetization obey power law rather than exponent law. "Big" SFRs would correspond to ordinary SFRs and would change the arrow of time. This could explain aging, rejuvenation and memory effects.
- 5. Adelic physics leads to a proposal that makes it possible to get rid of the replica trick by replacing thermodynamics with p-adic thermodynamics for the scaling operator L_0 representing energy. What makes p-adic thermodynamics so powerful is the extremely rapid convergence of Z in powers of p-adic prime p.

Is there an analogy between dark information molecules and spin glasses?

1. The TGD based model for spin glass involves dark flux tubes with a local magnetization and the state could be seen as a kind of flux tube spaghetti. Also the dark variants of basic information could be seen as this kind of flux tube structures.

Quantum criticality of TGD suggests that the flux tube configuration has a large number of energy degenerate states and that this is essential for morphogenesis controlled by counterparts of dark genes. In fact, the huge non-determinism of Kähler action due to the existence of vacuum extremals with a CP_2 projection, which is Lagrangian manifold, led to the notion of 4-D spin glass. Twistor lift removes the non-determinism and reduces degeneracy by adding to the action a small volume term, whose coefficient is proportional to a length scale dependent cosmological constant. 4-D spin glass degeneracy is expected to reduce to 3-D spin glass degeneracy.

2. Spin and weak isospin distinguishing between dark neutron and proton are in a key role in the proposed model for the dark nucleon realization of the genetic code [L196]. Codons correspond to closed flux tubes containing 3 dark nucleons connected by pion-like flux tube contacts. The states of this object give rise to dark information molecule DX paired with X, X=DNA, RNA, tRNA, and AA. The states correspond to tensor products of spin-isospin states in representation $4_I \times 4_s$ of 3 dark nucleons with the angular momentum state of stringlike flux tube possessing orbital angular momentum L and correspond to $5 \oplus 3$ (spin 2 and spin 1) for DDNA, DRNA and DtRNA and singlet 1 for DAA as representations of rotational group. In spin and nuclear spin degrees of freedom DDNA corresponds to $(1/2, -1/2)_I \otimes 4_s$, DRNA to $(3/2, -3/2)_I \otimes 4_s$ and DtRNA to $2_I \otimes 2_s$. 32 DtRNAs are predicted and this is the minimal number. The pairing of DtRNAs with tRNAs need not be unique.

Remark: Genetic code has a complete (U-C) symmetry and almost complete A-G symmetry with respect to the third nucleotide of RNA codon. These symmetries have an interpretation in terms of rotational symmetry [L196]. What could be the interpretation of purine sequences (A and G) paired with pyrimidine sequences (T and C) in this picture?

Could one understand how the dark information molecules DX (X refers now to DNA, RNA, and proteins P rather than codons and AAs) could control the conformations of X?

1. The spin state of the dark codon varies along the flux tube so that dark information molecules as flux tubes carrying various spin states differ from the simple ferromagnetic or antiferromagnetic system locally. In spin glasses, ferromagnetism and antiferromagnetism compete and the notion of frustration meaning that there is a large number of states with the same free energy implies complexity. Still DX is much more complex that spin glasses.

One can however ask, whether the variation of the spin state of DX along the flux tube is analogous to the frustration of spin glasses? Could the total (free) energy of the dark nucleon triplet depend only very weakly on the codon content so that the frustration would be maximal and give rise to a maximal representative power.

2. The nuclear spin of the dark nucleon triplet couples with the stringy angular momentum of the closed flux tube of the codon. One can expect similar coupling in longer scales between the total angular momentum of subsequent codons along the flux tube and also with the stringy angular momenta assignable to larger units of DX such as gene, promoter region, or a control region like Alu in the case of DNA. One would have a tensor product of representations of the rotation group for codons and longer basic units. These tensor products decompose to irreps.

Could various irreps in these decompositions correspond to various flux tube configurations for the units of DX, X = DNA, RNA. DAAs have stringy angular momentum at the level of codons as closed flux tubes. Dark protein (DP) flux tube has angular momentum and it can couple to the angular momenta of DAAs?

Could this coupling make it possible for the units of DX to control the dynamical geometry of the flux tube as phase transitions between different irreps of the rotation group? Could these transitions occur at quantum criticality?

3. If this picture is correct, the degeneracy of the angular momentum states of the dark information molecules DX (genes, RNA, proteins) would correspond to a degeneracy of the geometric configurations of information molecules X. DX would serve as a control knob. This is just what a morphogenetic field should achieve. The feed of metabolic energy would induce transitions in the quantum spin glass energy landscape. Also protein/DNA/RNA folding and unfolding induced by energy feed could be understood in this manner.

9.3.3 Communications to and control by MB

Communication from the biological body (BB) to MB and its control by MB would rely on dark photons, which can transform to ordinary photons with a large h_{eff} and vice versa. Molecular transitions would represent one form of control.

- 1. Cell membranes could act as generalized Josephson junctions generating dark Josephson radiation with energies given by the sum $E_J + \Delta E_c$ of ordinary Josephson energy E_J and the difference ΔE_c of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential modulates the Josephson frequency and codes the sensory information at the cell membrane to a dark photon signal sent to MB.
- 2. The large effects of radiation at ELF frequencies observed by Blackman and others [J7] could be understood in terms of the cyclotron transitions in $B_{end} = .2$ Gauss if "h" in E = hf is replaced with h_{eff} . h_{eff} should be rather large and possibly assignable to the gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. For the simplest model, M represents the Earth's mass coupling to the small mass m, and v_0 is a parameter with dimensions of velocity expected to have discrete spectrum. The energies $E = h_{eff}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K20, K31].
- 3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model for planetary orbits [E1], the predicted cyclotron energy scale is 3 orders of magnitude higher than the energy scale of visible photons. Several solutions of this problem were considered [L171]. The most plausible

solution [L171, L155] is $\beta_0 = v_0/c = 1/2$ for living matter so that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius at the surface of Earth and brings nothing new to the original Nottale hypothesis.

Cyclotron photons and Josephson photons as basic tools of control and communication

By its higher level of "IQ", MB would naturally be the master controlling BB by cyclotron radiation - possibly via a genome accompanied by dark genome at flux tubes parallel to the DNA strands.

- 1. Cyclotron BE condensates (BECs) of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear as dark matter in living systems and the $h_{eff} = h_{gr}$ hypothesis predicts a universal cyclotron energy spectrum in the range of bio-photon energies. Dark matter and MB would use the biological body, defined in very general sense since life is a universal phenomenon in TGD, as a sensory receptor and motor instrument. MB would receive sensory input most naturally as generalized dark Josephson radiation and control it by dark cyclotron radiation.
- 2. All charged elementary particles and basic biological ions would have dark variants and could define Josephson currents. Dark photons and BE condensate-like states formed from them would give rise to the analogs of morphogenetic fields. Dark Josephson radiation associated with electrets, which are indeed electric dipolar structures, replaces Fröhlich condensates in the TGD framework.
- 3. The key equation is $f = ZeV/h_{eff}$ which allows to associate low Josephson frequencies with large energies, say the Josephson energy associated with cell membrane to ELF frequency. Second key equation $E_c = \hbar_{eff}f_c = \hbar_{eff}ZeB/m$ assigns to a low frequency, such as EEG frequency, a large cyclotron energy.
- 4. There is a connection with biophotons [I155, I97, I191, I55, I125, I136], which is a phenomenon having no feasible biochemical explanation. In the TGD Universe, biophotons can be regarded as ordinary photons resulting from the transformation of dark photons to ordinary photons in an energy conserving manner [K20, K31]. This dramatically reduces the wavelength and in this manner couples long and short length scales dynamically.

In ZEO, the field body (FB) and MB correspond to 4-D rather than 3-D field patterns and quantum states correspond to quantum counterparts of behaviors and biological functions. Conscious holograms could be generated as a result of interference of a dark photon reference beam from MB and a dark photon beam carrying the sensory information. This hologram would be read by MB using the conjugate of the reference beam. In ZEO time reversals of these processes also take place. This makes it possible to understand memory as a result of communications with memory mental images.

If one accepts the view that dark Josephson radiation is a universal communication tool in communications between biological body and MB, one can as whether DNA could utilize it. Consider first the situation at the level of the cell membrane.

- 1. Dark generalized Josephson radiation associated with the generalized Josephson junctions defined by membrane proteins would make possible communication of local sensory data to MB [K92, K93, K45]. These Josephson junctions are idealizable as continuous Josephson junctions with a geometry of a cylindrical shell. Ground state would correspond to a soliton sequence and the dark variant of nerve pulse would correspond to a perturbation of the soliton sequence propagating like a nerve pulse.
- 2. The feedback as control actions could take place via genome as transcription of genes or more general gene expression. This would require communications from genome to nuclear membrane to cell membrane perhaps made possible by magnetic flux tubes connecting them. Their braiding would also make possible topological quantum computation type processes [K7, K122, K8].
- 3. This model generalizes to a model for the communications of "sensory" data from nuclear membrane to MB.

One can consider several analogs of Josephson junctions at the level of DNA double strand and even at the level of DDNA.

- 1. One can of ask whether the linear structures formed by the electron chains [I178, I176, I177] assigned with the stack of aromatic rings and proton chains defined by longitudinal hydrogen bonds inside the DNA double strand form Josephson junctions so that Josephson currents would consist of protons and electrons.
- 2. Could Josephson junctions between base pairs make sense? What is missing is the membranelike structure and nanoscopic Josephson junctions as analogs of membrane proteins. Base pairs could in principle give rise to Josephson junctions if there is voltage between them. In this case, even the analogs of soliton sequences and nerve pulse could make sense.
- 3. There exists a longitudinal electric field along DNA [L222, L224]. It could be that nucleotides define analogs of Josephson junctions and they might generate collectively dark 3N-photons as generalized Josephson radiation. In this case, the analog of nerve pulse would not make sense.

Control of DNA and other biomolecules by MB

How MB could control the DNA and other biomolecules?

- 1. Suppose that the monopole fluxes of dark DNA strands generate currents flowing in aromatic rings of strands. Also spin magnetization could be induced and this in turn would genrate currents in aromatic rings. This could give rise to an analog of magnetized state. Also a diamagnet with vanishing total magnetic field perhaps giving rise to superconductivity is generated.
- 2. The control of the network of formed by the typically linear structures and membranes is an essential part of biosystems in supramolecular scales. Here an analogy with spin glasses is highly suggestive. Spin glass has become a prototype of complex system. They characterized by a local magnetization with a varying direction. Spin glass landscape has fractal energy landscape having valleys inside valleys and p-adic physics suggests an elegant description of it [L166]. This kind of phase would be ideal control tool used by MB.
- 3. In the TGD framework, spin glass could correspond to a dark magnetized flux tube network. Spin glass phase could couple to biophotons produced from dark cyclotron photons with large h_{eff} transforming to ordinary biophotons of dark photons with a smaller value of h_{eff} and induce transitions between valleys of the energy landscape corresponds to different geometric and topological configurations of flux tubes. Reconnections and changes of flux tube lengths induced by the change of h_{eff} would be basic processes.
- 4. Braiding would make possible topological quantum computation using magnetizations associated with flux tubes as analogs of qubits. These qubits would be highly stable as magnetized multi-spin systems. Entanglement would be between magnetizations instead of spins. The first version of topological quantum computation discussed in [K7, ?, K122] did not yet involve spin glass hypothesis.

9.3.4 Dark counterparts of information molecules and dark realizations of genetic code

There are good reasons to expect that genetic code is something very fundamental and realized at the level of fundamental physics. Genetic code relates to information processing and dark matter at MB has higher "IQ" as the dimension of extension of rationals identifiable in terms of h_{eff} . This leads to two realizations of the genetic code in terms of dark photons and dark nucleons and also strongly suggests that the genetic code is a universal phenomenon having many other realizations besides the biological ones.

Dark analogs of the basic information molecules

The basic information molecules DNA, RNA, tRNA and aminoacids (AA) would have dark counterparts in TGD Universe. DDNA, DRNA, DtRNA, and DAAs would serve as sources of dark 3N-photons representing genes and in special case codons. There would be resonance couplings between DDNA and DRNA, DRNA and DtRNA, DtRNA and DAA. Also resonant coupling change the value of h_{eff} and the frequency by energy conservation $E = h_{eff_1}f_1 = h_{eff_2}f_2$. If h_{eff} changes there is only energy resonance.

During the interaction, these systems should be quantum critical in order to make control, communication and sensory sensitivity optimal which suggests that temporary transitions to quantum criticality is basic aspect. Since the increase of h_{eff} requires energy, metabolic energy would be needed to achieve these transitions. The layers of MB with different values of h_{eff} forming a slaving hierarchy would couple by energy resonance.

Also the communications and control of the ordinary biomatter by dark biomatter is needed. There must exist couplings between DX and X. DX-X pairing would represent permanent interaction of this kind of interaction. Since $h_{eff} = h$ does not actually correspond to the minimum value h_0 of h_{eff} , it would seem that resonant interaction must be involved. Energy resonce gives strong conditions on cyclotron transition energies of DX and transition energies of X. The transition energies for X should be chemical transition energies.

That biophotons, which could result from dark *N*-photons, have energies in visible and UV range, conforms with this picture. This would make possible direct control of chemistry. Also transitions changing molecular conformations could be activated: the energies for them are in THz range and analogs of biophotons in microwave range are highly suggestive. Dark *N*-photon could consist of dark photons with energy corresponding to Thz range. Vibrational and rotational transitions could be also activated.

Two realizations of genetic code

TGD inspires the proposal of two dark realizations of genetic code whose most recent forms are discussed in [L196].

- 1. The first realization represents codons as dark nucleon triplets [L77, L103] and the second realization as dark photon triplets that is 3-chords [L16] [L136, L159, L196].
- 2. The models for dark codons generalize to models of genes. Galois confinement predicts that dark N-particles states are possible. In particular, genes could correspond to dark 3N-nucleon states as a bound state of dark 3-nucleons associated with flux tubes parallel to DNA strands and to dark 3N-photon states as analogs of BE condensate.

The communications and control would be based on 3N-resonance in which frequency modulated Josephson radiation would produce a sequence of resonance pulses at MB possibly related to nerve pulses. The genetic codon would determine the address of the receiver as in LISP and modulation would encode for the information transmitted.

- 3. The icosa tetrahedral model of the genetic code introduced as a model of music harmony has justification in terms of icosa tetrahedral tessellation of the hyperbolic space H^3 defining mass shell [L159]. These mass shells define holography and allow explosion of cognitive representations since all algebraic integers are allowed as points. Genetic code would be therefore universal and could also have 2- and 3-D representations. Even cell membranes could define such a representation.
- 4. One can say that dark matter at MB and Josephson junctions involving the flow of dark ions define morphogenetic fields in the TGD framework and their interactions are based on signals propagating along topological light rays parallel to the flux tubes. N-resonance making possible precise selective receival of the signals and frequency and amplitude modulation codes for the message.
- 5. The new view about genetic code leads also to a vision about the evolution of language known to be initiated by mutations of only few genes [L226, L227]. The ideas is that the value of h_{eff} increases for the highest layers of MBs associated with these genes and led to the cultural evolution which quite generally corresponds to evolution at the level of MB.

To sum up, dark Josephson and cyclotron 3N-photons could define the TGD analogs of morphogenetic fields. The communication would be based on 3N-resonance and information would be coded using frequency and amplitude modulation and would generate a sequence of resonance pulses.

9.4 Water memory

Water memory, or homeopathy, is still not taken seriously by mainstream biologists although the empirical support is unquestionable. In this section I will discuss the findings of Benveniste's group and Montagnier's group from the TGD point of view.

9.4.1 Biological signaling by EM means

Yolene Thomas discusses the history of the notion of water memory in the articles "*The history* of the Memory of Water" [I193] in particular the basic findings of Benveniste's group. In [I194] further findings are discussed. These findings serve as bench tests for the TGD view.

Basic findings of Benveniste's group

Yolene Thomas worked in the group of Benveniste. Among other things Benveniste had discovered an allergy test using blood cells known as basophils. At 1980's Jacques Benveniste and Bernhard Poitevin started to study homeopathy. Antibodies causing basophil degranulation were added to water. A repeated dilution together with agitation led to a situation in which the concentration of the molecule was extremely low and should have caused any effects. The solution however induced a degranulation of the biomolecule itself. The finding was in conflict with the standard lock-and-key mechanism. The conclusion was that the information about antibodies might have been transferred to solution during dilution/agitation process by some unknown molecular organization.

The results were checked in other laboratories and eventually an article by Benveniste and Poitevin was published in Nature but induced violent reactions of skeptics. Instead of a scientific committee, Nature sent Magician James Randi and Walter Stewart, a fraud investigator, to the laboratory of Benveniste. They did not find any evidence for fraud. Nevertheless, they concluded that Benveniste had failed to replicate the claimed results.

Although Benveniste becamed isolated from the community, the research continued.

- 1. It was found that the vigorous agitation involving vortexing was essential for the effect. Pipetting up-and-down did not have the effect.
- 2. The effect was found to occur also for the dilutions of ethanol and propanol but not for dilutions of dimethyl sulphoxide.
- 3. Heating, freeze-thawing or ultrasonication suppressed the activity of highly diluted solutions, but not the activity of several active compounds at high concentrations.

Molecules reacted to heat according to their distinctive heat sensitivity, whereas all highly diluted solutions ceased to be active between 70 and 80 C. This suggests that the mechanism is independent of the nature of the original molecule.

4. It was found that the activity of highly diluted agonists was abolished by the application of 50 Hz magnetic field of strength 150 Gauss for 15 minutes (Earth's magnetic field has strength .5 Gauss and the endogenous magnetic field explaining the findings of Blackman has strength .2 Gauss). There was no comparable effect on original molecules.

What can one conclude from these findings in the TGD framework?

1. Vortex formation could correspond to the formation of magnetic monopole flux tubes which provide a representation for the MB of antigen. Also Z^0 magnetic flux tubes could be involved in TGD based hydrodynamics and accompany hydrodynamic vortices [L168]. The agitation could feed kinetic energy as a metabolic energy feed for primitive non-chemical lifeforms generated at the flux tubes. The different effects of freeze-thawing or ultrasonication effects on the antibody and on the diluted solution supports the view that something representing the antigen in some respects was formed at the flux tubes.

Pollack effect [I110, I111, L20, I162, I197] generating in the presence of say IR radiation negatively charged region as exclusion zones (EZs) suggests that part of protons of water molecules were transferred somewhere.

The TGD based explanation [L20] is the formation of dark proton sequences at the flux tubes as analogs of nuclei at the flux tubes defining a primitive lifeform utilizing IR radiation as metabolic energy source: metabolic energy feed would increase the value of h_{eff} . These life forms would correspond to MBs assignable to water clusters.

The flux tubes of MBs would reconnect with the molecules of the MB of antigen and change their thickness to tune into resonance. In this way they would form representations of antigen by mimicking the cyclotron frequency spectrum of the antigen. They could induce the same effects as antigen if the cyclotron frequencies are a basic control tool of biochemistry. Water clusters would catch the invader molecules. This mechanism would underlie the biochemical immune system and biocatalysis.

One can even ask whether genetic code is realized for these life forms: the restriction of dark nucleon sequences to those consisting of protons gives as outcome 32 codons, the minimum number of tRNA codons.

- 2. The effect occurs for ethanol and propanol but not for dimethyl sulphoxide. Hydrogen bonding requires OH-groups. Ethanol and propanol have OH groups but not dimethyl sulphoxide so that the hydrogen bonding could explain the difference. The proposal indeed is that water allows long hydrogen bonds with non-standard value of h_{eff} containing delocalized proton or even several protons. This can explain the numerous anomalies associated with the thermodynamics of water.
- 3. The 50 Hz oscillatory magnetic field abolished the effect. Note that 50 Hz is a cyclotron frequency of ⁷Li in the "endogenous" magnetic field $B_{end} = .2$ Gauss explaining Blackman's findings and interpreted in the TGD framework as magnetic field assignable to monopole flux tubes. Could it be that the reconnection with flux tubes of MB of the antibody catches parts of its MB and also ⁷Li ions at it?

Was the mere oscillatory character of the magnetic field essential or does 50 Hz correspond to a cyclotron or Larmor frequency associated with the magnetic flux tubes so that resonance was involved?

For instance, could the resonance have abolished dark proton condensates at the monopole flux tubes as life forms mimicking the cyclotron spectrum of the antigen to flux tubes of external nono-monopole magnetic field? Does 50 Hz frequency belong to the ELF spectrum of the antigen?

Between 1992 and 1996, the group of Benveniste learned to transfer molecules signals, in real time, molecular signals indirectly to water or directly to cells. Cells were placed in a 37 C humidified incubator on one coil attached to the oscillator, while an agonist (or vehicle as control) was placed on another coil at room temperature. In one such exploration, it was found that molecular signals associated with a common phorbol ester could be transmitted by physical means directly to human neutrophils to modulate reactive oxygen metabolite production.

Since 1995 it has been possible to record, digitize, and replay water memory.

Some further findings of Benveniste's group

In the second article "*Biological signaling by EM means* [I194] (https://cutt.ly/EAe67sy) Yolene Thomas summarizes some findings of Benventiste's group represented by Benvenist in 1994. The findings were related to cell lines, isolated guinea-pig heart and in vivo in a mouse model.

1. Heavy metal poisoning causes serious disorders, either inflammatory or strinctly immunological. For the isolated cell lines the effects of Cd at very low doses were studied. For 5-10 μ M Cd a high mortality was observed. The pre-treatment with non-toxic doses of HD of Cd with dilution log 16-25 or 26-35 for several days, a significant modulation of cellular activation and growth was observed either directly, both before and after the otherwise lethal concentrations.

- 2. Isolated guinea-pig or rat hearts were perfused at constant pressure in the so called Langendorff system with highly diluted vasoactive amines. ACh, histamine and water above the aorta. Variation in the coronary flow (CF) was observed. Significant effect on CF was observed. Also now the application of 50 Hz magnetic field abolished the effect.
- 3. HD of silica (cytoxic for macrophages) was applied to mice in vivo. The effect on macrophages was compared for the treated and control mice. The impact on synthesis of paf-aceter, mediator of inflammation and its precursor lyspaf-aceter was studied. Significant differences were observed. Increase in synthesis of paf-aceter was found. No effect on the synthesis of the precursor in the HD sample was detected.

All these findings conform with the water memory interpretation and TGD based model for

it.

Results of other groups

Thomas describes also some findings of other groups.

- 1. During the period 1990-1994 Endler studied thyroxine controlled morphogenetic regulation of amphibian Rana temperaria in the transition from 2- to 4-legged stage. Animals that were pretreated with HD of thyroxine metamorphosed more slowly. One could interpret this as immunity against the effect of actual thyroxine produced by the organism produced by false thyroxine. Same effect was achieved with electronic circuitry using recorded frequency spectrum with frequences below kHz.
- 2. Luc Montagnier has studied since 2005 the effect on mycoplasma, HIV and bacteria. Certain bacteria and DNA extracted from bacterial suspension are filtered and diluted, and the HD is found do emit low frequency em waves.
- 3. What is interesting is that emission stops when the medium gets in close contact with an infected individual. What could this mean?

In the TGD framework, this question can be reformulated. Suppose that the emission is analogous to biophoton emission and consists of dark (N-)photons, which have transformed to ordinary photons. Could the flux tubes of the representation of the micro-organism or of its DNA in HD reconnect with the infectant flux tubes of infected invidual so that the radiation does cannot leak out anymore as ordinary photons?

- 4. It is possible to detect the em radiation of HIV DNA even when the RNA of virus has disappeared from blood. Could this mean that HIV DRNA remains in the organism?
- 5. Montagnier's group has also reporpted that it is possible to reconstruct DNA sequences from the EM signal produced by HD [I92, I91]. I have already discussed the findings these findings from the TGD view point in [L4, L6].

9.4.2 Water bridging dynamics of PCR chain reaction

This section discusses the article: "Water Bridging Dynamics of Polymerase Chain Reaction in the Gauge Theory Paradigm of Quantum Fields" of Montagnier et al [I93](https://cutt.ly/yArqeJz) from the TGD view point.

The basic goal is to understand the DNA-enzyme coupling in DNA polymerization. The polymerization process is a highly organized time-ordered sequence of steps with a precise spatial organization. Computer program is the first analog that pops up into mind. DNA polymerization and biocatalysis in general are extremely difficult to understand in a nothing-but-chemistry approach, which suggests a stochastic process in a sharp conflict with these features.

The proposal of authors in accordance with the vision of Fröhlich that quantized dipole electric fields make possible states which are known as Fröhlich condensates but can one argue bringing in quantum field theory is not enough. The coherence of living matter would naturally follow from quantum coherence in long scales but standard quantum theory fails to produce this: the value of Planck constant is simply too small.

The characteristics of the process fits nicely with the basic predictions of ZEO that quantum states are superpositions of space-time surfaces obeying not only determinism dynamics but being analogous to Bohr orbits. This together with hierarchy of Planck constants would also explain the long scale coherence and precise spatial organization.

The findings

Polymerize chain reaction (PCR) is a method of detecting the presence of DNA in a solution. The article reports findings about highly diluted viral or bacterial DNA in water. The solution contains also DNA polymerase (DNAP), which is thermostable up to 80 C and even above it albeit non-functional, This DNAP, briefly Taq, is associated with a heat tolerant strain T. aquaticus. Taq is used in PCR quite generally. The properties of Taq do not seem to be relevant for the findings.

- 1. Some viral or bacterial DNAs in a very highly diluted agitated solution (HD) $(10^{-6} 10^{-10})$ emit electromagnetic radiation (EMS). In the ELF range 40-2000 Hz EMS is several orders of magnitudes more intense than elsewhere. The log-log plot of power is in this range linear and there are self-similar fluctuations regarded as a signature of coherent dynamics at microscopic level.
- 2. This radiation is recorded and the first dilutions show no signal. The recorded radiation pattern generates electric current creating a time dependent magnetic field in a sample containing only water and *Taq* and oligonucleotide primers.

IT is assumed that coherent nano domains representing DNA are formed in water or cellular water. The signal would be read by Taq polymerase in presence of primers and XTPs, X= A,T,C,G. A polymerization of the viral or bacterial DNA is observed by PCR. In the TGD based model [K136] the term "remote replication of DNA" is used. It would seem that Taq pairs with coherent nanoscale domains representing DNA and induce a polymerization of ordinary DNA around it.

3. In the second experiment water is replaced with a flask of living cultured tumor cells or in vitro cell lines. DNA polymerization is observed by PCR also now. Cell growth is inhibited and cells die.

How do Taq and oligonucleotide primers find each other to make DNA amplification possible? The proposal is that dipole electric fields define morphogenetic fields somehow representing DNA. These fields are treated in the gauge theory paradigm involving symmetry breaking and generation of Goldstone bosons generating long range correlations as collective modes. But can collective modes really represent detailed information about genetic codons? This is local information in nanometer scale requiring wavelengths of order nm meaning energy of order 10^3 eV for photons and considerably above the natural energy scale of few eV for molecular transitions.

TGD based model for the findings

The TGD explanation for the findings would go as follows.

- 1. The mechanism to be discussed works in both experiments. The relevant system would be the dark counterpart of DNAP (DDNAP), which would be modified so that it coules only with the DDNA transmitted to the system electromagnetically. In the first experiment DNAP would *Taq* and in the second experiment the DNAP associated with the cells of the sample.
- 2. The nanoscale domains would correspond to the remotely generated DDNA as flux tubes at which codons are realized as dark nucleon triplets [L196, L136, L159]. The resonance mechanism for the pairing of DDNA and dark DNA polymerase proteins (NDNAP) paired with DNAP proteins applied to DDNA-DDNAP pair could explain the findings in both

cases. Dark 3N-nucleons as a representation of dark genes/proteins accompanying ordinary genes/proteins pair via dark 3N-resonance.

3. DDNAP would tune to the cyclotron energies and frequencies of electromagnetically transmitted DDNA by changing the radii of the dark magnetic flux tubes of DDNAP paired with DNAP. Dark 3N-resonance coupling would lead to the polymerization.

The general mechanism would be the same as in homeopathy and water memory [K62] in which MBs of water clusters tune their flux tubes to the cyclotron energy (and possibly also frequency -) spectrum of the invader molecules and in this manner form its low frequency representation.

- 4. This mechanism would be the fundamental mechanism of the immune system and of biocatalysis.
 - (a) U-shaped flux tubes would act as tentacles inspecting the environment for invader molecules and eliminate them by reconnection. Flux tubes would continually vary their thickness to vary the frequency scale of their siren's song and the invader molecule would be caught when a reconnection at resonance is formed.
 - (b) In bio-catalysis in which reconnections between U-shaped flux tubes to a pair of flux tubes in resonance would form bridges between reactants and catalyst and the reduction of h_{eff} would shorten the flux tubes and bring them close to each other. The energy liberated would help to get over the potential energy wall so that the reaction would proceed swiftly.
- 5. The magnetic flux tubes of the DNAP would change their thickness so that the cyclotron frequency spectrum of DNAP tunes to that of the DNAP of the EMS emitting system. There would be tuning of the frequency scale and perhaps also frequency ratios to some extent. DNAP would return within few days and start to resonanate with the frequency the spectrum of the DDNA representing the electromagnetic invader.
- 6. The tumor cells and in vitro cells would die because their DDNAP tunes to the DDNA of the invader and loses its tuning with the DDNA of the tumor/in vitro cells. What happens if non-tumor cells are used? If the healthy cells do not die, they could have an electromagnetic immune system preventing the modification of the cyclotron frequencies of the flux tubes of their DDNA. This immune system could explain why remote mental interactions between different organisms are very rare [K114].

9.5 DNA resonance code

The experimental findings represented in three articles by Savelev et al motivated this section. The articles are

- Savelev et al: "On The Existence of The DNA Resonance Code and Its Possible Mechanistic Connection to The Neural Code" [I178] (https://cutt.ly/KAe6BOd).
- Savelev and Myakishev-Rempel "Possible traces of resonance signaling in the genome" [I176] https://cutt.ly/rArqdlA
- Savelev *et al* How the biofield is created by DNA resonance [I177] (https://cutt.ly/EArqzSL).

The motivating observation is that molecular gradients and neuronal signals are too imprecise if one wants to understand processes like DNA polymerization.

Gurwitch, Miller and Webb, Burlakov, Montagnier, Meyl, etc... introduced the notion of morphogenetic field, Miller and and Webb assumed that the morphogenetic field is holographic and is generated by DNA.

Th finding of Meyl that there is no dissipation involved with the morphogenetic field, suggests that quantum coherence in long scales is involved and that this coherence might induce the coherence of biomatter.

It is argued that if the morphogenetic field is generated as a dipole field by moving charge carriers, they should have a low mass and be isolated from the cellular water. Base pairs are hydrophobic and this forces the distances of the bases to be minimal whereas the charges of the phosphate tend to make DNA as straight as possible. This leads to a proposal that DNA strands or at least parts of them act as resonators producing the morphogenetic field, which could represent the genetic code as the findings of Montangier *et al* suggest. It is proposed that the repeating parts of DNA which do not code for proteins and are usually identified as junk DNA could act as kind of quantum antennas.

9.5.1 Some findings of Burkalov and their TGD based explanation

There are several experimental findings supporting the presence of morphogenetic fields. Gurwitch and Benveniste who studied water memory belong to the pioneers of the field. Also biophotons, which are not discussed in the articles commented in this article, could closely relate to the morphogenetic field.

Burkalov studied fish embryos inside two quartz cuvettes above each other, 50 fish embryos in each cuvete in sealed quartz cuvettes. They are incubated for several days in a metal box lasting for several days. It was found that older embryos inhibit the development of younger embryos.

It was also found that a germanium mirror accelerates the development if a single cuvette is placed on it. Quartz retroreflector prism in turn represses the development and causes abnormalities. Retroreflector has the basic property that it reflects back by 180 degrees independently of the angle of incidence. Reflector reflects in this manner only if the incidence is normal.

Consider now a possible TGD based explanation for the findings of Burkalov.

1. MB has an onion-like hierarchy of layers and would take the role of a morphogenetic field as a controller. Magnetic flux tubes would determine the morphology. Some higher layer of MB could send control commands through the genomic repeats which in turn would control the transcription and other basic processes. Alu repeats involve promoters.

The lowest level in MB hierarchy would correspond to DDNAs paired with DNAs? Same for other linear information molecules. Higher layers of MB could use genomic repeats as control knobs.

- 2. The frequency scale for bioharmony changes with aging, and the first guess is that it slows down. Younger embryos have very sensitive MBs able to rapidly modify the flux tube thickness and tune to the external source. Older embryos therefore induce a modification of the frequency scale of the dark flux tubes of younger embryos. Development slows down or stops because the resonance between DDNA and DNA is lost or does not conform with the biological evolutionary age for proteins.
- 3. In the experiments involving reflector, the dark photons leaking out as ordinary radiation are reflected and leave the system. In retroreflector the ordinary radiation returns back and causes the decoherence of dark N-photons: instead of dark N-photon ordinary photo is absorbed. Could retroreflection slow down the gradual scaling of frequency scale?

9.5.2 Electron and proton chains along DNA as sources of morphogenetic field?

The proposal is that electron and proton chains along the stack formed by base pairs serve as the source of the morphogenetic field. The proposed electron and proton chains are called HIDERs (Homologous If Decoded Elements, Repetitive).

1. Morphogenetic field is identified as electromagnetic dipole field assigned to DNA. Resonant oscillations of delocalized electron and proton chains in the base stack of DNA are proposed to serve as the source of the field.

- 2. Hydrophoby pushes bases together and phosphate charges make DNA maximally linear. This volume is insulated.
- 3. Base pairs of the double DNA strand (A-T, C-G) oscillate between tautomeric states with frequency in the MHz-THz range. G-C base pairs have three tautomeric states whereas A-T has 2 tautomeric states. There are also aromatic rings oscillating between aromatic and non-aromatic states. They are predominantly in non-aromatic states and one can ask whether the switching forth and back between these states has some role in biocontrol.
- 4. Aromatic rings are suggested to unite into a stack such that electrons are delocalized along this stack. There is evidence for pi electron chains along hydrophobic base stack associated with purine (A,G) stretches. There is also evidence that these stretches get longer during evolution and that they are conserved.

DNA charge transfer provides support for the electron chain concept. DNA acts as 1-D conductor and semiconductor and both electrons and holes act as charge carriers.

5. The proposal is that proton chains associated with the longitudinal hydrogen bonds, which is introduced as a new notion, exist. Both electron and proton chains would reside inside a linear double-helical crystal with insulation caused by hydrophoby. This suggests that the dissipation of energy for the chains is very low as the experimental findings about the morphogenetic field require.

Genomic repeats as a source of morphogenetic field?

Genomic repeats are introduced as a further key concept.

- 1. The starting point is the observation that only 1 % of the human genome corresponds to a coding genome. The non-coding is called junk DNA. 2 % of the genome is conserved and non-coding and must have some important function. The function of the rest 97 % is unknown. Introns, which are spliced from mRNA in the maturation of the final mRNA product belong to the non-coding part.
- 2. Genomic repeats associated with the intronic portions of the genome must have some important function. There are many kinds of repeats. The smallest repeating structure is a single nucleotide. Also 2-,3-,4-, and 5-nucleotide repeats called microsatellites are frequent. Telomeric and centromeric repeats. Telomeric and centromeric repeaters belong to the simplest repeaters. Typical telomeric repeat is 6 bases long GGGTTA. Human telomeres are around 2500 repeats long. The proposal is that they define fundamental resonators.

Purine (A,G) repeats are identified as the most important repeats. There is evidence that the lengths of purine chains increase during evolution and that they are conserved.

3. Alu repeats are about 300 bp long, appears in primates only, and has the highest number in the human genome. There are about 1.1 million copies of Alu. Alu is an interspersed repeater meaning that it does not repeat periodically but in a random manner. Alus are near genes and strongly bind to nucleosomes and often serve as a crystallization point for chromatin condensation. Alus coil around almost two nucleosomes. Alus are frequent and conserved in gene promoters, which suggests a possible regulatory role.

Alus code for an untranslated RNA so that they decompose to codons. The variations with an Alu sequence in a gene promoter correlate with the transcriptional activity of the gene. Alus are normally silent but are activated during cellular stress. The methylation pattern for Alus vary and this affects the RNA expression. It is not clear whether methylation affects the possible control role otherwise.

Alus are possessed only by primates and the proposal is that Alu makes us humans. Alus would receive the wave information of the morphogenetic field and convert it to bioinformation by controlling gene expression.

Some objections as a way to end up with the TGD based view

The work of Fröhlich [J26, I107, I119] [J26] has inspired the idea about the fundamental role of electric dipoles in biology (https://cutt.ly/3AmIKQi). Electric dipoles would give rise to Fröhlic condensates explain the coherence of biosystems which remains a mystery in standard quantum physics. No direct evidence for them have been found.

There are some objections against the fundamental role of electric dipoles and dipole radiation.

- 1. In contrast to magnetic moments, the electric dipole moments of elementary particles vanish to extreme accuracy so that electric dipoles should be associated with composite states such as atoms and molecules which are however heavy so that morphogenetic field would be generated by mass motion of DNA and require considerable metabolic energy feed.
- 2. The time scale of control dynamics should be slow as compared to the time scale of electric dipoles. For instance, DNA transcription involves time scale of order .1 second assignable to alpha rhythm. Cyclotron frequencies in the magnetic field of order Earth's magnetic field correspond to this time scale. It would seem that cyclotron radiation relates more naturally to the notion of a morphogenetic field. Here however the extremely small energy is the problem and led to the $h_{eff} = n \times h_0$, which later emerged from the number theoretic vision of TGD.
- 3. One can however consider a different realization of the electric dipole idea. Electrets populate biology, which suggests that nano-scopic and microscopic structures formed from dipole-like entities are crucial. Electret property implies a coupling between acoustic and electromagnetic degrees of freedom and is very probably crucial for hearing. Basically acoustic oscillation corresponds in TGD framework to oscillations of flux tubes connecting particles and if for charged particles forming a dipole this coupling becomes possible.

For instance, in the TGD vision cell membrane can be regarded as a (actually a generalized) Josephson junction and if dark matter hierarchy is accepted, Josephson frequency is given by ZeV/h_{eff} and is very small for large enough h_{eff} . One obtains the desired slow time scale and energy scale just above thermal energy. Also DNA and microtubules have longitudinal electric fields.

Comorosan effect [I170, I56] means that there are 5 second and 10 second periods associated with molecules. They are not understood but the interpretation in terms of Josephson frequency of a polarized molecular bond is attractive [K131].

Magnetic dipoles at elementary particle and ion level and macroscopic electric dipolar structures like cell membrane, DNA strand and microtubule would play a fundamental role in the TGD inspired biology and the hierarchy of Planck constants would make the interaction between them possible.

It is quite possible that genuine quantum coherence is realized only at the level of MB and the coherence of biomatter is induced by MB and is not genuine quantum coherence. This would solve the problem due to the fact that the standard value of Planck constant does not allow quantum coherence in long scales.

TGD view about the role of genomic repeats

The TGD view about how dark information molecules DDNA, DRNA, DtRNA, DAA couple with each other and with ordinary information molecules has been discussed. One would have a slaving hierarchy with levels labelled by h_{eff} controlling each other by energy resonance coupling using dark variants of genes as dark 3N-photons analogous to BE condensates.

They would have energies in biophoton range (visible and UV), very probably also in IR range since metabolic energy quantum around .5 eV must be included, and possibly also in microwave photon range and the energy scale of about .2 eV defined by membrane potential.

These transitions would control chemical reactions, induce conformational changes of biomolecules, etc...

The motor actions of MB would naturally induce conformational changes of molecules and also larger objects. The geometric degrees of MB would be behind morphogenesis. Biological growth could quite concretely correspond to the growth of MB meaning increase of h_{eff} of the highest level present in the hierarchy.

How does this view relate to the proposal that repeating DNA sequences serve as antennas, resonators and circuits?

1. HIDERs could be present. Electron and proton spins could be important and DDNA could induce spin magnetization in turn generating magnetic fields inside DNA inducing currents in aromatic rings.

An interesting question is whether these currents create a magnetization summing up to zero with spin magnetization: one would have perfect diamagnet. Does this mean electronic super-conductivity inside DNA. I have indeed proposed this earlier. The idea that HIDErs serve as electric dipole oscillators does not however look attractive.

2. Repeating DNA sequences, in particular Alus, must have an important role in communication to and control by higher layers of MB. The presence of higher layers of MB conforms with the fact that Alus are not present in non-primates. Also the connection with epigenesis is suggestive.

Could Alus serve as control knobs or could they send sensory information to MB and therefore play the same role as cell membrane? Could electric dipolar structure play quite generally the role as generators of sensory input and could MB respond by sending cyclotron radiation as a response?

Consider now in more detail the possible role of Alus in the TGD framework.

- 1. DNA and also Alus carry a longitudinal electric field making it a long dipole. Also codons act as dipoles with dipole moment depending on the codon. Could the idea that the entire Alu acts as a long Josephson junction make sense? This would not allow information transfer using genetic code.
- 2. Could codons act as Josephson junctions with Josephson energy $Ze\Delta V$ depending on the codon. Could these Josephson junctions form a 3N-Josephson junction generating coherently dark Josephson 3N-photons as sensory input to MB. The modulation of Josephson current would code for sensory input. This would induce a sequence of resonance pulses at the layer of NB producing a feed back sending sensory data to MB, which could induce control actions, such as DNA transcription.
- 3. From the length of Alu of order $L \sim 10^{-7}$ meters (300 bps/100 codons) the estimate for the Coulomb energy of electro associated with the entire length is about $Z^2 e^2/L$, for opposite charges at the ends of Alu if it has charges $\pm Z$ at its ends. This corresponds to energy of order few eV and is in the biophoton energy range. This would conform with the energy scale of dark cyclotron photons.

DDNA could serve as the nearest boss of DNA. Also higher levels in the hierarchy of MB layers would realize dark genetic code if the icosa tetrahedral tessellation at H^3 defines a universal realization of genetic code.

Since genetic code would be used in the communications, the sensory signal would go to MB with dark codons similar to Alu.

4. Somehow a control response should be generated as a response. Suppose that Alus, and perhaps entire DNA, is magnetized. This could be made possible by possible spin polarization of electron chains and/or rotating currents in aromatic rings. Could MB realize control commands by using dark cyclotron 3N-photons absorbed by Alu?

A universal standard control knob property Alu, or of a repeating unit in general, would allow minimal complexity of the nucleotide content. The flux tube connections would allow targeted control commands such as activation of propometers of gene transcription. Note that Alus also code for RNAs having some function but are most of the time silent and are used only in emergency situations (cellular stress). There is an interesting experimental finding, which could be seen as a support for the presence of dark UV photons at magnetic flux tubes.

- 1. The irradiation of cultured mouse fibroblasts at low power millimeter waves at certain wavelengths protects DNA against damaging effects of UV radiations. What comes to mind is the shielding of the biosphere by the magnetic field of Earth: the cosmic radiation sticks to the flux tubes.
- 2. Could UV radiation be caught by MB flux tubes with large h_{eff} and transform to dark radiation with much longer wavelength? Could some fraction of the millimeter irradiation transform to dark photons with UV energies? Could the flux tubes of MB tune to millimeter radiation so that they become sensitive to it? Could a BE condensate of photons with energy in UV range emerge and serve as induce the BE condensation of ordinary UV photons so that they would be defused?

9.5.3 Is DNA magnetic?

The article also discusses the possible magnetism associated with DNA. DNA strands seem to behave like pairs of magnets. Ring currents could cause the magnetization but their presence requires an external magnetic field inducing magnetization.

The problem is that in an external magnetic field DNA becomes orthogonal to it and no magnetization is generated. The source of the external magnetic field must stay parallel to DNA which is impossible in standard view about DNA.

The proposal is that the ring currents are induced by some enzyme in the presence of ATP. There is also the question whether the magnetization is static or oscillatory.

The TGD view of DNA as a magnetic system would be following.

- 1. DNA strands seem to behave like pairs of magnets. Ring currents could generate magnetization. A strong enough magnetic field parallel to strands is needed to induce the magnetization. The DDNA associated with dark monopole flux tubes (no current needed to create the magnetic field), necessarily parallel to DNA, would induce the magnetization of DNA. Connection with DDNA in icosa tetrahedral picture emerges.
- 2. How DDNA could couple with the DNA magnetization? The magnetic field is strong and from flux quantization it would be of order 100 Teslas. Cyclotron frequency scales are totally different. $f_c(e) \sim 3 \times 10^{11}$ Hz. For $h_{eff} = h$, the cyclotron energy is of order 3 meV and below thermal energy. Could DNA interior be thermally insulated from the environment. $h_{eff} = nh$, $n \sim 10^3$ would give a few eV scale for the cyclotron frequencies.
- 3. Large h_{eff} cyclotron 3N-photon transforms to a single ordinary photon with much larger energy and is absorbed in ordinary cyclotron transition by DNA magnet and induces motor action of DNA.
- 4. Control communication from higher layers of MB could take place via repeats whereas for coding regions only the lowest layers of MB, such as DDNA would be involved. Alu regions as control knobs in gene expression controlled by MB. All layers of MB could realize dark genetic code but in a different scale proportional to h_{eff} .

9.5.4 Dark 3N-resonances and quantum teleportation

Could the communication by 3N-resonances relate to quantum teleportation? This is possible but requires modifying the previous assumption that the states of dark proton sequences are fixed and correspond to those of ordinary genes with which they are in energy resonance when communicating. One must loosen this assumption.

1. Give up the assumption that cyclotron states of the dark 3*N*-proton are always the same and correspond to a gene. Assume that in some time scale, perhaps of order cyclotron time, dark proton sequences representing genes decay to the ground state configuration defining an analog of ferromagnet. 2. Assume that some excited dark 3N-photon states, dark geme states, can be in energy resonance with ordinary genes, most naturally the nearest one if dark DNA strands are parallel to an ordinary DNA strand. Even this assumption might be unnecessarily strong. Dark 3N-proton would interact with its ordinary counterpart by energy resonance only when it corresponds to the dark variant of the gene.

Same applies to dark genes in general. Only identical dark genes can have resonance interaction. This applies also to the level of other fundamental biomolecules RNA,tRNA and amino acids.

3. What is this interaction in its simplest form? Suppose dark 3N- proton is in an excited state and thus defines a dark gene. Suppose that it decays by SFR to the ground state (magnetization) by emitting dark 3N-photon. If this 3N photon is absorbed in SFR by a dark proton sequence originally in ferromagnetic state, it excites by resonance the same gene. The transfer of entanglement takes place.

This is nothing but quantum teleportation but without Alice, doing Bell measurements and sending the resulting bit sequences to Bob , performing the reversals of Bell measurements to rebuild the entanglement.

This suggests a modification of the earlier picture of the relation between dark and chemical genetic code and the function of dark genetic code.

1. Dark DNA (DDNA) strand is dynamical and has the ordinary DNA strand associated with it and dark gene state can be in resonant interaction with ordinary gene only when it corresponds to the ordinary gene. This applies also to DRNA, DtRNA and DAA (AA is for amino acids).

This would allow DDNA, DRNA, DtRNA and DAA to perform all kinds of information processing such as TQC by applying dark-dark resonance in quantum communications. The control of fundamental biomolecules by their dark counterparts by energy resonance would be only one particular function.

- 2. One can also allow superpositions of the dark genes representing 6-qubit units. A generalization of quantum computation so that it would use 6-qubits units instead of a single qubit as a unit, is highly suggestive.
- 3. Genetic code could be interpreted as an error code in which dark proteins correspond to logical 6-qubits and the DNA codons coding for the protein correspond to the physical qubits associated with the logical qubit.
- 4. The teleportation mechanism could make possible remote replication and remote transcription of DNA by sending the information about ordinary DNA strand to corresponding dark DNA strand by energy resonance. After that, the information would be teleported to a DNA strand in a ferromagnetic ground state at the receiver. After this, ordinary replication or transcription, which would also use the resonance mechanism, would take place.

Could there be a connection with bioharmony as a model of harmony providing also a model of genetic code [L16, ?, L159]?

1. In the icosa-tetrahedral model, the orbit of the face of icosahedron under the group Z_6, Z_4 , $Z_{2,rot}$ or $Z_{2,rot}$ in $Z_{2,rot}$ would correspond to single physical 6-qubit represented as dark protein.

This representation of the logical qubit would be geometric: orbit rather than sub-space of a state space. One could however assign to this kind of orbit a state space as wave functions defined at the orbit. This representation of $Z_6, Z_4, Z_{2,rot}$ or $Z_{2,refl}$ would correspond to a set of 6-qubits, which replaces a single 6-qubit.

2. The TGD proposal for TQC [L189, L195] is that the irreps of Galois groups could replace qubits as analogs of anyons. Could these orbits correspond to irreps of Galois groups or their subgroups, say isotropy groups of roots?

Another option is the finite subgroups G of quaternionic automorphisms, whose MacKay graphs, characterizing the tensor products of irreps of G with the canonical 2-D irrep, give rise to extended Dynkin diagrams [L186]. What puts bells ringing is that $Z_6, Z_4, Z_{2,rot}$ or $Z_{2,refl}$ are subgroups of the icosahedral group, which corresponds to the Dynkin diagram of E_8 .

These alternatives need not be mutually exclusive. I have proposed that Galois groups could act as the Weyl groups of extended ADE Dynkin diagrams given by McKay graphs of finite subgroups of SU(2) interpreted as the covering group for the automorphism group of octonions. The Galois group and its subgroup would define a cognitive representation for the subgroup of the covering group of quaternion automorphisms.

The communications by the modulation of frequency scale 3N-Josephson frequency scale are still possible.

- 1. The 3N-resonance occurs when the receiver 3N-proton is in ferromagnetic ground state and the 3N-Josephson frequency corresponds to 3N-cyclotron frequency. If the time scale for the return to the ferromagnetic state is considerably shorter than the time scale of modulations, a sequence of resonance pulses results and codes for the frequency modulation as an analog of nerve pulse pattern. This communication can lead to communication if the ordinary gene accompanying the excited dark gene is in energy resonance with it.
- 2. It must be noticed that the communications by dark 3N-resonances are not possible in standard physics and are made possible only by Galois confinement and h_{eff} hierarchy. In standard physics only single photon fermion interactions would be present and would be relatively weak. In quantum computation, this suggests the possibility of quantum coherent manipulation of N-qubit states by dark N-photons instead of qubit-wise manipulations prone to errors and destroying the coherence. There is evidence for N-photon states with these properties [D3, D3]: for the TGD inspired comments see [L167].

Chapter 10

TGD view of Michael Levin's work

10.1 Introduction

This article was inspired by the work of Michael Levin's group in biology. I have already earlier (2014) commented the work of Levin [I139, I140, I182] in the article [L18]. To my view, these discoveries profoundly modify the views of the role of genes and lead to a completely new vision about morphogenesis about which genetics cannot tell much.

The amazing discoveries by Michael Levin and others related to morphogenesis (such as the discovery of xenobots as synthetic life forms) could lead to the correct track not only in biology and neuroscience but also in attempts to define and construct AI and artificial life.

The articles [I141, I143, I135, I50, I122, I142] provide a good view of the vision of Levin. Interested readers can listen the interviews and talks of Levin in web.

I started with the interview of Michael Levin at https://youtu.be/XheAMrS8Q1 with title "The electrical blueprints that orchestrate life". The talk "Plasticity without genetic change: bioelectric embryos & synthetic proto-organisms" (https://www.youtube.com/watch? v=5ChRM4CEWyg) gives a summary of the role of bioelectricity in embryos and about the synthesis of artificial organisms known as xenobots.

The talk "Understanding the Collective Intelligence of Cells: bioelectrical navigation of anatomical morphospace" at (https://www.youtube.com/watch?v=jLiHLDrOTW8 provides a view of morphogenesis as a navigation in morphospace towards the final morphology as a goal represented as a memory.

The talk of Josh Bongard titled "A xither of xenobots: demolishing dichotomous thinking with synthetic proto-organisms" (https://www.youtube.com/watch?v=7EA2AqS05tQ discusses the implications of the findings for fields like AI. The talk is about brain/body -, genotype/phenotype -, and tape/machine dichotomies, which have made a real progress in ortodox AI difficult, if not impossible. The article [I122] discusses the same topics.

The approach of Michael Levin does not mention quantum biology at all. At least from the perspective provided by the TGD inspired view of quantum physics and quantum biology, the findings are however extremely inspiring. In the sequel, I will discuss these findings and the theoretical vision inspired by them, and also the interpretation of findings in the framework of TGD inspired theory of consciousness and of quantum biology. These findings provide crucially important bits of data for a further development of the already existing TGD view of morphogenesis [L18, L194, L183, L178]. Also the interpretation of the zero energy ontology (ZEO) [L118] becomes more precise.

10.1.1 About the basic vision and experimental findings of Michael Levin

The basic challenge is to understand how organisms evolve from embryo to their final shape. Genetics applies at the level of a single cell and does not offer clues of how genes might determine the shape and size of the organism. Therefore the dogma that genotype determines phenotype has remained an unproven hypothesis. Already the emergence of epigenetics has made clear that genes are not enough: the same genome has very many transcriptions, which can vary in a very rapid time scale for a given organism. The work of Levin's group has shown that the correspondence between genotype and phenotype is even more flexible: one can even create new life forms using a given genome (zenobots).

Does bioelectricity code for morphogenesis?

The underlying idea is that the dynamics of the brain as a collective of neurons has evolved from the morphogenesis of cell groups. Instead of a communication using nerve pulses patterns, the communications use the distribution of membrane potentials (hyperpolarization and depolarization). Static gap junctions in turn take the role of much more dynamic synaptic contacts.

- 1. Dynamical patterns of membrane voltages assignable to cell membranes, which are determined by the voltages assignable to voltage gated ion channels and pumps, connectivity of cell groups determined by the distribution of gap junctions, plus long range potential gradients controllable by the patterns of membrane potentials, seem to act as a new control level which also controls the epigenetic level. The membrane voltage pattern and distribution of gap junctions are controlled in the experiments of Levin's group using biochemical tools.
- 2. The potential gradients in the scale of the organism or organ associated with the embryo in turn determine the morphogenetic goal as an analogue of memory in the same way as voltage gradients correlate with the state of the brain.
- 3. Electric signals as oscillation patterns of membrane potentials between cells mediated via gap junctions are proposed to actualize an analog of a computer program. This signalling is also referred to as conversation, which would be something less deterministic. The program would code the destiny of the cell group.
- 4. Self-organization in some sense is involved. Dissipation takes care that self-organization leads to a very few final states from a larger number of initial states. It is not however clear whether biological self-organization can be described by the standard picture in which self-organizing dissipates incoming energy and ends up to a thermal non-equilibrium. Related question concerns homeostasis: how is the system able to stay near a critical state, which is by definition unstable? Here self-organized criticality is a suggestive notion and to my best understanding not very well-defined.

Some astonishing findings

Manipulation of gap junction distributions and very specific ion channels has led to a handful of very astonishing findings providing deep insights of the basic mechanism of morphogenesis.

1. Planarians are animals which create offspring by replicating. They can be split even to 200 pieces cuch that every piece develops to a full-grown planarian. One might say that planarians do not experience aging at all. Long length scale electrical gradient rather than genome determines the positions of head and tail. Knowing also when to stop the growth is very important. How this is realized is not understood. Does the morphology of an adult planarian have a representation serving as a template in growth?

It is possible to manipulate the ion channels and gap junctions such that electrical field configuration changes and the split planarian develops to two planarians having two heads. This feature is preserved in further splittings of the planaria.

Also the memories of the parent planarian (defined as behavioral patterns) are inherited by the daughter planarians. The development of larva to a butterfly is a second example. The phenotype and also the brain of the larva are dramatically changed in the transition but the memories of the larva are preserved. This suggests that the memories are not presented at the level of the brain.

2. The gut cells of frogs, whose membrane potentials and gap junctions have been appropriately manipulated to give rise to long range electric gradients, can generate a functioning ectopic eye located outside the head. Also other organs, even those usually bot possessed by frog, can be generated in this way.

3. In Picasso frogs the embryo is mixed so that various parts of the embryo are in the wrong places. The embryo however develops into a normal frog. Therefore morphogenesis cannot be a hardwired set of movements. There is minimization of error and goal directed behavior.

Computer scientists would talk of a computation determining the large scale anatomy, with computation interpreted as a search of the goal configuration in morphospace and represented as a stable memory. Conscious theorists would talk of a goal directed behavior as intentional behavior.

4. Xenobots are a completely novel life form evolving from appropriately manipulated frog embryos involving removal of a fraction of cells. Genetically unaltered cells coalesce and are liberated from the rest of the body. Novel bodies are different from tadpoles and epigenesis is different. For instance, cilia have a different function. In the frog, they transfer the mucus whereas xenobot uses the cilia for swimming.

10.1.2 Giving up genetic determinism

The basic belief is that genotype determines the phenotype. Only adaptations can change the phenotype. Programming by machine code serves as a metaphor. The computer itself is modified in the programming. The emergence of computer languages meant a revolution and information science was born. There was no need to modify the hardware anymore. Computer programs, represented as input signals, defined the computation. Only the simplest functions are realized as programs at the level of hardware and their functional composition gives rise to programs in accordance with the Turing paradigm.

One can say that most of the recent biology studies only the machine code level. Genes code for the basic building bricks (proteins). Biological systems would be like computers determined by the genetic code. Genetic determinism reflects this belief. This approach leaves open how the behaviors analogous to running computer programs emerge. Machine code metaphor would suggest they are determined completely by the hardware, genes.

The revolutionary idea is that there exists an analog of higher level computer languages based on electric fields. Bio-electric programs would correspond to electrical signalling. Morphology would be based on patterns of electric voltages assignable to cell membranes determining potential gradients in longer scales. For the early embryo these gradients would code for the morphology.

The examples mentioned in the introduction allow us to deduce conclusions of this programming.

1. The morphology of an adult planarian is coded by the long scale electric fields of the embryo. Also the memories interpreted as behaviors are inherited in the replication of planarians by splitting. This means that the morphogenesis is goal directed and goal corresponds to a stable memory.

If the long range potential pattern of adult planarian is manipulated to produce 2-headed planarian after the splitting, the planarian is not affected. Therefore one can say that the memory of the electric field pattern matters but that in the splitting the memory is replaced by a new one. Also the descendants of split planarians have two heads so the memories are inherited in splitting.

- 2. The example of Picasso frog tells that even dramatic perturbations are not able to prevent the development towards a correct goal. Goal is indeed a stable memory coded by the electric state of an early embryo and the system is able to make error corrections.
- 3. The gut cells or frogs, when appropriately manipulated to modify the connectivity determined by gap junctions and the long range electric fields can develop to ectopic eye. Also other organs can be generated in this way. Even organs not usually possessed by planarians, such as fish fins, can be generated. Xenobots are novel life forms with the same genome as the frog.

These findings imply that the memory telling the goal can be rewritten and does not depend on gene expression. The same genome corresponds to the entire morphospace consisting of different organisms with different functions. Epigenetic level is however differently realized. These findings are consistent with the proposal that goal is represented as a memory which is characterized by long-term stability, lability (rewritability), latency (conditional recall: the 2headed planaria is generated only if the planarian is gut first), and discrete set of possible outcomes.

This inspires the computational hypothesis. Goal is computed. Electric signalling and classical long range potential gradients define an analog of genetic code and one can wonder whether some kind of morphic code based on the grading of the membrane potential exists. Difficult questions relate to the realization of the memory. How it can be stable if the organism itself is evolving. Some kind of time travel would be required for memory recall. Is it a conscious memory?

10.1.3 Xenobots challenge the dichotomous thinking in biology and AI

The talk of Josh Bongard having title "A xither of xenobots: demolishing dichotomous thinking with synthetic proto-organisms" (https://www.youtube.com/watch?v=7EA2AqS05tQ discusses the implications of the findings of Levin's group for fields like AI. The topic of the talk are brain/body-, genotype/phenotype-, and tape/machine dichotomies, which, according to Bongard, have made a real progress in ortodox AI difficult, if not impossible.

1. Brain/body dichotomy states that the brain tells the body how to move. In this picture, the body is a dead robot, hardware, and the conscious brain is the central intelligence, the software, which determines how the body moves. This view has dominated the view about AI. Although this view is plagued by several paradoxes due to the fact that nerve pulse transmission is quite too slow to realize the multiple feedback needed to actualize the commands of the brain, it still dominates the thinking.

The talk illustrates the basic failure of robotics by videos of falling robots. This illustrates the basic difference between robots and living matter. Humans do not fall down although they are about to fall down all the time. This is because of homeostasis. Living matter is a critical system which by some mechanism is able to remain near the criticality. Robots are not such systems and they fall down.

Biology suggests how to make this view more realistic by assuming that both the brain, software and the hardware can adapt. For rigid robots only the brain adapts. The talk describes smooth robots whose shape can vary. The challenge is to have a moving robot and a genetic algorithm indeed allows to find brain/body adaptation strategies. The genetic algorithm indeed discovers unexpected strategy in a situation making movement possible. Brain actually adapts very little for the model considered.

2. Genotype/phenotype dichotomy more or less equivalent with genetic determinism states that genotype determines phenotype. Epigenesis means the failure of the strictest form of this dichotomy. Xenobots mean much more dramatic failure. Same genome can give rise to different organisms.

AI has played an important role in the development of the Xenobots and a simple in silico model of the xenobot consisting of skin tissue and muscle tissue is discussed. In this model skin selves receive impulses from random actions of motor parts and are able to generate coherent motion. How this happens looks like a mystery. The mystery is much deeper: how selfish cells having only personal goals are able to transform to unselfish parts of an organism. This remains one of the deepest challenges of biology and the notion of emergence remains only a magic word without actual content.

3. Tape/machine dichotomy is central in computer science. Turing machine serves a a mathematical model of computer. Tape would represent the program and the machine would produce from the input table the output buble. Self-replication machines are Turing machines able to replicate. The talk represents a simple model for von Neumann self-replicator, which consists of 4 parts A,B,C, and D representing the tap. A makes a copy of A+B+C and B then makes the copy of D and combines A+B+C and D together. This kind of self-replication is called kinematic self-replication.

In living matter this dichotomy is far from obvious although the notions of input as a generalized sensory percept and output as motor action make sense. In living matter the selfreplication is very different and takes place by growing. There is no obvious identification of tape and machine.

Xenobots represent a biological actualization of a kinematic self-replication. Few generations of xenobots are possible. Genetic algorithm has been used to develop a simulation of self-replicating xenobots.

10.1.4 Brief comparison of Levin's views with the TGD view

Despite very different starting points, there are many similarities between Levin's views and TGD view.

1. Levin emphasizes the importance of cognition and also introduces the notion of self. Levin also talks of collective intelligence (swarm intelligence) and cognition and argues that all intelligence is basically collective intelligence.

TGD inspired quantum theory of consciousness predicts self hierarchy. In the TGD framework, number theoretic physics involving p-adic and adelic physics provides a mathematical framework for the description of cognition. One can say that number theory becomes part of physics. $M^8 - H$ duality would actualize the duality between the view about physics as geometry and physics as number theory.

One of the predictions is hierarchy of Planck constants identifiable as dimensions of algebraic extensions of rationals assignable to polynomials of real argument, which define space-time surfaces by $M^8 - H$ duality. This number theoretic holography involves almost deterministic holography at space-time level implying in biology an almost exact structure-function duality. Once one knows the 3-D surface, the 4-D space-time surface is almost uniquely determined as an analogue .bvcx of Bohr orbit.

Number theoretic vision leads also to a universal mechanism for the formation of bound states, which would also describe the formation of quantum coherent units from parts, such as selfish cells.

2. The experiments of Levin's group demonstrate the failure of genetic determinism and genetic reductionism. For a given genome one can have a large number of very different phenotypes involving different epigenomes. Genes would be only a hardware or lowest level of biological scale hierarchy and higher levels would control the lower levels rather than being determined by the gene level. Examples are genetic level, transcriptional level (epigenesis), morphogenetic level, physiological level, neurological level, and even higher levels. Multiscale competency is the term used by Levin. This means self-organization and slaving hierarchies.

In TGD these hierarchies correspond to fractal hierarchies of space-time sheets (MBs and EBs), p-adic length scale hierarchies, hierarchy of effective Planck constants labelling dark phases of ordinary matter, various algebraic hierarchies for symmetry algebras associated with TGD, to the hierarchies of inclusions of extensions of rationals, to the hierarchies of hyperfinite factors of type II_1 , and self hierarchies as hierarchies of conscious entities, selves.

3. Levin proposes electric coding of morphogenesis based on membrane resting potentials and that gap junctions connecting cells to each other give rise to connected morphogenetic units. For instance, cancer cell population would disconnect from the population. Furthermore electric signalling between cells based on membrane oscillations would be essential for morphogenesis.

TGD suggests that ordinary genetic code is only a special case. The genetic code is universal and there is a hierarchy of realization of genetic code. One fundamental realization of the genetic code would be in terms of so-called icosa-tetrahedral tessellation of H^3 [L159] and it would induce various realizations at the space-time level. Dark genes would provide 1-D realization and cell membranes might provide 2-D realization of the genetic code and even 3-D realizations can be considered.

Realizations of genetic code in terms of dark proton sequences with codon realized as dark proton triplet and dark photon sequences with codon realized as dark photon triplet are predicted.

In TGD, cell membranes correspond to electric bodies (EBs) and the proposal is that they act as Josephson junction communicating with the magnetic body (MB) using dark Josephson radiation and a cyclotron resonance mechanism transforming frequency modulated Josephson radiation to a sequence of pulses. Besides ordinary nerve pulse patterns, patterns of pulses in mV scale assignable to gap junction connected cell groups are predicted [L183] inspired by the experimental work of Prakash et al [I152, I150, I151] and Adamatsky [I45] and the TGD view of quantum gravitation [L178] predicting that quantum gravitational coherence is possible in arbitrarily long scales and is especially important in quantum biology.

- 4. The notion of morphospace corresponds in the TGD framework to the "world of classical worlds" (WCW) [K97] [L169, L197], which in the number theoretic vision has unique number theoretic discretization using appropriate extension of rationals.
- 5. In TGD, the notion of cognitive light-cone introduced by Levin corresponds to causal diamond (CD) [L118, L177] [K132], which is the basic notion in zero energy ontology (ZEO) providing a new ontology of quantum theory solving the basic paradox of quantum measurement theory. CDs form a fractal hierarchy.

Consider now the basic differences.

The basic difference is that Levin does not mention quantum theory at all. In the TGD framework, quantum theory is based on ZEO [K132] rather than the standard ontology of quantum mechanics, which relies on the identification of subjective time and geometric time of physicists. ZEO has rather non-trivial implications such as the prediction that in the ordinary state function reductions (SFRs) the arrow of time changes. These implications are crucial for understanding consciousness and biological self-organization. The views of free will and consciousness are different. Levin suggests what he calls a technological approach to Mind [I142]. The engineering based approach is proposed to lead to the notion of self, to explain cognition, and also even free will as an illusion, and perhaps even consciousness. Self would be determined by the morphogenetic or some other goal, and would be in principle an experimentally testable notion. Levin assumes that cognition is universal and appears in all scales. Also in TGD cognition is fundamental and number theoretical physics (adelic physics) [L66, L67] is needed to describe the mathematical correlates of cognition. This leads to the view the physics as geometry and physics as number theory are complementary descriptions of physics [L127, L128, L197, L191] The ZEO based quantum measurement theory extends to a theory of consciousness. In the TGD framework, Sslf as it is identified by Levin, would correspond to the unchanging part of self, kind of "soul". Self is predicted to also have a changing part determined by the generalized sensory input and motor actions. The unchanging part of self would by holography serve as a memory dictating the goal of the evolution of self, in particular in morphogenesis.

Note: I give the references to the articles related to TGD, which appear at my homepage. The articles have been published also in the journals founded by Huping Hu (PSTJ, JCER, and DNADJ) and the list of the published articles can be found at my homepage (https: //www.tgdtheory.fi/tgdmaterials/curri.html). The reason is that the articles at homepage are updated versions of original ones.

10.2 Levin's vision

In the following I try to summarize Levin's view of cognition and the big vision about implications of the new view of morphogenesis. The articles [I141, I143, I135, I50, I122, I142] provide a good view of the vision of Levin. The interviews and talks of Levin provide the best way to get a view of Levin's vision and the following only tries to summarize the most important points. The following interviews and talks provide a good overall view of Levin's work.

- The electrical blueprints that orchestrate life (https://youtu.be/XheAMrS8Q1c)
- Plasticity without genetic change: bioelectric embryos & synthetic proto-organisms (https: //www.youtube.com/watch?v=5ChRM4CEWyg)

- Understanding the Collective Intelligence of Cells: bioelectrical navigation of anatomical morphospace (https://www.youtube.com/watch?v=jLiHLDrOTW8)
- Biology, Life, Aliens, Evolution, Embryogenesis & Xenobots (https://www.youtube.com/ watch?v=p3lsYlod50U)

10.2.1 Technological approach to Mind

Levin proposes what he calls a technological approach to mind [I142]. Levin suggests an active engineering approach in which new structures are constructed and studied instead of a passive study of existing structures.

- 1. Levin suggests definitions for the notions of cognition, intelligence [I143, I135] and of self [I141]. It remains unclear to me whether cognition is assumed to involve consciousness.
 - (a) There would be no privileged substrate of cognition. This might be taken to mean that cognition is something universal. This also suggests panpsychism.
 - (b) Intelligence is identified as the ability to solve problems in abstract spaces. The abstract spaces correspond to spaces of possible goals of the system in various scales and form a hierarchy. Problem solving means achieving a goal in the space considered. The same goal achieved by different means: this would be the basic characteristic of intelligence.

Ordinary 3-space, morphospace and physiological represent basic examples of spaces. One can also talk of genetic and transcriptional spaces. The goal space at a given level can "bend" the space at the lower level so that the agents at the lower level start to collaborate instead of behaving in a selfish manner. In organisms, selfish genes become unselfish. In cancer just the opposite happens and means that the cancer cells as a subsystem quite concretely separate from the system.

- (c) Somewhat cryptically, the notion of self is identified as boundaries of goals that the system is capable of pursuing. More concretely, one might also say that the developmental goal of the organ or organism assigns self to it.
- 2. Developmental bioelectricity is another key notion. It is identified as a phylogenetic precursor of brain dynamics, a physiological medium for the software of life, and a medium of the cognition of morphogenetic swarm intelligence of cells. All intelligence is basically collective intelligence in which the subsystems start to collaborate to reach the collective goal.
- 3. Evolution would be greatly potentiated by multi-scale competency architecture [I50]. Evolutionary step would not be finding a solution to a problem but building a new kind of machine solving more complex problems. Increase of the scale and emergence of a new evolutionary level would be in question.

Selection by evolutionary pressures and random mutations drive the evolution in the Darwinian view. Levin expresses his view by saying: "where the goals come from, if not from selection?". One can of course ask whether the increase of complexity closely related to intelligence is a basic evolutionary goal of the Universe. This view seems to be in conflict with the second law however.

10.2.2 Levin's view of cognition

Multiscale competency architecture

Multiscale competency [I50] architecture is a key notion used by Levin.

1. Evolution uses multi-scale competency architecture to evolve machines that solve problems. The meaning of machine is however different from that in the recent technology [I122]. One could translate "multi-scale competency architecture" to a fractal slaving hierarchy in which
higher levels whose dynamics is in longer spatial and length scales interact with lover levels and receive information from these levels and control them.

Scaling is a key aspect of evolution. Evolution step means the emergence of a system characterized by larger spatial and temporal scales of coherence and of higher complexity and consisting of the already evolved systems, which start to co-operate. The spans of memory and anticipation increase.

- 2. DNA specifies cellular hardware but is controlled by agential materials inducing different epigenetic patterns.
- 3. Dynamics is robust due to anatomical homeostasis. Morphogenesis can be seen as an intelligent behavior of a cellular collective solving problems in anatomical morphospace. Computationalist would say that problem solving reduces to a search in the morphospace in order to reach a goal.
- 4. The cognitive glue that harnesses cells towards large scale outcomes ("bends" the lower levels to collaborate) is developmental bioelectricity. Goals are represented by long scale electric patterns generated in the embryonic stage and are identifiable as pattern memories utilized by collective intelligence of the organ. The experimental work of Levin et al makes it possible to read and write pattern memories.

Collective intelligence of cells

https://www.youtube.com/watch?v=jLiHLDrOTW8

Usually one distinguishes between centralized intelligence (brain would be the basic example) and collective/distributed/swarm intelligence. Levin proposes that all intelligence is collective intelligence.

The proposed multiscale competency [I50] in which higher level "bends" lower levels to co-operate, could be translated as a slaving hierarchy involving "bosses". One can also speak of a nested cognition.

There is a high multiscale competency already at the level of a single cell and in this case the smaller subunits are subsystems of the cell down to the level of genes. Single cell morphology and behavior are indeed very complex. The cell can detect bodies in its environment by generating vibrations which are reflected from objects. Kind of sonar is in question and allows us to build a map of the environment. The cell is able to reach the desired targets of the environment using this information.

Levin lists the following key aspects of collective intelligence.

- 1. Navigation in morphospace towards the goal and multiscale competency architecture (slaving hierarchy) makes this possible. Higher level morphospaces "bend" the lower level morphospaces forcing them to collaborate.
- 2. Goal-directedness involves recognizing, building, and controlling and communicating with agents in possibly unconventional embodiments (non-standard phenotypes). Self is defined as a cognitive boundary identified as the goal of the system.
- 3. Anatomical control reflects the collective intelligence of cells navigating in the morphospace. Bioelectric networks and their proto-cognitive medium (ancestor of brain function) → impact on biomedicine. The term "proto-cognitive" suggests that ordinary cells are not assumed to cognize. The goal of an organ or organism is coded by the electric field patterns during early embryo stage and can be regarded as a memory.
- 4. Synthetic bioengineering as a construction of new bodies and new minds corresponds to the active, engineering aspect of the approach. What is new and racial is that the novel organism does the job itself when the goal is given.

The novel life forms have no evolution behind them and their possibility suggests that same genomes can give rise to widely different organisms and that also different life forms can give rise to similar organisms. This view forces us to reconsider what evolution is. One can imagine applications to biomedicine and robotics, and one can ask whether the term robot is anymore appropriate. This vision raises deep questions in ethics, which is based on the view that life forms are products of long evolution and has been strongly human centered. What are the universal principles of ethics, is the question.

The basic critical question is that the notions of cognition, intelligence, self, multiscale competency, goal, and evolution are not defined at the deeper, presumably quantum physical level. Quantum physics as we now understand it, does not of course allow the formulation of these notions. The same applies to the notions of memory, and self, goal or intention. These notions would require a theory of conscious experience telling what distinguishes living systems from dead systems (if such even exist).

10.2.3 The dream

The dream of Levin [I142, I122] is to understand, recognize, create, and relate to truly diverse intelligences regardless of composition or origin story. Besides understanding of familiar creatures one would understand colonial organisms and swarms, even say something universal about exobiological agents. This would make possible synthetic biology, bio-inspired AI.

Communication with cell groups allows rewriting of the morphogenetic goals. Rewriting would be like activating one particular program module in the hierarchy of program modules. This module would call lower levels modules and in this way recruit the agents at the lower levels of the scaling hierarchy. No knowledge of the details of the process at lower levels would be required. This approach is a diametric opposite to the usual approach based on gene level manipulations.

One can even dream of the emergence of an anatomical compiler, which assigns to a plan of an organism, generated using AI utilizing the available empirical data, a new organism with desired functions. This dream is of course very far from reality. Levin mentions as an example the chimeric embryo formed from azoloti larva and frog larva. The existing models cannot predict what the outcome of the morphogenesis in this case could be.

Regenerative medicine would provide obvious applications for this kind of compiler. Consider only birth defects, degenerative diseases, aging, and cancer. Reprogramming a multicellular level could allow to normalize tumors, repair birth defects, induce regeneration of limbs, etc... Levin mentions also the development of electroceutical drugs based on chemical manipulations of cell membranes. What ion channels? These would be the basic questions?

Aso other than biochemical tools for the programming of the morphic goal might be possible but this would require a deeper understanding of how the goal identified as a memory is represented. Here quantum biology could come to rescue. One should understand how the goal as memory is defined at quantum level and how the manipulation of the voltages assigned to ion channels affect the goal.

One can imagine applications to computer science, say bio-computers for which search corresponds to finding a goal in the morphospace. Whether this can be realized using ordinary computers or even quantum computers relying on the standard quantum theory, is of course far from obvious.

The goal directed behavior could involve the feedback loop involving sensory perceptions about the state of the organism, which are compared with the goal, and generate feedback as a control signal.

One can also imagine a neuro-inspired view of sensory perception as a pattern recognition and completion in which the morphogenetic goal is represented by standardized mental images representing the possible outcomes of pattern completion. One could also consider the bio-inspired analogue of machine learning.

10.3 TGD view of morphogenesis

The TGD inspired view of life and consciousness leads to a view of morphogenesis discussed in detail in [L194] (2022). The discoveries of Levin's group described in [I139, I140, I182] have been discussed in [L18] (2014).

10.3.1 A possible TGD based view of morphogenesis

The basic notions relevant to the TGD description of morphogenesis.

- 1. The notions of magnetic and electric bodies (MBs and EBs). Magnetic flux tubes and possibly also sheets form a network connecting cell membranes and higher level membrane like structures. They correspond to EBs formed by light-like outer boundaries of 3-D surfaces representing the bodies of the network.
- 2. The phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$, tentatively identified as dark matter, play a key role in the TGD inspired quantum biology. These phases can reside at MB and EB. In the models considered hitherto MB is in a key role but it is clear that EB has an important role.
- 3. The notion of genetic code is generalized. One can speak of dark code with codons realized in terms of dark proton and dark photon triplets. In the number theoretic vision dark genes are realized as 3N-protons and photons. The so-called icosa tetrahedral tessellations of hyperbolic 3-space H^3 define a candidate for a universal realization of the genetic code. The genetic code could be realized at the level of cell membranes in terms of ion channels. One representation for the codons as 6-bit sequences could be as graded membrane potentials. The 2-D pattern of codons would define a set of 2-D genes. Electrical manipulations affect these genes and they become dynamical. This could also define what might be called "morpho-genes".
- 4. The electric programming of cell groups by electrical manipulation could affect the 2-D genetic codons, which would define the morphogenetic program. This would be possible at the early embryo state during which the system would be quantum critical. The fixing of membrane potentials of ion channels and pumps could fix the frequency of dark Josephson radiation from cell membranes to MB for them and select parts of MB for which cyclotron frequency is same as for the ion channel. This would map the electric pattern of the cell membrane to MB. After this period the situation would stabilize.
- 5. Zero energy ontology (ZEO) and holography might play a key role. The basic problem is to understand how a goal is realized as a memory. In ZEO the initial state as a superposition of 3-surfaces at the passive boundary of CD would remain invariant during the evolution of the zero energy state. It would naturally define the counterpart of memory and dictate to almost deterministically the evolution of self by "small" state function reductions (SSFRs). The memory would correspond to the part of self which is not changed during the evolution by SSFRs.

The comparison of the zero energy state defining self would in the simplest model be based on communications to the passive (past) boundary of self with negative energy signals with reversed arrow of time. The feedback would be a positive energy signal back to the future. This process essentially pattern recognition and completion and would gradually lead to the goal. This picture is completely general and morphogenesis would have only one particular application. One can consider more complex models in which the information about the goal at the MB is preserved and sensory communication could be also in standard time direction whereas the feedback would be in the opposite time direction. "Big" SFRs (BSFRs) would be involved in both cases.

Pairs of BSFRs involving temporary change of the arrow of time could be involved with large error corrections. Note that the sensory communications to the geometric past and the feedback can be seen as a pair of BSFRs at a lower level of hierarchy.

10.3.2 How the membrane potentials and gap junction connections could define morphogenetic program?

The behavior of the planaria is goal directed. There are reasons to assume that this is quite generally true.

Facts

- 1. The membrane potentials and gap junction connection network during the early embryonic stage code for the goal of the organism in morpho-space.
- 2. After this period, various perturbations, even very dramatic such as mixing of the parts of the embryo, do not prevent achieving the goal and the system is able to correct its errors. There are several ways to achieve the goal: this is interpreted as intelligent behavior.
- 3. If planaria is cut in pieces, the pieces grow to full individuals so that the memory of the goal is represented in such a way that the splitting does not affect it.
- 4. The modifications of the membrane potential of a full grown planaria and gap junction network do not affect the goal. One can say that the system goal corresponds to a stable memory of what point of the morpho-space the system should reach.
- 5. If membrane potential is manipulated and the planaria is cut after the modification, the resulting planaria have a new goal coded by the new pattern of membrane potentials and gap junction network. For instance, the modification can give rise to 2-headed planaria. If one assumes that the development corresponds to an analog of a computer program, one can say that the modifications lead to new morphology only if the planaria is split.

How could one realize this picture in the TGD framework? In accordance with earlier vision, it is natural to assume that MB, or actually a hierarchy of MBs, defines a slaving hierarchy with levels labelled by the values of h_{eff} defining scale hierarchy assignable to hierarchy of causal diamonds (CDs), which are analogs of cognitive light-cones of Levin.

Especially important levels of the hierarchy are labelled by gravitational Planck constant $\hbar_{gr} = GMm/v_0$ originally introduced originally by Nottale [E1]. Here M corresponds to either Earth mass or solar mass and m corresponds to particle mass. The large values of \hbar_{gr} make possible gravitational quantum coherence in long length scales, even Earth scale. The gravitational Compton length $\Lambda_{gr} = BM/v_0$ does not depend on the value of the particle mass m and the cyclotron frequencies of charge with mass m does not depend on m: this conforms with Equivalence Principle. This view leads to a view about the role of quantum gravitation in biology [L183, L178, L185].

Questions related to the electric coding of the goal

There are several questions to be addressed.

- 1. Why electric modifications have effect only if they are done during the early embryonic state? The possible explanation is that the MB during the early embryonic period is quantum critical and therefore highly sensitive to perturbations of the biological body represented as modifications of gap junction network and membrane potentials. During this stage the classical pattern of membrane potentials correlates strongly with the state of the MB, which defines the goal as memory. Quantum criticality is later lost and further modifications do not affect the goal anymore.
- 2. How the organ/organism remembers the goal and how the memory can be stable? Here ZEO provides a possible explanation. Zero energy states are pairs of ordinary 3-D states at boundaries of causal diamond CD and represented by superpositions of space-time surface. Holography, which is forced in TGD by the general coordinate invariance, forces almost deterministic correlation between the 3-D states at the opposite boundaries of CD.

The sequence of SSFRs preserves the state at the passive boundary of CD and passive boundary but affects the active boundary and the states at it and the temporal distance (geometric time) between boundaries of CD increases: this correlates the flow of subjective time as SSFRs with the increase of the geometric time. The sequence of SSFRs defines the notion of self as a generalization of the Zeno effect. The state which is unchanged in Zeno effect is replaced with the memory about the goal.

By almost deterministic holography, the state at the passive boundary defines the goal of the system towards which it evolves.

10.3.3 How the potential gradient is generated?

The generation of potential gradients is essential in morphogenesis. Potential gradients play a key role also in the brain functions and the direction of the gradient correlates with the state of consciousness. Potential gradients accompany DNA and microtubules. Hyperpolarization occurring during sleep corresponds to a reduction of the level of consciousness. On the other hand, the direction of a long scale electric field determines whether the brain is conscious or not. Therefore the polarization at the level of neuronal membranes correlates with the direction and strength of the electric field. Why this should be the case, is actually far from obvious, and TGD suggests that new physics, involving quantum gravitation, is involved.

From the videos, I concluded that the potential gradient is generated by manipulating the membrane potentials and that the change of the membrane potential of a given cell is constant and is the same at the two sides of the cell membrane defined by direction of potential gradient. I failed to understand how the variation of membrane potentials in this way can generate a potential gradient along part of the body. The manipulation of membrane potentials of cells such that membrane potential is constant for the entire cell membrane does not generate potential gradient.

Potential gradient means that cells are in an electric field for which potential increases in a given direction and is approximately constant inside a given cell. The simplest expectation is that the membrane potential is modified by the same constant amount for the entire cell.

The membrane potentials should be modified in such a way that the membrane potential is different at different sides of the membrane in the direction of the voltage gradient? Intuitively it is implausible that one could achieve a different effect on the opposite sides of a membrane by using the biochemical methods considered for which cell groups are targets and a single ion channel is selected.

Typically the second end of a structure carrying a longitudinal electric field is negatively charged and the second end is positively charged. How is this polarization generated? It seems impossible to generate it by manipulation of the membrane potentials since the change of potential over over distance defined by the cell is not affected at all unless the charge densities at the cell exteriors are rearranged to generate the gradient.

Does the generation of the potential gradient have anything to do with the manipulation of membrane potentials or is the mechanism indirect? It seems that in the case of the brain this is the case.

In the case of axonal microtubules, I have considered a new physics based mechanism based on quantum gravitation in the TGD sense. The mechanism would also generate a change of polarization in the axonal membrane since the effective microtubular charge in the interior of the axon would change.

- 1. The proposal is that very long "gravitational" hydrogen bonds with length even of order of Earth scale are possible due to the large value of gravitational Planck constant \hbar_{gr} . Ions would be transferred from the microtubule to these long hydrogen bonds and go outside the axon-microtubule system so that the effective charge of the microtubule would change and the transverse electric field created in this way affects the membrane potential. This could give rise to a propagating depolarization giving rise to hyperpolarization.
- 2. In this way it is also possible to create a longitudinal electric field in, say, the head-tail direction of the organism. This mechanism would be at work also in the case of the brain and relate to the DC currents of Becker [J5]. If the modification of membrane potentials generates a voltage gradient, the manipulation of the membrane potential must induce an effective charging of the cell interior. The number of ions transformed to long hydrogen bonds depends on the value of the membrane potential and that the effective charge depends on the value of the membrane potential being for instance proportional to it.

This could allow the MB to control the polarization based on the modification of membrane potentials. Actually MB, would keep it constant at the morphogenetic level. In the case of the brain the direction could be changed when the organism falls asleep (BSFR).

3. What the analogue for the choice of a subroutine in the manipulation of embryo or split planarian could mean in TGD? Ionic channels define Josephson junctions and for large values of h_{eff} Josephson frequencies can be even in ELF scale. These frequencies correspond by resonance condition to cyclotron frequencies of dark ions at MB. The resonance condition selects a part of MB to which communication of sensory data is possible and which can control the organism by resonance mechanism. The frequency modulated signal is transformed to a pulse pattern and this pulse sequence could define an analog of nerve pulse pattern [L183]. The empirical findings [I152, ?, I151, I45] and the TGD view of the role of quantum gravitation lead to identification of new kinds of pulses with the voltage scale in mV scale.

The goal of the organ is characterized by an electric field pattern, which in turn is dictated by the membrane potentials assignable to channels, pumps and gap junctions. How could the electric field pattern achieve this? The cells along the linear structure send Josephson signals to different parts of MB. Flux tubes whose thickness and therefore B varies?

Part of the organism corresponds to MB. The magnetic field strength at MB corresponds to the value of voltage at the cell membrane to guarantee resonance in communications. Voltages define a map of an organism at MB. This map is realized only at quantum criticality when the organism is very young and its MB is highly sensitive to the pattern of electric voltages..

10.3.4 How the state of the MB can serve as a template for evolution?

The model for the generation of sensory perceptions, regarded as states of subsystems defining selves, generalizes as such to the development of morphology. The MB contains the representations of possible mental images in sensory perception.

1. In sensory perception, the MB carries a representation of standardized mental images. The sensory input to the MB generates a virtual sensory input to sensory organs, which is determined by the difference between the actual sensory input and desired one. This difference is minimized and the process leads to the standardized mental image nearest to the original sensory input.

The process continues until the difference is small enough. The signalling from the MB is based on dark photon signals so that the process is roughly million times faster than ordinary nerve pulse communications so that standardized mental images emerge rather rapidly.

2. In the case of morphogenesis, the morphogenetic goal replaces standardized mental images so that the situation is much simpler. The SSFRs define sensory input to the MB and virtual sensory input is replaced with an analog of a motor action, which tends to drive the system towards the goal in the morphospace. There are good reasons to propose that motor actions quite generally correspond to pairs of BSFRs (as analog of death or sleep) changing the arrow of time temporarily and also having interpretation as quantum tunneling events.

The dissipation with the reversed arrow of time looks like self-organization with respect to the original arrow of time and leads to the final state as an analog of self-organization pattern. After the second BSFR the system starts to evolve in the original arrow of time. This pair of BSFRs is analogous to sleep, which is known to have a healing effect.

This mechanism would be used in all biologically relevant scales [L225] and would be a basic mechanism of homeostasis making it possible for a critical system to stay near criticality by changing the arrow of time repeatedly. This mechanism saves from the basic problem of robotics: robots tend to fall down since the vertical position is unstable. Note that also the dissipation in standard helps to achieve the final state as a self-organization pattern but is not enough if the system is critical as living systems are.

Morphogenesis would be like carving a statue. MB is the sculptor and starting from a rough sketch and proceeding to shorter scales. Now this process from long to short scales would process downwards in the hierarchy of MBs.

3. If the passive boundary of CD codes for the goal, the sensory input to it should correspond to signals travelling with a reversed arrow of time. Their generation requires BSFR of the system generating them and a pair of BSFRs would define the signal to the MB at the boundary and the response. Is the same mechanism involved with sensory perception?.

What happens in the splitting of the planaria?

One can say that in the splitting of planaria replication of planaria takes place. What does this mean in ZEO? Does it correspond to BSFR, SSFR or something different. Or are two new CDs identifiable as perceptive fields of new organisms created.

1. A natural guess is that MBs and EBs replicate. One of the basic questions in ZEO is whether new CDs can emerge. Since the zero energy states have indeed zero energy at the limit of infinitely large CD, nothing prevents their creation in SFRs. This is prevented by the conservation laws in the standard ontology but not in ZEO. The creation of a CD would correspond to a quantum jump which cannot be regarded as either BSFR or SSFR.

It however seems obvious that standard ontology is a good approximation due to the formation of CD networks in which the CDs are connected by particle lines to form an analog of the Feynman diagram with CDs representing vertices. There the CDs of split planaria would be connected to the CD of the non-split planaria by "particle lines" .However, In principle the generation of CDs from vacuum is possible without a violation of the conservation laws.

2. The simplest model explaining the findings about the regeneration of planaria from split planaria assumes that each split planaria is accompanied by its own CD and its passive boundary provides the memory determining by holography the growth of planaria as an analog of almost deterministic computer program (quantum superposition of them). The non-split planaria of the geometric past and its CD could still continue to exist and make BSFRs and evolve. This would happen even in astrophysical scales and explain stars older than the Universe and the galaxies older than the Universe detected by James Webb telescope [L190].

10.3.5 Some questions

The findings of Levin et al raise interesting questions in the TGD framework.

1. Chinese medicine talks of acupuncture points and meridians. Could these notions be reduced to the hypothesis that ordinary cells form networks analogous to CNS such that communications take place by the analogs of nerve pulses (miniature potentials) in the scale mV scale for which empirical evidence indeed exists [I152, I150, I151, I45] and is discussed from the TGD viewpoint in [L183]. Could the disorders at this level correspond to the loss of quantum coherence at the level of MBs and EBs caused by the reduction of the value of h_{eff} naturally caused by the failure of the metabolic energy feed needed to preserve the distribution of the values of h_{eff} . This would lower the "IQ" of MB and the control would fail. Could the splitting of the gap junctions be due to the same reason?

This would suggest that the healing of disorders could reduce to the control of communications between EBs and MBs and basically to the control of Josephson frequencies (membrane potentials) and cyclotron frequencies (magnetic field strengths coded by the thickness of the monopole flux tube). Besides chemical tools other tools can be imagined. For instance, irradiation at desired frequencies might be such a tool avoiding the side effects of the chemical tools [L82].

- 2. The vision of ZEO has developed slowly and the question whether BSFR and SSFR are the only quantum jumps or whether new CDs can be created from vacuum. The model for the splitting of planaria suggests an affirmative answer to this question.
- 3. A second open question has been whether the passive boundary of CD carries conscious information. The holography of consciousness suggests that the conscious experience at a given level of the self hierarchy remains constant between two subsequent SSFRs. The quantum state at the passive boundary is unaffected in SSFRs so that one can argue that there is no conscious experience giving information of the passive boundary. Could "silent wisdom", determining the goal of the self by holography, characterize the contribution of the passive boundary. Could the state of the passive boundary define "Self" or "soul" as a conscious experience, which tends to be masked by the contributions of the active boundary of CD. This "Self" would be changed in BSFRs.

10.4 About the recent findings of Michael Levin's group

I watched a video discussing two articles just published in Nature (thanks to Marko Manninen for the links). Besides Michael Levin present was Gizem Gumuskaya from the team behind the first article [I79] "Motile Living Biobots Self-Construct from Adult Human Somatic Progenitor Seed Cells". Also Angela Tung from the team behind the second article [I102] "Embryos assist morphogenesis of others through calcium and ATP signaling mechanisms in collective teratogen resistance" participated in the discussion.

It seems that the findings of Levin's group [I139, I140, I182] are really revolutionizing biology. The Darwinian vision of life as a struggle for existence is being replaced by life as survival based on cooperation, where conscious collective intelligence plays a key role. The findings suggest that life forms can be artificially created for various purposes: the applications in medicine can only be guessed at.

I have written a couple of articles [L18, L90, L216] about the observations of Levin's team. These ideas are emerging outside of biology as well: I have considered Gershing's vision of self-building machines from a TGD perspective in the article [L211].

10.4.1 A summary of the findings

A brief summary of the approach and findings of Levin's team [I139, I140, I182] is in order.

Epigenesis as means to produce new phenotypes

Instead of genetic engineering, epigenesis would serve as means to produce new phenotypes.

- 1. Epigenesis can produce completely different outcomes even though the genes are the same: genetic determinism must be given up. Electric fields of the cell membranes in the embryonic stage control epigenesis, but in the adult phase they no longer have an effect. Different phenotypes can be produced in a controlled manner. How epigenesis is realized under the control of electric fields is a mystery.
- 2. In the approach of Levin's team, there is no need to construct new genomes as in genetic engineering: the same end result, the phenotype, can be achieved with several genomes. Genetic determinism, i.e. the idea that the whole organism is encoded in genes, would be simply wrong. The protein-coding parts of the genes determine the protein level, but the phenotype would be determined by morphogenesis, which would be based on epigenesis.

A fascinating question is how independent the phenotype actually is on the genome. This kind of independence would be analogous to the substrate independence of AI based consciousness. In TGD this would conform with the idea that the magnetic body (MB) is the boss and controls the biological body so that the genetic code would be basically a code used by communication and control signals.

3. Epigenesis means that the same basic genome can code for a wide variety of mRNA molecules, which in turn code for proteins: even an mRNA chain does not determine proteins unambiguously, but can be split into parts (slicing), some of which determine a protein. This makes cell differentiation possible, only a small fraction of the genes is expressed, just like only a small part of the modules of a word processing program are in active use.

The realization of epigenesis relies on chemical modifications of DNA, such as DNA methylation and histone modification, which prevent normal gene transcription locally. Epigenetic expression can vary even on a time scale of hours. On the other hand, epigenetic modifications can be passed on to subsequent generations. What controls epigenesis is not understood. It is not even clear what epigenesis should include: should one just say that epigenetic is all that is not genetic. The notion of morphogenetic code emerges naturally.

Membrane potential as a new control level during embryonic stage

1. Already the earlier observations of Levin's team demonstrated that there is a completely new level of control that has been ignored before: the electric fields associated with the cell membrane, which are central to neuroscience but ignored in biology. Only the embryonic stage is sensitive to the effects of the electric fields so that these electric fields can control epigenesis only during this stage. The vision is that there is a multi-level control hierarchy above the genes that could extend even to the population level.

For instance, in the case of frogs it is possible to induce dramatic modifications of the phenotype such as several heads or no head at all. These modifications are stable and inherited by the next generations.

2. This inspires the idea of creating life forms, biobots, but without applying genetic engineering. Only epigenesis is utilized and has been controlled by manipulating the electric fields of the cell membrane in different ways, for example chemically or using external electric and magnetic fields at the scale of the embryo.

From frog embryos to human cells and populations of embryos

Earlier simple life forms such as frog embryos were studied, but now human cells have been the target and the earlier observations are made also now.

- 1. In the past, xenobots were studied as artificial life forms built from frog cells. For example, cells taken from epithelial tissue can be used. The important thing is that the system is sensitive to the control of the electric field of the cell membrane only in the embryonic stage and the genetic expression stabilizes after that.
- 2. Now anthrobots [I79] have been studied as artificial life forms formed from human cells. The spheroid shape group of cells generated under normal conditions is transformed by external stimuli so that the usually inward-directed cilia point outward and the structure can move with their help. Embryo is turned inside-out.
- 3. The population formed by the embryos has also been studied [I102] and unexpected collective effects have been observed. The collective survives a perturbation better than a mere individual. The vision of vulgar Darwinism about life as a struggle for existence (to which also our materialistic view of society relies on) is simply wrong.

10.4.2 TGD view of the findings

Consider now a summary of what has been observed from the TGD perspective.

Structure determines function

It seems that at the level of the organism, the 3-D structure determines the function and that these functions are a discrete set in the studied situations. This is highly non-trivial but in line with the TGD vision, which differs from the standard physics in the sense that holography is realized at the space-time level.

3-D surfaces in $H = M^4 \times CP_2$ identified as a generalization of point-like particles of quantum field theories is the starting point of TGD. The 4-D spacetime surface is determined from the 3-D surface providing holographic data and is therefore analogous to the Bohr orbit. The almost deterministic Bohr orbit is analogous to the notion of function of biology, a genetic program determined the structure having 3-D holographic data as a counterpart. Quantum states are superpositions of these Bohr orbit-like space-time surfaces.

What distinguishes TGD from other quantum theories is that there is no path integral so that one avoids the usual divergences and classical physics becomes an exact part of the theory.

In particular, the fact that there seems to be a very small number of different structures and associated functions conforms with holography.

At the quantum level, biological functions are time evolutions that obey statistical determinism. What distinguishes biosystems from deterministic computers is that statistical determinism can be violated because quantum coherence in all scales is possible. Quantum coherence in time scales longer than say the EEG periods implies this violation. This is what makes matter alive. An interesting question is whether this violation can take place also for ordinary computers.

Cells behaviour depends on the size of the population

- 1. A surprising result of [I102] is that cells behave differently depending on the size of the population. Furthermore, cells, embryos, etc... are cooperative social beings helping each other to survive. For example, in a population, a single cell recovers from damages much better than a solitary cell. This happens only if the entire population has experienced the same perturbation. Cells survive better in a larger population and develop differently in them.
- 2. This strongly suggests the presence of collective consciousness and intelligence, which is much more than what is thought to be, for example, the swarm intelligence of AI systems. The magnetic body (MB) as a conscious entity could provide the TGD realization of collective intelligence and produce a hierarchy of levels of consciousness. The bigger the population, the larger the value h_{eff} as a measure of algebraic complexity and quantum coherence scale also at the level of the individual: this would explain why the increase in population size makes individuals smarter too.
- 3. When a single cell of the population is damaged, it generates a Ca⁺⁺ wave that spreads to the environment and induces ATP production and Ca⁺⁺ secretion. This involves the transfer of information, which makes it possible for the population to react as a coherent entity, a kind of life form. If the Ca⁺⁺ wave or the generation of ATP is blocked, the embryos behave as if they were alone.

Communication need not involve mere chemical signals, as the standard biology would predict. It is not understood how the mere presence of other individuals helps in the healing process.

4. What could be this unknown means of communication? This brings to mind the observations of Blackman and other pioneers: ELF radiation at the cyclotron frequency of Ca⁺⁺ in the case of mammals affected both behavior and brain physiology. In the TGD framework, the generation of a Ca⁺⁺ wave could correspond to the communication induced with the help of Ca⁺⁺ ions to a certain layer of the system's magnetic body. Communication would take place at the cyclotron frequency and its multiples, which in Blackman's experiments was 15 Hz and would indicate the presence of an endogenous magnetic field of .2 Gauss, which is 2/5 of the nominal value of the Earth's magnetic field.

Ca⁺⁺ waves could act like neurotransmitters are believed to do, that is by activating communication lines from cells to the MB. The embryos would become a coherent unit through these connections. The MB would control the entire system. Quantum entanglement in the scale of MB would be present making the population a coherent unit: mere classical communications are not enough.

5. A nerve impulse would do the same between neurotransmitters. Here one should think critically about the previous TGD view of the role of nerve impulses. According to the TGD view of brain [L57], nerve pulses do not correspond to fundamental communications. Rather, neurotransmitters would simply connect the magnetic flux tubes associated with pre- and postsynaptic neurons to form one long channel along which dark photons with large h_{eff} would propagate from the sensory organs to the cortex and from cortex to the MB.

A more general alternative would be that dark photons signals to the hierarchy of layers of the MB of the brain take place also from the activated neurons along the neural pathway and not only from the cortical neurons. The activated neurons, the neuronal pathway, would have a quantum coherent and quantum entangled entity at the level of MB and define an association chain at the level of conscious experience. Neuronal synchrony would relate closely to this quantum coherence.

Morphogenetic code

The proposed communications should involve a morphogenetic code, which is not understood.

- 1. TGD inspires the idea that the genetic code as a universal code defines also the morphogenetic code [L90, L194]. Dark codons of DNA, RNA,.. and their counterparts would be realized as dark proton triplets in various scales. Dark genes with N codons would correspond to 3N dark protons. Communications would rely on dark 3N-photons (N would correspond to the number of codons of gene) as analogs of bound states of 3N dark photons would realize the genetic code in the sense that that they would induce 3N-resonant transitions between dark genes as dark 3N-protons.
- 2. Also the communications between dark and ordinary information molecules would rely on the resonance mechanism. The idea that dark genes are mere copies of ordinary genes does not look attractive. Actually, dark DNA, RNA, etc could be almost independent of their chemical variants and participate in quantum information processing not directly visible at the level of ordinary biomatter. Only in the communications with ordinary gene or its part, dark information molecules could transform to a state corresponding to the ordinary information molecule or its part.
- 3. The realization of the genetic code could be universal and could correspond to the so-called icosa tetrahedral tessellation of the hyperbolic 3-space and it would appear in all scales, not only in biology [L199].

Hierachy of collective intelligences

Levin proposes that collective intelligence is present in several scales. TGD predicts the existence of several scale hierarchies based on a new view of spacetime and a number-theoretic vision of TGD as dual to geometric vision.

I have built a model for the birth of language [K133] based on the observation that the appearance of a few crucial genes was crucial for the emergence of language. The proposal is that this meant the appearance of a layer of MB with a considerably larger h_{eff} . A collective level of consciousness on a much larger scale was born. Language would make possible the communication between individuals and promote the birth of these larger collectively conscious structures. Language in human society would have a role similar to that of Ca⁺⁺ waves in the collective behavior of embryos [I102].

Somewhat surprisingly, Levin does not speak at all about the possible role of quantum theory in biology. I think it would be important to build a bridge from the observations of Levin's group to the models of quantum biology. The team's findings force us to take quantum coherence at long scales seriously.

Typically, theories of consciousness do not have much to say about this aspect. One reason, of course, is that standard quantum theory doesn't have much to say.

Chapter 11

Molecular Signalling from the TGD Point of View

11.1 Introduction

I learned recently about interesting findings about communications of information molecules. The Quanta Magazine article "*Biologists rethink the logic behind cells molecular signals*" (https://cutt.ly/iA281qn) summarizes the findings of Elowitz *et al* described in the article "*The context-dependent, combinatorial logic of BMP signaling*" [I85] (https://cutt.ly/yA8r07b).

11.1.1 Observations

Messenger molecules attaching to receptors are thought to be responsible for chemical communications. Intercellular communications would involve first messengers (hormones, neurotransmitters,...) and intracellular communications second transmitters, which are not proteins but rather light molecules.

The standard interpretation has been that messenger molecules themselves define the message. Lock-key hypothesis states that the ligand has a special region (key), which attaches to the receptor in a context independent way determined by the geometries of these regions. Induced-fit hypothesis states that the regions in question can modify their surfaces to achieve a perfect fit. For bacteria only intracellular communications are possible and for them there is evidence that in some special cases lock-and-key principle works as was demonstrated by Michael Elowitz, the leader of the research group behind the recent work.

The findings of the Elowitz and his coworkers force them to conclude that this model fails for the multi-cellulars.

- 1. The group studied so-called bone morphogenetic proteins (BMP) (https://cutt.ly/oA7kZna), which regulate how cells proliferate and differentiate in various tissues by directing them to turn sets of genes on and off. These proteins have many other functions than bone growth.
- 2. BMPs are so-called 1st messengers and mediate communications between cells. BMPs attach to the receptors of various types at the surface of the cell. This step is followed by signal transduction activating the corresponding signalling pathway. Eventually this leads to a generation of transcription factors in the cell nucleus controlling the genetic response. The work concentrated on the study of the binding of BMPs to the receptors at the cell membrane.
- 3. Mammals have genes that encode 11 or more distinct BMP proteins. BMPs occurs dimeres of the same or different proteins and also these pairs can pair up. The family of BMP proteins sticks to the associated family of receptor proteins, which also appear as dimers of pairs of them. BMP molecules are not very selective but given BMP sticks to several dimer pairs of receptors.

Several interesting findings were made.

1. The response of a cell to several ligands is not simply the sum of responses of individual ligands. The lock-key mechanism assuming 1-1 correspondence between ligands and receptors fails in the presence of several ligands whereas for a single ligand there is strongly preferred receptor for a given ligand.

The simplest chemical (and thus local) explanation that in presence of several ligands the affinities K_{ijk} of ligands L_i to the receptors R_{jk} formed by dimers (j,k) of homologous or nearly homologous molecules change so that approximate 1-to-1 correspondence becomes 1-to-many. This is called promisculty.

The responses as concentrations at the cell membrane for the activated signalling pathways P_{ijk} associated with receptor i+jk would be still linear in concentrations of L_i but the matrix characterizing the rate for the creation of P_{ijk} would not be diagonal matrix anymore with respect to pairs (i, jk).

- 2. This situation is easy to model mathematically but it is difficult to understand the physical mechanism behind the promiscuity.
- 3. The affinities are context dependent in the sense that they depend on the target cell and the developmental stage of the cell.
- 4. One can classify the ligands in terms of whether they tend to increase or reduce receptor expression. Ligands can be also classified in terms of their positive, or negative synergies with other ligands. In the simplest situation one studies all possible pairs of ligands and finds their responses. Two ligands L_i and L_i are regarded as equivalent if the responses for the pairs (L_i, L_k) and (L_j, Lk) are identical for all k. This defines functional equivalence. Sequence similarity (biological homology) does not in general reflect the functional equivalence.

The effects of the ligands in equivalence classes depend on the context (cell type and cell age correlating with receptor concentrations). However, it is found that the equivalence classes are context independent. The proposal is that a single linear parameter could characterize the equivalence classes for BMPs considered.

5. This inspires a chemical model for the situation. The basic parameters would be affinities K_{ijk} telling the tendency of ligand L_i to attach to dimer (j,k), signal complex activities ϵ_{ijk} characterizing the rate for the formation of signal complex P_{ijk} . Also the receptor concentrations A_i and B_i for the receptors of type I and II appear as parameters. The empirical data makes it possible to find the best fit for the parameters. Promiscuity is the basic prediction. The model could be understood in terms of the competition of ligands for receptors (j,k).

An inverse relationship between affinities and activities is predicted. Small number of affine ligands with weak activity or vice versa.

11.1.2 TGD view about the findings

What can one say about the situation in the TGD framework? Here only the key ideas of the TGD inspired quantum biology are described. More detailed summaries can be found in various articles related to dark variant of biochemistry [L228, L62, L164], to dark realizations of genetic code [L16, L136, L103, L159, L196], and to the models for cell membrane as generalized Josephson junction [K92, K45, K93] [L155], of Pollack effect [?], and of water memory and morphogenesis [K62] [L194].

1. The basic notion is magnetic body (MB) carrying dark matter as $h_{eff} = nh_0$ phases of the ordinary matter and behaving quantum coherently in length scale proportional to h_{eff} . MB would control biomatter.

Communications to MB, sensory input, would be in terms of generalized dark Josephson radiation from the cell membrane and the control by MB in terms of dark cyclotron radiation. The sensory input would be from the entire cell membrane and induced by the attachment of the ligands to the receptors.

The earlier proposal was that the control signals from MB affect directly the genome. The existing chemical picture based on signal pathways activated at the cell membrane however suggests that the situation is not so simple. The control signal arrives from MB to the receptors and activates signal pathways. At the nuclear membrane similar processes would occur and lead to the activation of transcription factors by similar signal pathways.

- 2. If the MB determines the response of receptors in a non-local way, promiscuity could be only effective. Another option is that MB can control the affinities of receptors (by modifying their surface geometries as in the induced fit model) so that the diagonal L-R matrix becomes non-diagonal.
- 3. Context dependence would conform with the idea that MB determines the response and changes during aging. The aging can be understood in the TGD framework as slow thermalization of MB so that its temperature approaches the Hagedorn temperature of magnetic flux tubes. Physiological temperature would be related very closely to Hagedorn temperature of MB.

The almost computer program-like determinism of biochemistry is in a sharp conflict with the stochasticity expected to result from the locality and statistical nature of chemistry.

- 1. In the TGD framework and at a given level of scale hierarchy the dynamics of the space-time surface as a preferred extremal is deterministic apart from small violations of determinism. Space-time region as a preferred extremal is a minimal surface with singularities, which would bring in the failure of determinism. Soap film with frames serves as a good analogy.
- 2. The notion of a magnetic body having flux tubes as body parts leads to a model of biocatalysis in which molecules are replaced with nodes of flux tube network. Molecules can find each other as part of this dynamical network involving reconnection of U-shaped flux tubes and their shortening in a reduction of h_{eff} liberating energy making to overcome the potential wall making the reaction low.
- 3. One can argue that the second law implies stochasticity in molecular scales. Zero energy ontology (ZEO) is another possible source of determinism. In so called "big" state function reductions (BSFRs) the arrow of time changes and the time evolution leads to the direction of geometric past so that for the observer with the standard arrow of time the time evolution obeys second law in wrong time direction and looks like self-organization which is basic characteristic of living matter and usually thought to involve metabolic energy feed in an essential way. In fact the time reversed time evolution would change dissipation as loss of energy with extraction of energy from the environment.

The findings of Elowitz *et al* [I85] lead to a formal model suggesting that ligands of type BMP have interactions. The interactions would be non-local so that that they could have chemical origin. The TGD based model for these long range interactions is based on dark photon resonance. For the simplest, receptors would correspond to fixed bio-harmonies. In a single ligand system the ligand would have the bio-harmony of its preferred receptor. The interaction between ligand magnetic bodies would be re-tuning and could replace the preferred bio-harmonies assignable to the participating ligands with distributions of bio-harmonies. Therefore the ligands of the multi-ligand system would couple by bio-resonance also to other than preferred receptors.

The model stimulates questions, which lead to a rather detailed model for the re-tuning and tuning processes at the level of codons and amino acids. The model suggests that the tuning to a given bio-harmony for the dark counterparts of basic biomolecules and its stabilization involves epigenetic control based on the methylation of some special DNA and RNA nucleotides and aminoacids acting as analogs of tuning forks.

The proposal that bioharmonies are molecular correlates for emotions suggests that this process involves minimal number of methylations, which define the seed of phase transition to a bio-harmony in the scale of the basic unit of genome (such as gene), mRNA sub-unit (splicing) and protein sub-unit.

11.2 Bio-harmony and context dependence

Also bio-harmony might relate to context dependence if fundamental communication and control signals take place at the dark level that is between DAAs instead of AAs (amino acids) as parts of proteins by energy and frequency resonances. DAAs would pair with AAs and communicate with energy resonance.

11.2.1 Bio-harmony

Consider first the bio-harmony [L16, L103, L136, L196] in more detail.

1. Z_6 , Z_4 , and $Z_{2,rot}$ or $Z_{2,refl}$ act as symmetry groups for the 3 icosahedral Hamiltonian cycles. Each cycle, one of type XZ_6 , one of type Z_4 , and one of type Z_2 , defines 12-note scale and 20 3-chords identified as icosahedral faces and DNA codons. The notes along the cycle are obtained as a quint cycle, that is by scaling the frequency of the note by factor 3/2 at each edge of the oriented cycle.

The orbits of faces under Z_n are assigned with amino-acids (AAs). This assumption has a concrete interpretation in terms of resonance mechanism for bio-communications [L196].

This gives 60 3-chords and the numbers of triangles at the orbits of triangles and the numbers of triangles at orbits correspond nicely to the numbers of DNA codons coding for AAs. 4 codons are however missing. The fusion with a unique tetrahedral code gives 64 chords and a dark 3-photon realization of the genetic code.

Also the identification of DtRNA, dtRNA, and DAA in terms of icosahedral code is possible as found quite recently [L196]. Also the dark realization of genetic codons in terms of dark proton triplets allows this.

- 2. Z_6 allows unique icosahedral harmony defined by 12-note scale realized as an icosahedral Hamiltonian cycle. The corresponding AAs correspond to 3 DNA 6-plets and one DNA 2-plet. Z_4 corresponds to 2 bioharmomies with 5 amino-acids which correspond to DNA 4-plets. $Z_{2,rot}$ and $Z_{2,refl}$ correspond to 10 2-plets both. $Z_{2,rot}$ corresponds to 3 icosahedral harmonies and $Z_{2,refl}$ to 5 icosahedral harmonies. This makes $1 \times 2 \times (3 + 5) = 16$ bioharmonies if the common key of the 12-note scale for the 3 icosahedral harmonies does not matter and the orientation of the Hamiltonian cycle does not matter. One can also consider the possibility that the key and the orientation of the cycle for the 3 icosahedral harmonies matter. The change of the orientation replaces quint cycle with quart cycle (CG corresponds to quint and CF to quart).
- 3. The interpretation of bioharmonies is as correlates for moods, emotional states. There is evidence for this interpretation from the strange finding that RNA is able to transmit conditioning based on negative or positive emotions generated by stimulus (https://cutt.ly/6SuLNqk) discussed in the TGD framework in [L86, L107]. The interpretation would be that DRNA represents the effect of stimulus by its bio-harmony characterizing emotional state, and can induce molecular emotional expression in DDNA-DNA pairing and also in DAA-AA pairing and DX-X pairing in general.

DX-X pairing by energy resonance mechanism would correspond to emotional expression. Something in X would depend on bio-harmony. In the case of DNA and RNA this something could be the methylation state and its analogs so that there would be a direct connection with epigenesis. Epigenesis would realize the dynamics of emotional expression.

One can raise several questions about bio-harmony.

- 1. How fast is the dynamics of the molecular and higher level emotions and moods? If epigenetics controls the dynamics of emotions, it could be rather fast at the molecular level. Note that the hierarchy of Planck constants predicts a hierarchy of time scales.
- 2. How large parts of a given organism a given bio-harmony could characterize? Biomolecules, cell nucleus, cell, organelle, ...? Is there a hierarchy of harmonies so that the harmonies in different scales need not be identical?

Concerning molecular bio-harmonies, epigenetics could help to answer the question. For instance, one can ask whether bio-harmony characterizes individual bio-molecules such as enzymes and receptors.

- 3. Could bio-harmony explain at least part of the context dependence found in the ligand-receptor dynamics by the group of? It would seem that bio-harmony appears as an additional aspect of the ligand-receptor pairing involving geometric constraints modelled in terms of lock-key or induced-fit mechanisms. The enzyme and substrate would be like daters. The resonance mechanism would allow E and S to meet and geometric constraints would determine whether this can lead anywhere.
- 4. This inspires several questions. Could the affinities and signal complex activities be determined by the molecular emotional state of the L-R composite coded by the bio-harmony of the DX-X complex? Could the "emotional" state DX-X control affect the state of X complex? How? Could this coupling have interpretation as emotional expression in a generalized sense?
- 5. For the simplest model this would predict that for Z_4 the 5 AAs coded by 4 DNA codons would have two emotional states and for Z_2 10 DAA-AA pairs could have 3 resp. 4 emotional states depending on whether one has $Z_{2,rot}$ resp. $Z_{2,refl}$.

11.2.2 Could ligand interactions reduce to a re-tuning of ligand harmonies?

The notion of ligand interaction has been introduced as a purely formal notion in the article and it is difficult to imagine a local chemical realization for it. However, the fact is that ligands change their behavior in the presence of other ligands. Could the ligand interactions be realized at the level of their MBs?

Ligand interactions as re-tuning

Could ligand interactions reduce to the re-tuning of ligand harmonies by the resonant dark photon interactions between DAA flux tubes?

- 1. Assume that ligands and receptors can have several bio-harmonies but that free ligands (single ligand situation) and in the absence of other ligands they correspond to single preferred bio-harmony. Assume that each receptors corresponds to a single bio-harmony (also this assumption could be relaxed). Free energy minimization could imply preferred bio-harmonies for both receptors and ligands. Assume that ligands can only pair with receptors with the same bio-harmony. The immediate question is whether the 3+4 receptors assigned with BMPs could relate to 3+5 Z_2 type harmonies. The problem is that one $Z_{2,refl}$ harmony would not correspond to a receptor.
- 2. Interactions between two ligands L_1 and L_2 with different bioharmonies could induce a retuning of L_1 to the bio-harmony of L_2 or vice versa. This tuning must respect the symmetry group Z_n , n = 6, 4, 2 in question. The Z_n orbits would be preserved but the corresponding 3-chords would be modified.

Some findings about water memory [L194] support re-tuning as a basic mechanism of communications between dark biomolecules and it is very natural in the resonance picture. Note that re-tuning is a basic mechanism in radio communications.

Re-tuning would replace the ensemble of ligands with an ensemble in which also non-preferred L-R pairings are possible. It would make the affinity matrix $K_{i(jk)}$ and activity matrix $\epsilon_{i(jk)}$ non-diagonal and induce promiscuity. Probability distribution for bio-harmonies of ligands would emerge in this way.

3. The large-scale quantum coherence at the level of MBs inspires the question whether the quantum superposition of bioharmonies could occur for DAAs.

Could quantum superposition allow to understand the observation that the increase of the parameters $K_{i(jk)}$ is accompanied by the decrease of $\epsilon_{i(jk)}$ and vice versa. Could one think that with a suitable normalization one has $\sum_{(jk)} K_{i(jk)} \epsilon_{i(jk)} = constant$. In ZEO one could regard the entire signal complex, which involves both ligand, receptor and what it induces, as a single zero energy state as a superposition of deterministic time evolutions.

If the formation of signal complexes involves a quantum transition from a single ligandreceptor pair to a their quantum superposition involving delocalization at the cell membrane followed by state function reduction involving localiation that is selection of the complexes, the condition $\sum_{(jk)} K_{i(jk)} \epsilon_{i(jk)} = constant$ could reflect probability conservation.

4. Re-tuning of the icosahedral harmony for Z_4 and Z_2 should have a counterpart affecting the physics of AAs. Could the re-tuning be generated at the level of DAA and result from the variation of flux tube thickness as a motor action of MB? Or could it be induced by re-tuning at the level of DDNA? Tuning must be visible at the level of AAs since DX-X resonance energies must be modified.

Tuning and re-tuning at the level of DX-X pairing

What could the re-tuning mean for the DX-X pairing?

1. For DDNA-DNA pairing dark cyclotron photons must couple to some degrees of freedom of DNA. In the TGD framework, DNA can be magnetized [L194]. The pairing with DDNA flux tubes carrying a monopole flux with DNA strands is expected to induce magnetization along DNA due to the ring currents of electron pairs of the aromatic rings analogous to Cooper pairs.

The simplest candidates for re-tuned frequencies are cyclotron frequencies for magnetized nucleobases. In re-tuning the cyclotron frequencies for electron pairs) assignable to aromatic rings of nucleotides would be modified in re-tuning. The change of the thickness of the monopole flux tubes defining the 12-note scale would automatically induce the re-tuning at DNA level. The re-tuning could be induced by DDNA, DRNA, and DtRNA and would not require chemistry.

2. What about the DAA-AA tuning? The only AAs with aromatic rings are Phe, tyr and trp. Could DAA-AA resonance coupling between cyclotron radiation of DAA and vibrational modes of AA with energies in the range .45-.045 eV spanning slightly more than 3 octaves?

The general forms of the vibrational and cyclotron energy spectra are the same and for a proper value of h_{eff} the scale of the DAA spectrum is the same and resonance is possible.

Re-tuning would require change of the conformations of the AAs so that the elastic constants would be modified. MB could induce this re-tuning as a kind of entrainment. As already proposed, this could be achieved at the level of DNA by methylation of the start codon fixing the bio-harmony.

Could special 3-chords act as tuning forks

Physical model for the tuning and re-tuning should be based on resonance model.

1. Tuning to a particular 3-chord or 3-chords should force the entrainment to the bio-harmony. These 3-chords would serve as an analog of a tuning fork.

The simplest, and perhaps unrealistic, option is that the met 3-chord associated with the start codon alone fixes the bio-harmony uniquely. The met 3-chord should be different for all Z_2 harmonies.

2. The chords fixing the bio-harmony (the tables for the 3-chords of bio-harmonies are given in [L16]) should be very special and thereindeed are very special chords in the icosahedral harmonies. The epigenetic modification of the amino-acids corresponding to these 3-chords could force the re-tuning of the bio-harmony. The triangles, whose edges do not belong to the Hamiltonian cycle, define 0-quint 3-chords containing no quint. These chords include dissonant chords possibly having semitones or tones intervals between the notes (octave equivalence and quit cycle along the Hamiltonian cycle is assumed). There are 8 different types of 0-quint chords with basic note X in 12-note scale labeled as Xexk, k = 1, ..., 8, if the key does not matter.

- 1. From the Appendix one learns that there the first possess no 0-quint chords Z_4 harmony. In this case, one could argue that the bit defined by the presence or absence of the 0-quint chord defines the tuning fork, which could correspond to a methylation of some codon coding for one of the 5 AAs coded by DNA 4-plet. It is not clear, whether the choise of the codon matters.
- 2. By looking at the tables of 3-chords in the chord tables of the Appendix, one finds that if key matters, it is easy to distinguish between harmonies using a single 0-quint chord. If the key does not matter, it is in principle almost possible to assign different 0-quint chords to, say, met. There are 2 $Z_{2,refl}$ harmonies with 2 0-quint chords, which cannot be distinguished in this manner. If one introduces a fixed key or uses a second special 0-quint chord as a turning fork, also $Z_{2,refl}$ harmonies can be distinguished from each other.

Interestingly, the number of BMP receptors possibly assignable to $Z_{2,refl}$ is 4 rather than 5.

3. Also tetrahedral codons define special chords in the sense that the intervals are separated by minor third. These 3-chords are identical under the octave equivalence. In the model considered in [L196], 3 of them correspond to stop codons whereas the remaining codon corresponds to trp.

Re-tuning as an epigenetic process

Re-tuning is an epigenetic process and can be seen as a control of MB. Methylation and its analogs are basic tools of epigenesis.

- 1. mRNA methylation (https://cutt.ly/1Srm06F) occurs after transcription and is controlled by genes coding the needed enzymes. The methylated RNA nucleobase is often called the "fifth RNA" base. Start codon AUG coding for met is methylated as also the 3-prime untranslated regions (3'-UTRs) immediately after the stop codon. This region post-transcriptionally influences gene expression.
- 2. The findings that the RNA of a conditioned sea snail scattered over neurons of second sea snail in Petri dish generate neuronal correlates of conditioning (https://cutt.ly/6SuLNqk), discussed from the TGD point of view in [L86, L107], support the view that the magnetic body of the RNA of sea snail infects the emotion/mood related to the conditioning. The emotional state, mood, of DNA and RNA would affect gene expression. Epigenesis could be based on emotional states lasting for several generations. This is natural in ZEO [L16, L107].

Hints about how the methylation could be involved with the tuning to a particular bioharmony comes from the research of the group led by Matthias Soller [I81] (https://cutt.ly/ OSeGnJu).

- 1. Post transcriptional methylation is known to occur for the few nucleotides of mRNA following the cap of mRNA, whose function has remained poorly understood. Soller and collaborators demonstrated that the two enzymes coding for the methylation of these nucleotides played an important role in the animals' reward learning process. The flies without the genes coding for the methylation showed a defect in their ability to learn the association of a specific odour with a sugar reward.
- 2. Earlier work by one of paper's co-authors, Prof. Rupert Fray, has demonstrated that that cap modifications are highly dynamic in mice and that these modifications played a role in transporting the mRNAs to synapses.

3. The lack of methylation implies a lack of the desired conditioning. Conditioning involves emotions, perhaps also at the molecular level: could the bio-harmony of proteins involved with the process differ from that associated with the protein activated by the odour molecules? The proteins would be out-of-tune and conditioning would not happen.

The role of cap modifications in the mRNA transport would conform with the assumption that dark photon resonance allows the mRNA to find synapses. If the bioharmony for them is wrong there is no resonance and the transport fails.

These findings suggest the following interpretation in the TGD framework.

1. The resonance mechanism would force DDNA and DmRNA to have the same bio-harmony. The post-transcriptional methylation of the first RNA codon could re-tune and stabilize mRNA bio-harmony.

Stabilization could involve a methylation of a large enough number of special RNA codons so that it would serve as a seed of a phase transition forcing the same bio-harmony for all codons. If bio-harmonies correspond to molecular moods, this would be analogous to the spread of an emotional mood in crowd. The special codons as signatures of the mood could be especially effective inducers of this phase transition.

2. Could a 0-quint 3-chord assigned to met in the beginning of mRNA fix the Z_2 harmony almost uniquely by acting as a tuning fork. Z_4 harmony could be fixed by the absence of methylation in some mRNA nucleotide in codon coding for one of the 5 AAs [(val,pro,thr,ala,gly)] coded by 4 codons.

Note that the methylation of 2 AUG nucleotides of met affecting the cyclotron frequencies of AUG could in principle select between the 16 bio-harmonies predicted by the simplest model. This estimate is however based on counting of bits and bio-molecules need not see each other as bit sequences as we do.

The methylation of the mRNAs associated with several 0-quint chords could help to stabilize the Z_2 harmony at the level of DmRNA. Could the proteins obtained by splicing and involving methylation in the beginning of mRNA portions coding them consist of functional sub-units with different bio-harmony?

3. What about DNA? Could the methylation of the start codon also now help to stabilize the Z_2 bio-harmony. Only A and C DNA nucleotides of DNA strand can be methylated (as also T and G nucleotides of the conjugate strand). Note that A and G appear often in DNA repeats defining part of what was called junk DNA. One can ask whether the methylation of A and C could stabilize the bio-harmony and DNA level.

The corresponding RNA codon contains at most one U or G nucleotide. Note that met corresponds to AUG whereas AGU corresponds to cys which together with trp (coded by tetrahedral codon) are the only sulphur containing amino-acids. Met is special in the sense that it belongs to a symmetry broken codon doublet for which ile has replaced met.

4. The first mRNA codon AUG codes for met so that the D(AUG)-Dmet pairing could induce the DAA bio-harmony and affect the vibrational frequencies of AA. This is perhaps enough for the stability of the bio-harmony. Could pretein methylation help to stabilize the bio-harmony of proteins? According to Wikipedia (https://cutt.ly/uSiVACT), protein methylation is a type of post-translational modification featuring the addition of methyl groups to proteins. It can occur on the nitrogen-containing side-chains of arginine and lysine but also at the amino- and carboxy-termini of a number of different proteins.

One can imagine 2 options for changing the bio-harmony at DAA-AA level. For the bureaucratic option, the re-tuning would occur at the DNA level. This would require enzymes coded by appropriate genes to re-tune the first codon of mRNA coding for AA.

For the non-bureaucratic option, DAA would re-tune AA directly by entrainment and this could involve re-methylation.

11.2.3 An attempt to concretize the model of ligand interactions

The following is a very naive first attempt to concretize the idea about ligand interactions as a re-tuning, which affects the matrices $K_{i(jk)}$ and $\epsilon_{i(jk)}$. Reader should take the following considerations as as free associations.

1. BMPs couple to 4+3 receptors. There are 3 Hamiltonian cycles with $Z_{2,rot}$ symmetry and 5 cycles with $Z_{2,refl}$ symmetry assignable to 10 amino-acids coded by 2 or single DNA (met) have 3. There are 4+3 receptors and 5+3 bioharmonies: could it be that the considered 4 receptors correspond to 4+3 Z_1 harmonies with the same Z_4 harmony and that there is also a fifth receptor of this kind but not considered?

A priori, any protein could correspond to any bio-harmony but the correlation of DAA and bio-harmony could be forced by dynamics since the DAA-AA resonances might be possible only for certain Z_2 harmonies (and only for one of the 2 Z^4 harmonies). Suppose that the receptors indeed correspond to one particular Z_2 harmony each.

2. If the binding sites for BMP-receptor pairs correspond to single AA (in analogy with tRNAmRNA binding), the binding site for Z_2 harmonies should correspond to a AA which is one of the 10 AAs coded by DNA doublet or singlet. The reduction of correspondence to the level of binding site AA would conform with the finding that the functional similarity of BMPs does not very closely correspond to the sequence similarity.

In the code table there are 9 doublet AAs and 1 singlet. Symmetry breaking is present [L196]. It is not quite clear which doublets correspond to Z_2 . For instance, phe could correspond to the doublet for Z_6 leaving 8 doublet AAs plus (ile,met) as a doublet with a broken Z_2 symmetry. UGG coding for trp and 3 stop codons would correspond to the tetrahedral cycle.

By resonance condition, at most 3 receptors should correspond to more than 1 BMP as their preferred receptor.

There are also chemical constraints on the AAs acting as a binding site. Resonance condition for DAAs implies that pairing AAs are identical. The pairing AAs must be neutral and must be coded by DNA doublets or singlets. This leaves the following cases under consideration.

- 1. Two amino acids have amide side-chains.
 - Asparagine (Asn): NH₂2COCH₂-
 - Glutamine (Gln): NH₂2COCH₂2CH₂

These side-chains do not ionize in the normal range of pH.

- 2. Two side-chains contain sulfur atoms, of which one ionizes in the normal range.
 - Cysteine (Cys): HSCH₂-
 - Glutamine (Gln): NH₂-COCH₂-CH₂-
- 3. Three amino acids have aromatic ring structures as side-chains. Of these, tyrosine ionizes in the normal range; the other two do not.
 - Phenylalanine (Phe)
 - Tyrosine (Tyr)
 - Tryptophan (Trp)

This would give 2+2+3=4+3 AAs. In the above mentioned option Phe is however assigned with Z_6 harmony but any other doublet AA could correspond to Z_6 harmony. This would suggest that AAs with amide side chains and containing sulphur correspond to $4Z_{2,rot}$ harmonies.

There are 10 BMPs with the decomposition 10=3+3+2+1+1. Using the standard biological notation, this correspondings to the decomposition [GDF5,GDF6,GDF7], [BMP5,BMP6,BMP7], -BMP2,BMP4],[BMP9], [BMP10]) to functional equivalence classes [I85]. Could the two 3:s correspond to the 3 $Z_{2,rot}$ harmonies and 2+1+1 to 4 of the 5 $Z_{2,refl}$ harmonies?

The two triplets [GDF5,GDF6,GDF7] *resp.* [BMP5,BMP6,BMP7] are weak *resp.* strong activators. Both GDFs (growth differentiation factors) and BMPs (bone morphogenetic proteins) belong to the transforming growth factor beta superfamily (TGF). If GDFs are excluded the correspondence between BMPs and receptor proteins is 1-to-1.

11.2.4 Could the dark matter hierarchy relate to the bio-harmony?

One can wonder how the hierarchy of algebraic extensions and algebraic evolution defining the evolutionary state for a given layer of MB affects the L-R pairings.

- 1. Dark 3N-photons and 3N-nucleons as dark variants of basic information molecules would correspond to Galois confined states for which the 4-momenta for components are algebraic integers summing up to ordinary integer when the momentum unit is defined by the p-adic length scale associated with the extension. Also frequencies would correspond to rational integers for Galois confined states.
- 2. These states depend on the algebraic extension of rationals defining $n = h_{eff}/h_0$ as its dimension although mass squared values and momenta are integer valued as also frequencies. This would give an additional context dependence. For instance, organisms at higher levels of evolution could have larger values of h_{eff} associated with the dark variants of the basic biomolecules.

11.3 Hen egg problem, dark biomolecules, and resonance mechanism

The notions of magnetic body, dark matter as $h_{eff} = nh_0$ phases, dark analogs of information molecules, and resonance mechanism could allow a solution to the hen egg problem of biology: which came first, DNA, RNA, AAs or proto-cell membrane. I have considered the hen egg problem in [K72] and proposed a model of proto-cell in [L129].

Hen egg problem usually means that something is missing from the conceptual picture and TGD based quantum biology suggests what this missing piece could be. The general solution of the problem in TGD would be that dark analogs of information molecules emerged first simultaneously as Galois confined states of dark proton-triplets and dark photon-triplets.

This made possible resonance communications and the basic recognition mechanism by 3resonance for dark 3-photons. DX-X pairing was based on energy resonance and these composites were able to find each other by resonance. The reduction of h_{eff} for connecting flux tubes in their shortening liberated energy making it possible to overcome the potential wall preventing chemical reactions to occur. This is not as easy as it looks at first since metabolic energy is needed to build the valence bonds and metabolic machinery is absent in early life.

The challenge is to develop a more detailed picture around these basic ideas. I have already earlier considered several proposals for the first steps of the evolution of basic bio-molecules [K52, K53, K72] but without the recent, rather detailed, view about resonance mechanism combined with the notion of dark 3N-photons and 3N-nucleons as dark analogs of basic biomolecules [L196].

11.3.1 Did the DX-X pairing occur simultaneously for all basic biomolecules?

Consider first the pairing of basic information molecules X (DNA, RNA, tRNA codons and AAs). Their polymers are not considered in this section. The simplest vision is that the dark variants of basic biomolecules emerged by Pollack effect [I110, I111, L20, I162, I197] in water irradiated by solar light.

- 1. Pollack effect generated exclusion zones (EZs) as negatively charged regions. Part of protons were transferred to magnetic monopole flux tubes of MBs assignable to water clusters and created phases of water with a hexagonal lattice-like structure.
- 2. An attractive possibility is that the notion of hydrogen bonds generalizes. The monopole flux tubes could be accompanied by hydrogen bonds. This predicts a length scale hierarchy of hydrogen bonds implying long range quantum correlations in arbitrarily long scales and allowing to understand the strange thermodynamic anomalies of water. The length of the dark flux tube is proportional to h_{eff} as also the total energy consisting of Kähler magnetic and volume contribution.
- 3. Galois confinement as a universal bind mechanism would give rise to sequences of dark protons as bound states. The states of dark proton triplet correspond to DDNAs, DRNAs, DtRNAs and DAAs.

The pairing of the dark analogs of biomolecules with ordinary biomolecules to form pairs DX-X gave rise to the observed basic biomolecules. DX-X pairing requires that the ordinary biomolecules have transition energies, which correspond to the cyclotron transition energies of DX for the value of h_{eff} considered. Ordinary cyclotron transitions and vibrational transitions are good candidates in this respect.

4. Energy resonance condition for the pairs gives powerful conditions and selects the allowed biomolecules. The selection has not been completely unique. In tRNA the third letter of the chemical codon paired with one of the 32 DtRNAs need not be an ordinary nucleotide and in some viruses adenosine (A) is replaced with 2-amino-adenine ("Z") [I96] (https://cutt.ly/hSRBSOK).

11.3.2 Did proto-cell and peptides emerge first?

It is not at all clear whether the dark variants of the polymers of basic bio-molecules can emerge spontaneously. The problem is that the formation of valence bonds requires energy. This forces us to consider the TGD counterparts of the usual purely chemical proposals in which basic building bricks DNA, RNA and AAs form polymers. Now one considers an analog of polymerization at the level of DDA, DRNA, and DAA.

The findings of Montagnier *et al* [I92, I91, I93] discussed from the TGD view point in [L194] suggests that remote DNA replication occurs in absence of DNA template but that the presence of DNA polymerase is necessary. Dark DNA sequences generated by remote replication would appear as a template. This suggests DDNA-DNA pairing could occur by polymerization and require the presence of enzymes and metabolic energy feed.

Could proteins (Ps) have served in the role of egg in the chemical sense in the TGD framework? Could the resonance mechanism together with the TGD view about bio-catalysis make it possible to generate DP-P pairs by a polymerization-like process using DP as a template?

- 1. The large h_{eff} between DP and P would be shortened in a given polymerization step. Energy would be liberated as the dark flux tube bond between DP and P is shortened. This energy should make it possible to overcome the potential wall preventing the formation of the peptide bond and also provide the energy of the peptide bond, which is about .08-.16 eV and considerably smaller than metabolic energy quantum about .5 eV.
- 2. The thermal energy at room temperature using the definition $E_T = kT$ is .025 eV. Second definition of thermal energy is as the energy for which the distribution of black-body radiation as function of energy is maximum: this gives the energy is $E_T \simeq .12$ eV and rather near to the Josephson energy of the cell membrane for charge Z= 2e is about .1 eV.
- 3. The energetic requirements for AA polymerization might be satisfied by using irradiation with photon energy around thermal energy at room temperature. An interesting possibility considered in [K72] and [L129] is that a proto-cell membrane formed from lipids was present from the beginning and before the polymerization. Lipid membranes can form spontaneously and in TGD Universe they act as generalized Josephson junctions [K92, K93] and induce Josephson radiaton, which would make possible communications from cell membrane to MB.

Could the Josephson radiation from the cell membrane with energy of order .1 eV provide the metabolic energy for the polymerization process of AAs?

4. In the case of DNA and RNA the carbon bond energy between two codons is about 3.2 eV and considerably larger so that the polymerization without enzymes looks highly implausible. Note also that also the formation of lipids is a problem since C-C bonds have energy 3.47 eV.

11.3.3 Empirical and experimental support for the model of peptide formation

There is evidence for amino acid glycine in the interstellar space (https://cutt.ly/HSYQPmP) but the independent confirmation is lacking. Also the formation of glycine peptides has been observed in laboratory conditions mimicking the interstellar medium (ISM).

The following summarizes the results described in the article of Serge Krasnokutski *et al* [I87] published in Nature. The following summarizes Krasnosutski's non-technical description of the results (https://cutt.ly/dSYm1Sn).

- 1. The ultra-low temperatures, common in astrophysical environments, have been believed to freeze out any chemistry in the dense areas of the ISM. Already the discovery of a high abundance of small organic molecules in molecular clouds was a great surprise. But also the formation of amino acids, nucleobases, lipids, and sugars in space has been confirmed.
- 2. What about the polymers of AAs? It has been conjectured that the condensation of carbon atoms at the surface of dust particles make possible the formation of organic molecules. Serge Krasnokutski *et al* indeed demonstrated the formation of glycine polymers from amino ketenes (glycine corresponds NH₂-CH₂-COOH, aminoketene to NH₂-CH-CO and polyglycine to NH-CH₂-CO) under laboratory conditions simulating the ISM conditions at temperature T=10 K (https://cutt.ly/3SYT169). A spontaneous(!) formation of relatively short peptides (less than 10-11 monomeric units) was found. The polymerization of amino acids under energetic processing (e.g. heat, pressure, or UV irradiation) is known to occur. Therefore, a further increase in chain length can be expected in natural environments.

Moreover, by adding other species instead of a proton to the α -carbon atom of amino ketene (nearest to the functional group) during the polymerization, a variety of different peptide chains can be formed. Furthermore, chemical and photochemical modifications of glycine residues in peptides into other amino acid residues were also demonstrated in many works. Thus, the glycine peptides observed in our experiments can be converted into different proteins.

3. These findings fit nicely with the proposed mechanism for the formation of proteins (or at least short peptides). The mechanism is not chemical, and no radiation is needed since the generalized Josephson radiation would provide the energy of the AA-AA bond, and the formation rate does not vanish at ultralow temperatures.

11.3.4 How did lipids, small organic molecules, and DNA and RNA polymers emerge?

There is a temptation to say that after the emergence of proto-cell membrane and peptides, the rest was history. This is not so simple.

- 1. The formation of the proto-cell membrane could occur spontaneously if lipids are available. Lipids however have C-C bonds with bond energy 3.47 eV and C==C bonds with energy 6.28 eV. These energies are in the UV range.
- 2. Also the energies of valence bonds associated with DNA, RNA, and also other basic biomolecules are in this range. The freezing of the chemistry at ultralow temperatures does not allow the generation of these bonds since the metabolic machinery provided by ATP molecules is not present. Simple organic molecules and even amino-acids are however detected in the interstellar medium. It seems that life-as-nothing-but-chemistry dogma must be wrong.

3. The Josephson radiation associated with proto-cell membrane with an energy scale of .1 eV could help in the formation of peptides but cannot help in the more general case. Could the splitting of a hydrogen bond provide the metabolic energy quantum of .5 eV in the absence of ATP machinery? The formation of water involving O-H bonds and their dynamics at temperatures of few K do not sound plausible unless one leaves the framework of the standard chemistry.

Metabolic machinery involves a lot of control and the standardization made possible by the metabolic energy quantum. This involves a lot of control. What could have served as a controller and energy source for bond formation at ultralow temperatures of few Kelvin and in the absence of the complex metabolic machinery based on ATP. In the TGD Universe, MB carrying dark matter is the answer to the question.

- 1. The existence of B_{end} was originally deduced by Blackman [J7] and other researchers. They found that ELF em fields had quantum-like effects on the vertebrate brain. These effects could be understood in terms of cyclotron transitions in the "endogenous" magnetic field $B_{end} \simeq 2B_E/5$ if the value h_{eff} of Planck constant was much larger than h, $h_{eff}/h \sim 10^{13}$ was required in order to scale the energy of 10 Hz photon to that of a visible photon with frequency 10^{14} Hz.
- 2. The large value of h_{eff} suggests its identification as gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ given by Nottale's hypothesis [E1]. M denotes here Earth's mass and m the mass of the charged particle. This predicts that cyclotron frequencies in B_{end} correspond to dark photon energies in the visible and UV UV range. Most remarkably, the energies do not depend on the mass m of charged particles. This realizes the Equivalence Principle.
- 3. Visible-UV energy range is associated also with biophotons [I155, I97] discussed from TGD view point in [K20, K31]. This motivates the identification of biophotons as decay products of dark photons or possibly even dark N-photons resulting in $h_{eff} \rightarrow h$ transition. Dark photons or N-photons in this energy. Note that the Nottale hypothesis and the notion of a monopole magnetic flux tube make sense only in the TGD Universe.
- 4. $h_{eff}/h_0 = n$ is identifiable as a dimension of extension of rationals in number theoretic vision about TGD. *n* serves as a kind of IQ [L66, L67]. MB with $h_{eff} = h_{gr}$ corresponds to a rather high level of number theoretic complexity assignable to the MB of Earth as a quantum system. MB has a long scale of quantum coherence - even of the order of the scale of Earth - and is by its high "IQ" the natural "boss" and controls the dynamics of the ordinary biomatter. The molecular transitions induced by the transformations of dark cyclotron (3N-)photons would serve as a natural control tool of MB. The cyclotron condensates at MB can provide quantized metabolic currencies in the absence of ATP machinery.
- 5. MB could generate already at few Kelvin temperatures various biologically important molecules by providing the metabolic energy for the formation of various valence bonds, such as carbon and peptide bonds and make possible the formation of lipids, DNA and RNA molecules and their polymers and also other basic organic molecule. Josephson radiation would in turn make possible the generation of proteins. Gravitation would be a key player in living systems and play an especially important role in the very early stage. The chemistry at ultralow temperatures would provide a direct experimental handle to the biophysics associated with MB.

11.3.5 What can one say about pre-tRNA?

What could be the prebiotic counterpart of tRNA?

1. DtRNA should have a molecular counterpart. The simplest guess is that it corresponds to an RNA type codon appearing in tRNA but somehow differing from it. Pre-tRNA could simply be the (AAC-H)3' end of the acceptor stem with AAC replaced with XYZ, where ZYZ denotes the codon part of tRNA. The addition of a hydrogen atom would relate pre-tRNA codon to ordinary RNA codon.

- 2. The bond energy for the pre-tRNA-AA pair as the energy of the ester bond would be about .5 eV, which corresponds to the metabolic energy quantum. Energy is therefore required to "charge" pre-tRNA. This requires metabolic energy and in the absence of ATP machinery, the energy should come from its precedessor. What prebiotic metabolism could be, will be discussed in the next section.
- 3. If this step works, the polymerization of tRNAs involving the transformation of the ester bond of pre-tRNA-AA to AA-AA peptide bond can occur spontaneously since the peptide bond has bond energy of order .1 eV. This would give rise to polypeptides. This process would be like a translation process for RNA but without an RNA template and therefore the outcome would be random. Also the RNA polymerization in this manner can be considered, now however the RNA-RNA valence bond has considerably higher bond energy.
- 4. If DRNA-RNA sequences are formed, they might be transformed to AA sequences by pretranslation process using pre-tRNA and resonance mechanism pairing DRNAs and dark counterparts of pre-tRNA-AA pairs. This would define the pre-translation process.

11.3.6 What could the prebiotic metabolic machinery be?

Metabolic machinery should have a prebiotic counterpart and have energy about .5 eV as metabolic energy quantum.

- 1. Could the splitting of a hydrogen bond with bond energy about .5 eV provide the energy needed in the formation of pre-tRNA-AA ester bond? IR photons are most effective in causing Pollack effect in water: could also they induce pre-tRNA-AA pairing? Both options would require the presence of water. In principle, the proposed mechanism could lead to a generation of water molecules (the energy of O-H bond is 4.81 eV) already at temperatures of few Kelvin.
- 2. Could MB somehow provide the metabolic energy quantum? Gravitational flux tubes are in a central role in the TGD inspired quantum biology. In [L172] it was observed that the gravitational binding energy of a nucleon in the gravitational field of Earth is .67 eV. This is somewhat larger than the metabolic energy quantum. A dark proton at a distance of about .34 R_E , R_E Earth radius, from the surface of Earth has gravitational binding energy of .5 eV.

The bond energy of the hydrogen bond is .5 eV. Could it correspond to the reduction of the gravitational binding energy due to the delocalization of a dark proton to a gravitational flux tube? Could the hydrogen bond become dark gravitational U-shaped monopole flux tube with $h_{eff} = h_{gr}$ so that the proton of the ordinary hydrogen bond would become gravitationally dark? the size scale of Earth would define the length scale of this flux tube. The flux tube could however still connect the same atoms.

The transformation $h_{gr} \rightarrow h$ induces a dramatic shortening of the U-shaped gravitational flux tube loop and the gravitationally dark proton at the gravitational flux tube of MB transforms to an ordinary proton. This localization has interpretation as falling of the proton to the surface of Earth. Could the liberated energy have an interpretation as a ametabolic energy quantum?

For a dark variant of hydrogen bond a gravitational flux tube between atoms should form a very long loop at which the gravitationally dark proton would reside. This kind of picture about dark flux tubes associated with gauge interactions has been suggested earlier. For instance, color flux tubes assignable to nuclear protons could extend to distances of the order of atomic size.

3. Phosphate is electronegative and forms hydrogen bonds. Phosphate ionization could be interpreted as a formation of a dark hydrogen bond. This would explain why phosphate ions have such a central role in metabolism. Effective ionization serves as the signature of the delocalization. Also other electronegative ions could play the role of phosphate and arsenite has done this in some bacterial systems (https://cutt.ly/ZS1fznG).

The pre-biotic counterpart of metabolic machinery should have involved phosphate ions or some other electronegative ions forming dark hydrogen bonds. 4. Also the valence electrons of valence bonds can become dark by the lengthening of the valence bond to a U-shaped gravitational flux loop. For electrons the gravitational binding energy at height $.34R_E$ is about .25 meV and .5 meV for their Cooper pairsm. Note that .3 meV corresponds to the energy of photons in the microwave background.

Could this define a second metabolic energy quantum important in scales by a factor $m_p/m_e \sim 2^{11}$ longer than nanoscale about 1 nm assignable to DNA. This is the length scale of the cell nucleus, microtubules and axons. Intriguingly, the minimal fluctuations of membrane potentials correspond to the so-called miniature end plate potentials .4 mV (https://cutt.ly/HSJIn76).

5. A gravitational valence bond, connecting a metal atom with an atom with an opposite valence, would lead to effective ionization of the metal atom. For instance, biologically important bosonic ions such as Ca⁺⁺, Mg⁺⁺, Fe⁺⁺ and Zn++ associated with their oxides could correspond to effective ions like this.

The signature would be a pairing with a neutral oxygen atom by a gravitational valence bond. I have introduced the notion of dark ion to explain the findings of Blackman [J7] and others and dark ion could correspond to this kind of pair. The original variant of the model assumed that the entire ion is dark, the later version assumed that the valence electron of free atom is dark, and the model consider here assumes that the valence bond is dark.

6. The effective ionization requires energy ΔE to compensate the increment of the gravitational potential energy given by $\Delta E = (\langle V_{gr}(R) \rangle - V_{gr}(R_E))$. Here $E_{gr}(R)$ is gravitational potential energy proton or electron, and R_E denotes the radius of Earth, and R is the distance of the point of flux tube from the center of Earth.

This estimate neglects the kinetic energy of the dark particle at the flux loop. This assumption is not consistent with the localization near the top of the loop so that the estimate can serve only as a rough order of magnitude estimate.

7. The maximal value for ΔE for electron Cooper pair (dark Cooper pair is at infinite distance) corresponds to $V_{gr}(R_E) = .36$ meV to be compared with the energy scale .3 meV defined by the temperature of 3 K microwave background and to the value .4 meV of the miniature potential. This suggests that, in the case of the electron, the reduction of kinetic energy contributes more than 10 per cent to the ΔE .

For a single dark proton one has $V_{gr}(R_E) \simeq .34$ eV, which is below the nominal value of the metabolic energy currency about .5 eV. If a single dark proton is involved, the reduction kinetic energy should contribute at least 32 per cent to ΔE .

For a dark proton Cooper pair, one has the maximal value of $\Delta E = .68$ eV somewhat above the metabolic energy quantum. These findings support the idea that both proton and electron Cooper pairs give rise to metabolic energy quanta. The challenge would be to understand the mechanism for the formation of proton Cooper pairs.

8. The transformation of electrons and protons between ordinary and gravitationally dark states would be a key process of metabolism and biocatalysis. This conforms with the fact that proton and electron exchanges play a key role in biology. For instance, phosphorylation means that the receiving molecule gains phosphate, which can form gravitationally a dark hydrogen bond so that the system becomes metabolically active. This would correspond to the activation in bio-catalysis.

DNA base pairs are connected by 2 (A-T) or 3 (G-C) hydrogen bonds. If these strands can appear as dark gravitational strands, the maximum of 2 (3) metabolic quanta could be liberated in A-T (G-C) pairs via a transformation to ordinary hydrogen bonds. Could this serve as a yet-unidentified source of metabolic energy in the replication and transcription?

9. In the same way, in a redox reaction, the electron donor is oxidized and the electron receiver is reduced. Reduced molecule gains the ability to have a gravitationally dark electron, and therefore becomes metabolically active in the electronic sense. Redox reaction would be the electronic counterpart for phosphorylation.

11.3.7 Could the metabolism of cilia and flagella rely on gravitationally dark electrons?

The recent work in TGD has led to considerable progress in the understanding of metabolism [L181] already discussed in the section 12.2.5. The TGD based view about metabolism involves in an essential way quantum gravity.

The observation is that the gravitational binding energy of dark protons at Bohr orbits in Earth's gravitational field for $h_{eff} = h_{gr} = Gmm/v_0$ [E1] [?, K85] [L172, L155] can correspond to metabolic energy quantum in good approximation. The proposal is that the transformation of protons of hydrogen bonds possible for electronegative atoms and occurring at least for phosphate generates gravitationally dark protons. Their transformation would liberate metabolic energy quantum.

The prediction is that besides gravitationally dark protons also similar electrons define a metabolic energy currency relating to standard metabolic currency like cent to dollar. It is proposed that the electronic metabolic currency can be applied to the purely understood metabolism of cilia and flagella (https://cutt.ly/WDkYZzx). I attach the proposal below almost as such.

According to [I185] (https://cutt.ly/EDkW2bu) the recent measurements in sea urchin sperm (length ~ 50 μ m long, diameter 0.2 μ m) show that the energy consumed per flagellar beat corresponds to $\simeq 2 \times 10^5$ ATP molecules. There is no GTP inside cilium as in the case of axonal MTs (https://cutt.ly/5DkYGB2). It is difficult to understand how ATP machinery could provide the metabolic energy feed.

This motivates the question about whether local ciliary metabolism could rely on the transformation of valence electrons of some biologically important ions to dark electrons at the gravitational MB and vice versa? The reduction of h_{gr} for electrons would provide the metabolic energy related by a factor $m_e/m_p \simeq 2^{-11}$ to the ordinary. According [I185], about 4×10^8 gravitationally dark electrons would transform to ordinary ones in a single stroke of cilium.

Electronic metabolic energy quantum would relate like cent to dollar and make possible a more refined metabolism with fine tuning. Electronic metabolism could also be an essential part of ordinary metabolism.

Consider now the idea more quantitatively.

1. What could be the electronic analog of ATP machinery. All biologically important ions can be considered as effective ions with some valence electrons at gravitational MB. In particular, the bosonic ions Ca^{++} , Mg^{++} , Fe^{++} and Zn^{++} could have Bose-Einstein condensates of gravitationally dark Cooper pairs at the gravitational MB.

 Ca^{++} waves play a key role in cellular biology, Fe^{++} is essential for oxygen based metabolism, and Mg^{++} and Zn^{++} are important in bio-catalysis: for instance, ATP must bind to Mg ions in order to become active.

2. What could be the mechanism transforming valence electrons to dark electrons? This should happen for positively charged biologically important ions, in particular for the bosonic ions Ca^{++} , Mg^{++} , Fe^{++} and Zn^{++} . The consumption of metabolic energy would correspond to a de-ionization of dark ion Ca^{++} and this might make it possible to test the proposal. For instance, Ca^{++} could accompany ciliary waves.

Where could the energy for ionization come from?

- 1. This question is also encountered in the chemistry of electrolytes [L62]. It is very difficult to understand how the external electromagnetic potentials, which give rise to extremely weak electric fields in atomic scales, could lead to ionization. The acceleration of electrons in the electric field along dark flux tubes involves very small dissipation and can easily give rise to electron energies making ionization possible.
- 2. MTs have a longitudinal electric field which by the generalization of Maxwell's equations to many-sheeted space-time (in stationary situation potential difference is same for paths along different space-time sheets) gives rise to an electric field along the magnetic flux tubes. These flux tubes need not be gravitational.

By darkness, the dissipation rate is low. Could the acceleration along flux tubes, in particular MT flux tubes, lead to the ionization? Could the electret property of linear biomolecules quite generally serve for the purpose of generating electronic metabolic energy storages in this way?

3. Assuming opposite charges $\pm Z_{MT}$ at the ends of dark magnetic flux tube associated with the MT, one obtains a rough estimate. The length of the cilium is $L \leq .5 \times 10^{-4}$ m and its radius is $R \sim 2 \times 10^{-7}$ m. The estimate for the energy gained by a unit charge e as it travels through the ciliary MT is $E \sim Z_{MT}e^2L/R^2 \simeq Z_{MT} \times 2.85$ eV. The valence electron energy for atomic number Z with principal quantum number n (giving the row of the Periodic Table) is $E \simeq (Z/n)^2 \times 13.6$ eV. The ionization condition would be $Z_{MT} \ge (Z^2/n^2) \times 13.6/2.85$. For the double ionization in the case of Ca^{++} with Z = 20 and n = 3 this would give $Z_{MT} \ge 212$.

11.3.8 Quantum gravitation in TGD inspired quantum biology

The theory of Penrose and Hameroff [J29] assigns to microtubules quantum gravity in Planck length scale. In the TGD Universe, one does just the opposite. The hierarchy of effective Planck constants assigns to quantum gravitation quantum coherence scale even in the scales of astrophysical objects.

The notion of gravitational magnetic body

The proposed picture allows us to reconsider a long-standing question relating to the notion of MB with an onion-like layered structure. What could this sentence mean quantitatively?

- 1. The 4-surfaces X^4 with 1-D CP₂ projection and 3-D M⁴ projection having 2-D membrane as E^3 projection are good candidates for various membrane objects in TGD Universe [L174]. The E^3 projection is not a minimal surface although X^4 is, and this possible if the 1-D CP₂ projection is dynamical. The flux tubes of MB should be assignable to kind of membrane-like surface.
- 2. The gravitational MB could be a layered structure containing the Bohr orbits with Bohr radii $r_n \propto n^2$ of particles in the gravitational field of Earth. Particles with different masses would concentrate at the same orbits. One would have the shell structure of the ordinary atom. This notion generalizes also to other interactions and for them the values of h_{eff} would be much smaller.
- 3. Flux sheets with a cylindrical rotational symmetry containing the orbits can be considered. These surfaces should be realized as preferred extremals of the action and should be minimal surfaces in $H = M^4 \times CP_2$. As closed surfaces they cannot define minimal surfaces of the Euclidean 3-space E^3 . Indeed, soap bubbles are not minimal surfaces but require a constant pressure difference between interior and exterior. The analog of pressure difference would be non-trivial and dynamic 1-D projection of 4-D surface to CP_2 [L174]. The liberation of metabolic energy quantum would be analogous to a transition of hydrogen atom to a lower energy state.

Cell membrane, nerve pulse and quantum gravitation

This picture makes it possible to formulate a more precise view about the model of cell membrane as a generalized Josephson junction for which the generalized Josephson energy for charge Ze is the sum $E_J = ZeV + \Delta E_c$ of ordinary Josephson energy ZeV and difference ΔE_c of dark cyclotron energies for the flux tubes at the two sides of the cell membrane having in general different strengths of magnetic field.

The model requires large h_{eff} in order that Josephson frequencies can correspond to frequencies in the EEG range. This justifies the assumption that dark ions have $h_{eff} = h_{gr}$. The ionization would be effective and caused by the transformation of protons of hydrogen bonds and valence electrons to dark charge carriers at the gravitational flux tubes.

The physical meaning of the criticality against the generation of nerve pulse for a critical membrane potential $eV_{cr} \simeq .05$ eV has remained open.

1. Since voltage gives rise to negative potential energy, it seems clear that there must be positive contribution to the energy and this could come from the reduction ΔE_{gr} of the gravitational potential energy due to the positive *resp.* effective ionization of atoms of metal atoms *resp.* electronegative atoms with hydrogen bonds.

The reduction of the gravitational potential energy for electrons is fraction m_e/m_p from that for protons so that protonic contribution should dominate in the reduction of gravitational potential energy if dark electrons and protons correspond to the same shell of gravitational atom. The first guess is that the energy shell and thus the distance from the Earth's surface is the same.

The parametrization of the reduction of the gravitational energy per atom and for the difference ΔE_c of cyclotron energies should in the standard picture correspond to a thermodynamical formulation using chemical potentials to fix the ion concentrations. The water has very special thermodynamic properties in the range between freezing and boiling points and anomalies are largest near physiological temperatures. This would be due to the presence of dark hydrogen bonds, which supports the view that the number of dark protons and electrons depends on temperature.

2. In the first approximation the negative Coulombic interaction energy for the cell membrane is given by $E_{Coul} = -Q_{tot}eV = -\sum_i N_i(out)Z_ieV$, where N_i is the number effective ions with charge Z_ie . The contribution of positive charges is negative since V corresponds to a negative net charge for the cell. The situation is stable for $|E_{Coul}| \ge |E_{Coul,cr}| = N_p \Delta E_{gr}$. The system becomes critical at $Q_{tot}eV_{cr} = N_p \Delta E_{gr}$. The value of the critical potential energy is given by $eV_{cr} = N_p \Delta E_{gr}/Q_{tot}$ and is roughly constant for a given neuron. This suggests that the ratio N_p/Q_{tot} characterizes the cell.

Neurons and ordinary cells could differ in that ordinary cells are either subcritical or so overcritical that nerve pulses do not occur. Subcriticality looks the more plausible option. The emergence of the nervous system would mean the discovery of quantum criticality as a control tool of MB.

3. In the generation of the nerve pulse the dark protons and electrons become ordinary ones in the reduction $h_{gr} \rightarrow h_{eff} \leq \leq h_{gr}$ for them and the membrane potential changes sign. In ZEO this transition could correspond to BSFR inducing time reversal and change of membrane potential. The second BSFR would bring back the original situation and membrane potential would return to the over-critical value.

Microtubules and quantum gravitation

In the TGD Universe quantum gravitation would be associated with the cell membrane, in particular neuronal membrane. Quantum gravitation has been speculatively assigned with microtubules (MTs) rather than cellular or neuronal membranes. What is the situation in TGD?

- 1. Axonal MTss are highly critical systems, which continually change their lengths. The surface of MTs has one GDP per tubulin dimer and the ends of MT has GTPs so that there is a constant negative charge per unit length. The number of GTPs is larger at the second end so that there is an electric field along MT.
- 2. GTP↔ GDP process accompanies the variation of the length of the MT. The transformation of the protons assignable to the phosphate hydrogen bonds to gravitationally dark protons could be an essential element of the MT dynamics. The periods of increasing/decreasing MT length could be initiated by BSFR and would correspond to different arrows of time. The effective ionization affects the effective charge of the axonal interior and therefore of membrane potential. This suggests a strong correlation with the variation of axonal MT lengths and nerve pulse propagation.

The propagation of nerve pulse through the myelinated sections of the axons, where ion transfer with cell exterior is not possible, is a mystery in the standard model. Without axonal MTs the nerve pulse propagation would not be possible. This could allow us to understand why various neuronal diseases involve a reduced MT stability [J15] (https://cutt.ly/4DaF6qc).

$$\begin{array}{lll} CEG \equiv C &, & CD \sharp G \equiv Cm &, & CD \sharp F \sharp \equiv C^o &, & CEG \sharp \equiv Caug &, \\ CFG \equiv C4 &, & CF \sharp G \equiv C4_+ &, & CGG \sharp \equiv C6_- &, & CGA \equiv C6 &, \\ CGB \flat \equiv C7 &, & CGB \equiv Cmaj7 &, & CGC \sharp \equiv C9_- &, & CGD \equiv C9 &. \end{array}$$
(11.4.1)

Table 11.1: Notation of chords inspired by popular music notations.

11.4 Appendix: Tables of basic types of 3-chords for icosahedral harmonies

11.4.1 Icosahedral harmonies as Hamiltonian cycles

One can find the list of Hamiltonian cycles at http://tinyurl.com/yacgzm9x. The edge $\{1, 2\}$ is fixed and cycles are oriented so that there are 1024 of them. All of them are relevant from the point of music interpretation and the change of orientation corresponds to major-minor duality, albeit not in the simplest sense. Note that this duality does not affect the characteristics listed above.

The general following general results hold true as one can learn at http://tinyurl.com/ pmghcwd. One can classify the cycles using their symmetries which can correspond to isometries of icosahedron leaving them fixed or to a reflection taking the vertex n at the cycle to vertex 12 - n. This symmetry is not same as change of orientation which is purely internal operation and cannot change the cycle.

One can even find images of the cycles possessing symmetries at http://tinyurl.com/ y8ek7ak8 and deduce the triplets n and p characterizing them by visual inspection. Also one can write explicitly the 3-chords defined by the three kinds of faces. I have deduced the triplets nand the 3-chords defining the harmony by the inspection of the images. "Bio-harmony" (4, 8, 8) forced by the model of extended genetic code involving also the 21st and 22nd amino-acids is of special interest. The classes of cycles with symmetries 6-fold rotational symmetry and two distinct reflection symmetries realize it.

Before continuing some terminology and notation is in order. Take C as the major key. Submediant or relative minor corresponds to Am, subdominant (sharp or flat) to F major (F) or Fminor (Fm), dominant to G. The notation for chords is such that quints correspond to subsequent notes in the chord. For 1-quint chords this means that first two notes define the quint.

Table 11.1 summarizes the notation inspired by the popular music notation. The basic difference is that the third is in most cases excluded so that the emotional character of the chord is not fixed.

Besides these notions it is convenient to introduce additional notations for various dissonant chords appearing as 0-quint chords.

$$CC\sharp D \equiv Cex1 , \quad CC\sharp D\sharp \equiv Cex2 , \quad CDD\sharp \equiv Cex3 , \quad CDE \equiv Cex4 , \\ CD\sharp E \equiv Cex5 , \quad CC\sharp E \equiv Cex6 , \quad CDF\sharp \equiv Cex7 , \quad CDG\sharp \equiv Cex8 .$$
(11.4.2)

Clearly, the sets $\{ex1\}$, $\{ex2, ex3\}$, $\{ex4, ex5, ex6\}$, $\{ex7\}$, $\{ex8\}$, corresponds to the span of 2, 3, 4, 6, 8 half notes for the chord.

The following summarizes the results. Note that Cex7 can be seen as part of D7 chord.

- 1. There are 6 collections of cycles without any symmetries containing 48 cycles each: these 48 cycle are mutually isometric so that one can say that there 6 different harmonies.
- 2. There is a collection with 6-fold rotational symmetry, 48/6=8 examples. n = (2, 12, 6). The chords of this scale define 6-note scale involving only total steps. CDF and its 6 translates by integer number of steps define 6 1-quint chords. $CE\flat G$ (Cm) and its 6 translates (they obviously correspond to the 6-fold rotational symmetry) define also 6 1-quint chords. The reflection transforms these series to those defined by $GB\flat G$ and its translate and by FAC

(F major) and its translates. Impressionists like Debussy used 6-note scale of this kind. Half-octave shift is an exact symmetry. 1-chords lack the third so that one cannot assign to 3-chords any emotional quality. The extension to 4-chord can however bring either "happy" or "sad" quality. Clearly, these harmonies have "jazzy" character.

0-quint chords are $Faug \equiv FAC\sharp$ and $Gaug \equiv GHD\sharp$ are transformed to each other by both half-octave shift and inversion.

3. There are 2 collections with 2 distinct reflectional symmetries with 12=48/4 representatives in each. Half-octave scaling is a symmetry of both these scales as one might guess.

The first cycle (see **Fig.** ??) has n = (0, 16, 4) so that there are no 0-quint chords which in general are dissonant. Second cycle (see **Fig.** ??) realizes n = (4, 8, 8) bio-harmony and deserves some comments. It will be discussed in detail later.

- (a) The 8 2-quint chords consist of $B\flat FG \equiv B\flat 9$, C9, F9, G9 and their half-octave scalings. Clearly, the simple four-note scale appears here.
- (b) Using the popular notion introduced earlier, 1-quint chords consist of two 4-plets Dmaj7, E9_, A7, A6 and G♯maj7, Bb9_, D♯7, D♯6 related by half-octave shift. The harmony contains no "simple" major or minor chord and only the extension to tetrahedral harmony can provide them. The same is true for the second bio-harmony.
- (c) The 4 0-quint chords are $Cex3 \equiv CDD\sharp$ and $Eex2 \equiv EFG$ and their half-octave scalings $F \sharp ex3 \equiv F \sharp G \sharp A$ and $B\flat ex2 \equiv B\flat BC \sharp G$.
- 4. There are 3 collections with Z_2 rotational symmetry with 48/2 = 24 representatives in each. The triplets *n* are (0, 16, 4) (see **Fig. ??**), (2, 12, 6) (see **Fig. ??**), and (4, 8, 8) (see **Fig. ??**).

All these harmonies are symmetric with respect to half-octave shift (tritonus), which obviously corresponds to the Z_2 rotation. Tritonus would not have been tolerated by catholic church! This symmetry characterizes all 3 harmonies. Basic 3-chords do not contain pure minor and major chords. The reflection of the scale does not leave the collection of chords invariant but it is not clear whether this corresponds only to a change of scale, probably not.

Consider the (4, 8, 8) case (see Fig. ??).

- (a) The 8 2-quint chords appear as four-plet $H9, C\sharp9, D\sharp9, F9$ and its half octave shift (tritonus interval) acting as a symmetry of the harmony. 2-quint chords are always of type X^9 (note that the third is missing) but also 1-quint chord can be of form X^9 as explicit construction of chords demonstrates: I have denoted these 1-quint chords by symbol X4 (CDG is obviously equivalent with CDG).
- (b) Using the popular music notation introduced earlier, the 8 1-quint chords are D7, Amaj7, $A4_+$, E7 and their half-octave shifts $G\sharp7$, $D\sharp7$, $D\sharp4_+$, $B\flat7$.

No major and minor chords are included and only the extension to tetra-icosahedral harmony can provide them and also break the symmetry giving rise to well-defined key.

5. The four 0-quint chords appear in two types. $D \sharp ex2 \equiv D \sharp EF \sharp$ and its half-octave shift $Aex2 \equiv AB \flat C$ plus $Hex3 \equiv HC \sharp G$ and its half-octave shift $Fex3 \equiv FGC \sharp$. According to usual thinking these chords involve dissonances. This dissonance character is a rather general phenomenon for the harmonic loners and classical views about harmony would exclude them as asocial cases! In the case of maximally symmetric harmony the loners are diminished chords and thus not so dissonant. In some cases there are no 0-quint chords.

There are 5 collections of 20 chords with Z_2 reflection symmetry (see **Figs.** ??, ??, ??, ??, ??, ??). The integer triplets n are (2, 12, 6), (2, 12, 6), (4, 10, 6), (2, 12, 6), (2, 12, 6). Bio-harmony has a representative also in this class (see **Fig.** ??). The half-octave scaling symmetry is broken for these harmonies.

Some comments (4, 8, 8) case are in order (see Fig. ??).

$[\mathbf{(n_0,n_1,n_2)}]$	0-chords	1-chords	2-chords
(2, 12, 6)	(Faug, Gaug)	$(Cm, Dm, Em, F \sharp m, G \sharp m, B \flat m),$	$(C9, D9, E9, F\sharp 9, G\sharp 9, B\flat 9).$
		$(F6, G6, A6, B6, C \sharp 6, D \sharp 6).$	

Table 11.2: Table gives various types of 3-chords for harmonies with Z_6 rotational symmetry. Note that half-octave shift is an exat symmetry. Note that $G^{aug} = CEG\sharp$, F^{aug} act as bridges between the groups related by half octave shift. The chords have been arranged so that they form orbits of Z_6 . "Amino-acid chords" correspond to preferred chords at the orbits.

$[(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})]$	0-chords	1-chords	2-chords
(0, 16, 4)		$(D7, D6, G\sharp 7, G\sharp 6),$	$(B\flat 9, B9, E9, F9).$
		$(G4+, A9-, C\sharp 4+, D\sharp 9-),$	
		$(Emaj7, Gmaj7, Bbmaj7, C\sharp maj7),$	
		$(C9-, A9-, F\sharp 9-, D\sharp 9-).$	
(4, 8, 8)	$(Cex3, Eex2, F \sharp ex3, B \flat ex2).$	(Dmaj7, E9-, A7, A6),	$(B\flat 9, F9, C9, G9).$
		$(G \sharp maj7, B \flat 9-, D \sharp 7, D \sharp 6).$	$(E9, B9, F\sharp 9, C\sharp 9).$

Table 11.3: Table gives various types of 3-chords for the two harmonies with $Z_4 = Z_2^{rot} \times Z_2^{refl}$ symmetry. 4-plets represent the orbits. First cycle has no harmonic loners. Second cycle gives rise to bio-harmony (4, 8, 8) for which 0-quint chords are dissonant. Both cycles have Z_2 rotation symmetry acting as a vertical reflection symmetry in figures and realized also as half-octave shifts so that 4-plets contains chords and their half-octave shifts. The genuine reflection symmetry acts as a horizontal reflection symmetry in figures. The cycles correspond to figures ??, ??

- 1. 2-quint chords appear as reflection related multiplets $C9, D9, H\sharp 9, D\sharp 9$ and $C\sharp 9, H9, F9, B\flat 9$.
- 2. 1-quint chords appear as symmetry related mutiplets G, D7, Amaj7, E7 and $C \sharp m, F \sharp 6, H6_-, E6$. Key G major and $C \sharp$ minor would be natural looking keys even without tetrahedral extension. For the mirror image $B\flat$ minor and E major would be the natural looking keys. For extension E major would be the key.

To sum up, half octave shift is a symmetry of all harmonies expected those having only Z_2 reflection symmetry, and fails thus also for the corresponding bio-harmonies. The tables below give list for the three types of 3-chords for the 11 harmonies possessing symmetries. A 3-chord with n quints is called n-quint chord. The harmonies are labelled by integer triplets (n_0, n_1, n_2) , n_i gives the number of n-quint chords.

The reversal of the orientation for the cycle induces the transformation $C \leftrightarrow C$, $F \sharp \leftrightarrow F \sharp$, $H \leftrightarrow C \sharp$, $F \leftrightarrow G$, $D \leftrightarrow B \flat$, $E \leftrightarrow G \sharp$, $A \leftrightarrow D \sharp$ and produces a new scale with minor type chords mapped to major type chords and vice versa.

The standard notation of chords used in popular music is used. One must however remember that all 3-chords except those which are simple majors or minors lack the third so that their emotional tone remains uncharacterized. For instance, C6 does could be replaced with Cm6 and G7 with Gm7. The reader can check the chords by direct inspection of the figures. The convention used is that vertex number 1 in Hamiltonian cycle corresponds to C note.

11.4.2 Tables for the 3-chords of icosahedral harmonies

The following tables give the 3-chords of the icosahedral harmonies.

11.4.3 Illustrations of icosahedral Hamiltonian cycles with symmetries

The figures below illustrate the Hamiltonian cycles involved. Quite generally, the Z_n symmetry acts by a shift by 12/n quints along the cycle and the orbits of chords consist of at most n chords of same type as the reader is encouraged to verify.

$(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})$	0-chords	1-chords	2-chords
(0, 16, 4)		$(Em, B\flat m), (Cm, F\sharp m),$	$(D9, G\sharp 9),$
		$(G6, C\sharp 6), (A6, D\sharp 6),$	$(E9, B\flat 9).$
		$(D4+, G\sharp 4+), (B4+, F4+),$	
		$(Cmaj7, F \sharp maj7), (G6-, C \sharp 6-).$	
(2, 12, 6)	$(Aex4, D \sharp ex2).$	$(Am, D\sharp m), (G9-, C\sharp 9-),$	$(C9, F\sharp 9),$
		$(C4, F \sharp 4), (E4+, B\flat 4+),$	$(A9, D\sharp 9),$
		$(Dmaj7, G \sharp maj7),$	$(D9, G\sharp 9).$
		(Bmaj7, Fmaj7).	
(4, 8, 8)	$(Aex2, Hex8, D \sharp ex2, Fex8).$	$(D7, G\sharp 7), (Amaj7, D\sharp maj7),$	$(G9, C\sharp 9), (A9, D\sharp 9),$
		$(A4+, D\sharp 4+), (E7, B\flat 7).$	$(B9, F9), (E9, B\flat 9).$

Table 11.4: Table gives various types of 3-chords for harmonies with Z_2 rotation symmetry acting as half-octave shift. The doublets represent 2-chord orbits. The cycles correspond to figures ??, ??, and ??.

$\boxed{(\mathbf{n_0},\mathbf{n_1},\mathbf{n_2})}$	0-chords	1-chords	2-chords
(2, 12, 6)	$(F \sharp ex3, Hex4),$	$(Am, D\sharp), (A6, D\sharp7),$	$(C9, F9), (B9, F\sharp 9),$
		$(D7, B\flat 6), (G6-, Fmaj7),$	$(E9, C\sharp 9).$
		$(D4+, B\flat 9-), (E9-, G\sharp 4+),$	
(2, 12, 6)	(Dex4, Hex4).	(F, Fm), (C6-, Bbmaj7),	$(C9, D\sharp 9),$
		$(D7, G\sharp 6), (Gmaj7, D\sharp 6-).$	$(D\sharp 9, C\sharp 9),$
		$(C \sharp 4-, A4+), (E4+, F \sharp 6).$	(E9, B9).
(4, 8, 8)	(Fex1, D # ex3, G # ex1, Aex2).	(E7, E6), (Amaj7, B9-),	$(D9, B9), (C9, C\sharp 9),$
		$(G, C \sharp m), (D7, F \sharp 6).$	$(F9, G\sharp 9), (D\sharp 9, B\flat 9).$
(2, 12, 6)	(Hex3, Eex7).	$(D7, G\sharp 6), (G, D\sharp m),$	$(C9, D\sharp 9),$
		$(F, Fm), (C6-, B\flat maj7),$	$(D9, C\sharp 9),$
		$(A9-, C\sharp 4+), (E7, F\sharp 6).$	(E9, B9).
(2, 12, 6)	(F # ex2, Fex3).	$(F, B\flat m), (C7, G\sharp 6),$	$(B\flat 9, D\sharp 9),$
		(Amaj7, B9-), (E6, E7),	$(C9, C\sharp 9),$
		$(G, C \sharp m), (D7, B6).$	(D9, H9).

Table 11.5: Table gives various types of 3-chords for harmonies with single reflection symmetry.The cycles correspond to figures ??, ??, ??, ??, ??.



Figure 11.1: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 6-fold rotation symmetry acting shifts generated by a shift of 2 quints.



Figure 11.2: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 4 reflection symmetries generated by reflections in vertical and horizontal directions.



Figure 11.3: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 4 reflection symmetries.



Figure 11.4: $(n_0, n_1, n_2) = (0, 16, 4)$ Hamiltonian cycle with 2-fold rotational symmetry realized as 6-quint shift along the cycle.



Figure 11.5: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold rotation symmetry.



Figure 11.6: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold rotation symmetry.


Figure 11.7: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry realized as horizontal reflection



Figure 11.8: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 11.9: $(n_0, n_1, n_2) = (4, 8, 8)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 11.10: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.



Figure 11.11: $(n_0, n_1, n_2) = (2, 12, 6)$ Hamiltonian cycle with 2-fold reflection symmetry.

Chapter 12

Quantum gravitation and quantum biology in TGD Universe

12.1 Introduction

This article summarizes the recent understanding about the biological role of quantum gravitation in the TGD Universe.

12.1.1 The role of quantum gravitation in TGD inspired quantum biology

In this article several new ideas related to quantum gravitation in the sense of TGD are introduced. The notion of quantum gravitational magnetic body (MB) leads to a considerably sharpening of the existing picture and provides an improved understanding of the real nature and role of biologically important dark ions.

- 1. The notion of magnetic body (MB) carrying ordinary matter as phases with effective Planck constant $h_{eff} = nh_0$ suggests that MB acts as a master and ordinary matter is at the bottom of the slaving hierarchy. There are reasons to believe that gravitational flux tubes with very large value $h_{eff} = h_{gr}GMm/v_0$ of gravitational Planck constant [E1] [?, K85] [L172, L155] are of special importance and correspond to the very high level in the hierarchy and to scales of order Earth scale. One could say that quantum gravity would transform chemistry to biochemistry and distinguish between the chemistries in *vivo* and in *vitro*.
- 2. Gravitational MB, which consists of very long loop-like flux tubes with gravitational Planck constant introduced by Nottale [E1] explains the findings of Blackman and others [J7], is of special interest and assumed to play a key role in metabolism. Gravitationally dark protons would be associated with very long gravitationally dark hydrogen bonds (HBs). Due to delocalization of the proton, hydrogen would be effectively negatively ionized.

Gravitationally dark electrons or their Cooper pairs would in turn accompany gravitationally dark valence bonds (VBs) connecting metal atoms or their Cooper pairs with molecules of opposite valence (hydrogen peroxide H_2O_2). Also the metal atom is effectively ionized. This provides a more accurate view of dark metal ions assumed to play a central role in the TGD inspired quantum biology.

A correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary is obtained. A more precise model predicts correctly the nominal value of metabolic energy quantum for proton triplets which appear also in the generation of ATP. For triplets of electron Cooper pairs, the same mechanism predicts an upper bound of the electronic metabolic energy quantum, which corresponds to the so-called miniature potential. This raises the question whether the letters of genetic code could be realized by the 4 states of electron Cooper pairs and whether the Posner molecule could realize it.

- 3. One obtains a correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary. A more precise model predicts correctly the nominal value of metabolic energy quantum for proton triplets which appear also in the generation of ATP. For triplets of electron Cooper pairs, the same mechanism predicts an upper bound of the electronic metabolic energy quantum, which corresponds to the so-called miniature potential of about .4 meV. This raises the question whether the letters of genetic code could be realized by the 4 states of electron Cooper pairs and whether the Posner molecule could realize it.
- 4. Also the gravitational MB of Sun could be involved and the prediction is that the energy range for the metabolic energy quanta corresponds to the range of visible energies so that photosynthesis could use photon energy to kick dark protons and dark electrons to the gravitational MBs of Earth and Sun to serve as a metabolic energy storage. Remarkably, the photosphere has temperature in thermal energy in the range [.4,.6] eV which corresponds to metabolic energy quantum.
- 5. This picture about dark HB leads to a rather detailed model of the role of phosphate in metabolism. Electronic metabolism could solve the problem due the lack of ATP machinery inside cilium and near it. Spikes having the same scale as miniature potentials observed in neurons could also appear in plants. For the recently observed spike sequences in fungi, the voltage spike has an amplitude with order of magnitude roughly consistent with the electronic metabolic energy quantum [I45].
- 6. A detailed model for the pairing of DNA and dark DNA (DDNA) emerges and forces to modify the earlier model somewhat. The HBs associated with base pairs could transform to gravitational HBs either by reconnecting directly with gravitational flux tubes or by double reconnection with gravitational HBs assignable to phosphate of the DNA nucleotide. This process could make possible the splitting of these HBs occurring in the replication and transcription. The very weak dependence of DNA properties on various salt concentrations in vivo is in sharp contrast to the strong dependence in vitro. This difference can be understood.

12.1.2 TGD based view of nerve pulse

The proposed model starts from the existing TGD based view about nerve pulse but the new quantum gravitational view about metabolism leads to a sharpening of the understanding of the role of biologically important ions in nerve pulse conduction.

1. TGD leads to a quantum view [K92, K45, K93] [L149, L155] about cell membrane as a generalized Josephson junction consisting of Josephson junctions defined by membrane proteins and to the proposal that soliton sequences analogous to a sequence of rotating penduli with phase difference increasing along the axon, define the resting states of the membrane.

Nerve pulse would be induced by a perturbation transforming rotation to vibration locally, this propagating perturbation could be called pre-nerve pulse. Also the variant, in which rotation is replaced by oscillation - one would have an "oscillon" sequence - so that perturbation would generate a propagating soliton, can be considered. Note however that one cannot associate a definite rotation direction to an oscillon. The criticality against the generation of nerve pulse has remained poorly understood.

2. TGD also leads to a speculative view about the function of nerve pulse patterns. Usually they are considered to serve as signals inside the brain. An alternative view [L149] is that they make signalling by dark photons propagating along flux tubes parallel to axons or massless extremals parallel to flux flux tubes. The synaptic vesicles containing neurotransmitters would temporarily fuse the pre- and postsynaptic neurons and also connect flux tubes to a single flux tube acting as a wave guide so that dark photon messages could propagate.

This would make possible very rapid communications between the brain (or even MB) and sensory organs and the building of standardized sensory inputs and standardized mental images by using a virtual sensory input from the brain or MB. Essentially pattern completion and recognition would be in question. Sensory perception would be an artwork rather than photograph. Nerve pulses could also send sensory information from the neuronal membrane to MB.

3. Could the meridian system serve as a precedessor of the nervous system such that gap junctions could define permanent flux tube connections between cells? In the nervous system the connections would be dynamical and used only when needed.

The quantum gravitational view about metabolism leads to a modification of the views of nerve pulse conduction.

- 1. In the earlier quantum model, the cell membrane acts as a generalized Josephson junction for biologically important dark metal ions. The ground state of the axon corresponds to a soliton sequence, which has a sequence of rotating gravitational pendulums as a mechanical analog. Action potential corresponds to a soliton (or several solitons) with opposite direction of rotation.
- 2. In the updated model, the dark ions are identified as gravitationally dark effective ions with gravitationally delocalized Cooper pairs of dark electrons. Also gravitationally dark protons assignable to HBs are involved. The delocalization of protons and possibly also electrons to gravitational bonds provides a concrete realization for the variation of the membrane potential in the myelinated portions of the axons, where ion currents are not possible.
- 3. One unsolved problem of the Hodgkin-Huxley model is the conduction of neural signals through the myelinated portions of the axons, where nerve pulse is impossible. The formation of dark hydrogen- and valence bonds induces an effective ionization, which takes membrane potential below the critical value for the generation of nerve pulse, which is generated in unmyelinated portions.
- 4. Microtubules (MTs) are believed to be important in many quantum biological approaches and deserve a separate discussion. In the TGD framework, the quantum antenna hypothesis was one of the first proposals in this direction [K83]. Their precise role has however remained unclear hitherto.

MTs appear in several variants. Cilia and flagella, which are analogous to axons, contain stationary MTs whereas axonal MTs are highly dynamical. The critical dynamics of axonal MTs involves a variation of MT length relying on GDP \rightarrow GTP transition, which involves the change of HB to gravitational HB and vice versa changing the local membrane potential. Therefore MT dynamics makes possible the propagation of the perturbation of the membrane potential in unmyelinated portions of the axon. The effect of anesthetics can be understood in terms of a reduced density of HBs preventing the formation of gravitational HBs so that MTs and the axonal potential freeze.

The findings about multicellular animals of Prakash et al [I152, I150, I151], which have no nervous system but behave as if they had brain, provide valuable hints in attempts to understand the role of MTs. A model of the pre-neural system, based on the gravitational MB and the predicted electronic metabolic energy quantum, is developed in order to explain how these animals control their cilia. Cilia have no mitochondria inside them or in their vicinity and the electronic metabolism could replace the usual metabolism.

12.2 Update of the general ideas of TGD inspired quantum biology

In the sequel I develop a TGD based interpretation of findings in the conceptualization provided by TGD. I will proceed from general to specific and use cilia as example to illustrate the general ideas.

12.2.1 Basic motion patterns as analogs of Bohr orbits

Prakash *et al* identify a small number of basic motion patterns of cilium [I152, I150, I151]. More complex motion patterns of cell can be constructed as combinations of from these using simple rules.

For a general mechanical deterministic system 3-D initial values for generalized positions and velocities determine the time evolution and huge number of different time evolutions are possible. A chaotic behavior is much more plausible than the highly organized behavior analogous to that for organisms possessing central nervous system.

These findings resonate with the general TGD based classical description of classical physics in terms of the topology of space-time surfaces $X^4 \subset M^4 \times CP_2$ as preferred extermals (PEs) of the basic action principle [L169].

- 1. In the TGD framework, space-time as a 4-surface in $H = M^4 \times CP_2$ is topologically nontrivial in all scales and various shapes of matter, usually assigned to matter in almost flat and topologically trivial space-time of general relativity, correspond directly to the topology of the space-time surface.
- 2. From the general coordinate invariance, space-time surface is a preferred extremal (PE) of a general coordinate invariance action principle, which realizes holography in the sense that 3-surface as boundary values determines almost completely the 4-surface, which is therefore analogous to Bohr orbit. There is however a small failure of determinism localizable at the singularities where minimal surface property fails. PEs are minimal surfaces with singularities analogous to frames of ordinary soap films [L174].
- 3. The space-time counterparts of all biological and neurological functions (this includes the development of mechanical and electromagnetic patterns such as nerve pulse patters) correspond to PEs. PEs are also analogous to the modules of computer programs. A small failure of quantum determinism corresponds to a selection of sub-modules in branching points and correspond to the non-determinism of soap films with frames.
- 4. Zero energy ontology of TGD which predicts that quantum states of a system are superpositions of space-time surfaces as preferred extremals (PEs) of action. "Small" state function reductions (SSFRs) as the TGD counterparts of "weak" measurements would select between different variants of space-time surface with same singularities (frames of soap film) and BSFRs would correspond to big changes.

The small repertoire of different motion patterns would correspond to a collection of PEs. From these patterns for cilia more complex patterns would be constructed for the motion patterns for a cell would emerge. From the patterns for cell motion the patterns for a multi-cellular system would emerge. There would be a hierarchy of complexity reducing to a hierarchy of extensions of rationals at fundamental level.

12.2.2 Quantum criticality

Also cilium and a ciliary system could be near quantum criticality and this could be essential for the changes of the state of the motion of cilia.

The motions of microtubules inside cilia force the bending of cilia. The beating waves with frequency 4-10 Hz propagating along cilia and having constant phase along a 1-D section curve of the 2-D transverse section of transversal plane of cilium are known to induce the motions of a single cilium. In multicilium system these motions are in the same phase and induce coherent motion

When the height h, the orientation of cilium, and the beating frequency f are near criticality, a BSFR would occur and induce a sudden change in the motion of cilium. The criticality of the beating frequency could mean resonance between the microtubuli inside cilium and BSFR would induce the shortening of the flux tube pair connecting them. This would induce the bending of the flux tube.

The presence of 3 parameters suggests a catastrophe theoretic description using Thom's catastrophe theory based on a butterfly catastrophe with 3 control parameters.

12.2.3 Excitable systems in zero energy ontology

In the TGD framework, the idea that excitable systems as systems making "big" state function reductions (BSFRs) as counterparts of ordinary SFRs in macroscopic spatial and temporal scales is suggestive. In BSFR the arrow of time changes and after BSFR the dissipative development occurs in reverse time direction and looks to the observer with the standard arrow of time like selforganization and generation of patterns. This BSFR is followed by second BSFR re-establishing the original arrow of time.

In quantum critical systems, the value of h_{eff} would be fluctuating and the change of h_{eff} could happen in BSFR. The dynamics of microtubules (MTs) could be quantum critical since it involves continual growth and decay of MTs, which would correspond to a sequence of BSFRS. During mitosis (cell replication) the expansion and contraction of MTs involving change of h_{eff} and BSFR would play a key role role.

Bio-catalysis is another example [L228]. The reactants would be brought near each other by a contraction of the flux tube pairs connecting them. The flux tubes pairs would be formed by a reconnection of U-shaped flux tubes of reactants acting as tentacles if there is cyclotron frequency resonance (the thicknesses of the U-shape flux tubes are identicals). The BSFR involving a contraction due to the reduction of h_{eff} . After reaction h_{eff} could reduce to its original value in second BSFR.

12.2.4 The notions of magnetic and electric body

The notions of magnetic body and electric body are central in TGD inspired quantum biology but their precise definition has been far from clear. The intuitive notion is that MB consists of U-shaped monopole flux tubes extending from the system considered and serving as kinds of tentacles. These flux tubes for two systems can reconnectand form a pair of flux tubes connecting the system if the cyclotron frequencies of the tubes are the same so that cyclotron resonance becomes possible.

MB is characterized by the value of the effective Planck constant $h_{eff} = nh_0$, where n corresponds to the dimension of the extension of rationals assignable to the space-time regions by $M^8 - H$ duality [L127, L128]. One can assign MB to flux tubes mediating electromagnetic, gravitational and even weak and color interactions, and the scale of MB correlates with the screening length of these interactions. For gravitation there is no screening and the values of $h_{eff} = h_{gr}$ can be very large. The large value of $h_{gr} = GMm/v_0$ [E1] implies that the dark cyclotron radiation in the EEG range would correspond to visible and UV energies.

In the TGD framework magnetic body (MB) would serve as the controlling agent receiving sensory information as a frequency modulated dark Josephson radiation and controlling the cell by using dark cyclotron radiation coming as pulses corresponding to resonant receival of Josephson radiation.

What could be the electric counterpart of the magnetic body? Magnetic flux tubes can also be dynamical and locally orthogonal helical magnetic and electric fields are possible. Electric body should be something different. Various membrane-like structures populate the Universe and they could correspond to electric bodies.

- 1. The 4-surfaces X^4 with 1-D CP₂ projection and 3-D M⁴ projection having 2-D membrane as E^3 projection are good candidates for various membrane objects in TGD Universe [L174]. The E^3 projection is not a minimal surface although X^4 is, and this possible if the 1-D CP₂ projection is dynamical. The flux tubes of MB should be assignable to kind of membrane-like surface.
- 2. The gravitational MB, it it exist, could be a layered structure containing the Bohr orbits with Bohr radii $r_n \propto n^2$ of particles in the gravitational field of Earth. Particles with different masses would concentrate at the same orbits. One would have the shell structure of the ordinary atom. This notion generalizes also to other interactions and for them the values of h_{eff} would be much smaller.
- 3. Flux sheets with a cylindrical rotational symmetry containing the orbits can be considered. These surfaces should be realized as preferred extremals of the action and should be minimal surfaces in $H = M^4 \times CP_2$. As closed surfaces they cannot define minimal surfaces of the

Euclidean 3-space E^3 . Indeed, soap bubbles are not minimal surfaces but require a constant pressure difference between interior and exterior.

The analog of the pressure difference would be non-trivial and dynamic 1-D projection of 4-D surface to CP_2 [L174]. The liberation of metabolic energy quantum would be analogous to a transition of hydrogen atom to a lower energy state.

12.2.5 The notion of gravitational magnetic body

The notion of gravitational MB turns out to be crucial for the understanding of the role of quantum gravitation in TGD inspired quantum biology.

Gravitational magnetic body as a controlling agent and the prediction of two metabolic energy quanta

In the TGD framework magnetic body (MB) would serve as the controlling agent receiving sensory information as a frequency modulated dark Josephson radiation and controlling the cell by using dark cyclotron radiation coming as pulses corresponding to resonant receival of Josephson radiation.

The large value of $h_{eff} = h_{gr} = GMm/v_0$ [E1] implies that the dark cyclotron radiation in the EEG range would correspond to visible and UV energies.

The intuitive notion is that MB consists of U-shaped monopole flux tubes extending from the system considered and serving as kinds of tentacles. These flux tubes for two systems can reconnect and form a pair of flux tubes connecting the system if the cyclotron frequencies of the tubes are the same so that cyclotron resonance becomes possible.

In [L181], the question of what the notion of gravitational MB does mean, was considered.

1. The dark flux tube would be "gravitational" with $h_{eff} = h_{gr}$. Gravitational flux tubes carry Kähler monopole flux but no gravitational flux. This would be in conflict with the irrotational nature of gravitational field at Newtonian limit. The monopole flux could however have interpretation as gravimagnetic flux. The attribute "gravitational" is motivated by the assumption that one has $h_{eff} = h_{gr}$. The ordinary, short, MB reconnects atoms A and B.

Gravitational flux tubes have lengths, which can be of the order of Earth size scale and the radii of gravitational Bohr orbits define a natural scale form them. Gravitational flux tubes are closed flux tubes with the shape of a highly flattened triangle with a long side in the vertical direction and having length of order Earth size scale and short side of order interatomic distance for the atoms A and B connected by HB.

This inspires a rather concrete vision about the structure of gravitational MB as a forest of gravitational flux tubes analogous to trees. This applies also to non- gravitational flux tubes with smaller values of h_{eff} . One would have a full magnetic flora. The larger the value of h_{eff} , the more complex the magnetic plant would be. MB would be like a fractally scaled-up variant of the ordinary forest. Reconnections would make possible transfer of gravitational flux tubes so that also magnetic fauna would be present.

2. One obtains gravitationally dark hydrogen bond (HB) from an ordinary HB when a HB from A to B reconnects with a pre-existing long gravitational flux tube to create a very long gravitational flux tube from A to B. Proton is delocalized as a gravitationally dark proton and its gravitational potential energy is reduced so that the flux tube stores metabolic energy. In the reverse process a reverse reconnection takes place and this metabolic energy is liberated.

The reconnection process requires a feed of energy: for instance solar radiation can provide it in photosynthesis. A similar description applies in the case of valence bonds (VBs). Note that the transformation of an ordinary, short HB to a long gravitational HB is not a realistic option since this would require a lot of energy since magnetic energy would be created.

3. The elongated gravitational flux tubes could correspond to either hydrogen bonds (HBs) or valence bonds (VBs). The loop-like bond could connect nearby atoms just like the ordinary bond. The delocalization of the charge to the flux tube leads to an effectively ionized donor atom.

- 4. All values of h_{eff} are possible. For electromagnetic flux tubes the values of h_{eff}/h are not very large. This picture leads to a view about hydrogen and VBs as bonds having $h_{eff}/h > 1$ [L62]. Also gravitational variants of hydrogen and VBs are possible. In this case, the proton or electron would be vertically delocalized in the Earth scale so that the donor atom would be effectively ionized. For instance, a phosphate ion could be an effective ion having a gravitational hydrogen bond with the hydrogen of a water molecule.
- 5. A gravitational VB, connecting a metal atom with an atom with an opposite valence, would lead to effective ionization of the metal atom. For instance, biologically important bosonic ions such as Ca⁺⁺, Mg⁺⁺, Fe⁺⁺ and Zn⁺⁺ associated with their oxides could correspond to effective ions like this.

The signature would be a pairing with a neutral oxygen atom by a gravitational VB. I have introduced the notion of dark ion to explain the findings of Blackman [J7] and others and dark ion could correspond to this kind of pair. Note that the original variant of the model assumed that the entire ion is dark, the later version assumed that the valence electron of free atom is dark, and the model considered here assumes that darkness is a property of bond.

6. The effective ionization requires energy ΔE to compensate the increment of the gravitational potential energy given by $\Delta E_{gr} = (\langle V_{gr}(R) \rangle - V_{gr}(R_E))$. Here $E_{gr}(R)$ is gravitational potential energy proton or electron, and R_E denotes the radius of Earth, and R is the distance of the point of flux tube from the center of Earth.

Classical energy conservation suggests that the value of vertical kinetic energy at the surface of Earth is equal to the increment of the gravitational potential energy at the top of the loop. From energy conservation one can estimate the metabolic energy quantum as a liberated kinetic energy in the normal direction equal to the increase of gravitational potential energy. Hence the naive guess could be correct.

7. The maximal value for ΔE_{max} for electron Cooper pair (dark Cooper pair is at infinite distance) corresponds to $V_{gr}(R_E) = .36$ meV to be compared with the energy scale .3 meV defined by the temperature of 3 K microwave background and to the value .4 meV of the miniature potential. This suggests that, in the case of the electron, the reduction of kinetic energy contributes more than 10 per cent to the ΔE .

For a single dark proton one has $V_{gr}(R_E) \simeq .34$ eV, which is below the nominal value of the metabolic energy currency about .5 eV.

8. The condition that the end of the vertical gravitational loop travels along a stationary orbit parallel to the plane of rotation of Earth such that the normal velocity of the dark particle vanishes at the top, implies for the tangential velocity v_T the condition $v_T^2 = \omega^2 R^2 = GM/R$ allowing to determine the radius of the orbit as

$$\frac{R}{R_E} = (\frac{r_{s,E}c^2}{2\omega^2})^{1/3} \times \frac{1}{R_E} \simeq 3.1 \ .$$

The change of the gravitational potential energy in the transition to an ordinary proton would be $\Delta E = \Delta E_{gr} = .68 \times V_{gr}(R_E)$, which would give $\Delta E = .18$ eV. In the dark genetic codons hydrogen bonds appear as triplets. 3 dark protons would give metabolic energy quantum .55 eV. Interestingly, a translocation of 3 protons fuels synthesis of ATP!

9. For an electron Cooper pair the upper bound for the metabolic energy quantum would be $\Delta E_{max} = .33 \text{ meV}$, which is below the miniature potential .4 meV. For the stationary flux tubes one obtains $\Delta E = .17 \text{ meV}$. Later the evidence for the 'spikes' in fungi [I45] discovered by Adamatsky will be discussed: their amplitude is reported to be in the range .03-2.1 meV which contains ΔE .

For an electron Cooper pair triplet one would have $\Delta E = .51$ meV consistent with the miniature potential .4 meV. Should one take this seriously? Could also dark electron Cooper pairs organize into triplets like dark protons would do and in this manner define dark genetic

code? TGD predicts that genetic code is universal: could also dark electron Cooper pairs define a dark variant of the genetic code?

Posner molecules $[(PO_4)^{-3})]_6 Ca_9^{+2}$, to be discussed in the sequel, consists of $3 [(PO_4)^{-3})]_2 Ca_3^{+2}$ acting as a basic unit. This unit could contain 3 electronic Cooper pairs with electronic metabolic energy quantum $\Delta E = .51$ meV. In principle, Cooper pairs can have spin 1 or spin state giving 4 states altogether. Could these states define letters of a dark genetic codon so that the basic unit would define a genetic codon and Posner molecule could correspond to a triplet of genetic codons?

The TGD view about formation of bound states as Galois singlets [L196] allows us to consider this possibility. For an extension of extensions of ... the Galois group would decompose to a hierarchy of Galois groups actings as normal subgroups. Codons as triplets would be Z_3 singlets in both the ordinary and the electronic genetic code. Genes would correspond to larger Galois groups decomposing to normal subgroups. Codon doublets of DNA double strands would be Z_2 singlets and triplets of triplets of Posner molecules would be Z_3 singlets.

10. A proper treatment of the situation would require Schrödinger equation for the dark particle at the flux loop. The situation is analogous to a quantum model of the fountain effect of super-fluidity discussed in [K39] in a situation when the gravitational potential can be linearized (WKB approximation).

One can consider Schödinger equation for h_{gr} idealizing the loop with a 1-D box with gravitational potential GMm/r. The Schrödinger equation reduces in dimensionless variable $u = (m/\hbar_{gr})z = 2\beta_0(z/r_s), r_s = 2GM$ to

$$(-\frac{\partial_u^2}{2} - \frac{\beta_0}{u})\Psi = \frac{E}{m}\Psi \equiv \epsilon \Psi \ .$$

A possible condition is that the vertical derivative $\partial_z \Psi$ vanishes at the top of the loop. The metabolic energy quantum equals $(GM/R_E - \epsilon(v))m$ and is quantized. The height of the loop could be quantized using the condition that the loop end is stationary with respect to Earth.

If this speculative picture makes sense, quantum gravitation would play a key role in metabolism and genetic code.

- 1. The transformation of electrons and protons between ordinary and gravitationally dark states would be a key process of metabolism and biocatalysis. This conforms with the fact that proton and electron exchanges play a key role in biology. For instance, phosphorylation means that the receiving molecule gains phosphate, which can form gravitationally a dark hydrogen bond so that the system becomes metabolically active. This would correspond to the activation in bio-catalysis.
- 2. In the same way, in a redox reaction, the electron donor is oxidized and the electron receiver is reduced. Reduced molecule gains the ability to have a gravitationally dark electron, and therefore becomes metabolically active in the electronic sense. Redox reaction would be the electronic counterpart for phosphorylation.

The role of solar gravitational field in metabolism

Also the gravitational field of the Sun could be important in metabolism.

1. At the distance of 1 AU of the Earth, the counterpart of single proton metabolic energy quantum .18 eV would be 2.6 eV, which is in the visible range. For a proton triplet, the energy would be 7.8 eV and in the UV range. This quantum would be realized as a long flux tube directed away from the Sun in the plane of the Earth's orbit and orthogonal to the orbit.

- 2. Could the visible solar radiation kick protons to solar gravitational flux tubes and the radiation of photosphere having energy range [.4,.6] eV to the gravitational flux tubes of Earth in photosynthesis? Could the solar part of dark gravitational energy for protons be transformed to ordinary metabolic quanta in metabolism? Note that the feed of the solar radiation energy to flux tubes suggests a modification of the proposed simple model involving only gravitation.
- 3. This picture would be true for all Sun-like stars and for planets at the distance of Earth and supports the view that Earth-like planets for Sun-like stars are favourable for life.

Metabolic energy depends on gravitational environment

According to the proposed simple model, bio-chemistry would strongly depend on the local gravitational environment.

1. For an object with mass M and radius R, the estimated maximal gravitational metabolic energy quantum E_{max} is scaled up by factor is scaled up by a factor $z = (M/M_E) \times (R_E/R)$. The values of z for Mercury, Venus, Mars, and Moon are (.2,.14,.86,.04). For Venus, which is called the sister planet of Earth, z is not too far from unity.

For the stationary orbits around an object with radius R_1 , mass M_1 , and rotation frequency ω_1 the ratio $\Delta E_1/\Delta E_E$ of metabolic energy quantum to that for Earth satisfies the scaling formula

$$\begin{array}{l} \frac{\Delta E_1}{\Delta E_E} = \frac{R_E}{R_1} \times (1 - x_1 x_2 x_3) \\ x_1 = \left(\frac{M_1}{M_E}\right)^{1/3} per, \qquad x_2 = \times \left(\frac{\omega_E}{\omega_1}\right)^{2/3} , \quad x_3 = \frac{R_E}{R_1} \end{array}$$

- 2. In the case of the Moon, E_{max} would be by a factor $z = R_E/R_{Moon} = .017$ smaller than at the surface of Earth. The stationarity condition would require a flux tube orbit radius smaller than the Moon radius. In the case of Venus, the sidereal rotation period is -243.0 days (retrograde): also now the orbit of stationary radius would be smaller than the radius of Venus. This suggests that only the metabolism utilizing the solar gravitational field photosynthesis is possible and would be essentially the same as at the surface of Earth.
- 3. In the case of Mars one has $\omega_1/\omega_E \simeq 1$, $M_1/M_E = .1$, $R_1/R_E = .533$. This gives $\Delta E = .24\Delta E_E$, which for the proton Cooper pair would give .13 eV. Could the solar gravitational field save the space traveller in case of Moon and Mars? The largest distance from Earth is about 1.7 AU and at this distance the maximal value of the solar metabolic energy quantum is scaled down by a factor .59.

Jupiter's (https://cutt.ly/CF8bteR) moon Europa (https://cutt.ly/HF8buAp) is one of the most promising candidates for a seat of life since it contains water in the form of ice. Is quantum gravitational metabolism based on the solar and Jovian gravitational fields consistent with Earth-like metabolism?

For the Jupiter's gravitational field, the gravitational potential energy at the surface of Europa is $V_{gr} = GM_Jm/R_{Eu}$ and defines the maximal value ΔE_{max} of the metabolic energy quantum for a flux loop defining dark gravitational HB oriented radially outwards along A line connecting Europa and Jupiter. The mean distance d_{Eu} from Jupiter is $d_{Eu} = 105.3 \times R_E$ to be compared with the radius $R_J = 10.97R_E$ of Jupiter. The mass of Jupiter is $M_J = 317.8M_E$. This gives $\Delta E_{max,Eu}/\Delta E_{max,E} = V_{gr,J}/V_{gr,E} = (M_J/M_E) \times (R_E/d_{Eu}) \simeq 3.0$.

For a single gravitationally dark proton, the maximal metabolic energy gain would be .99 eV, which is twice the metabolic energy quantum. Standard metabolic energy quantum .5 eV corresponds to a radially oriented loop with height $h = d_{Eu}$. If a proton triplet defines the metabolic energy quantum, one would have $h = (1/5)R_{Eu}$.

Solar radiation should provide metabolic energy. The average distance d_J of Jupiter from Sun varies between 5.0AU and 5.4AU so that the gravitational metabolic energy quantum has upper bound $\Delta E_{gr,Sun,J} \leq \Delta E_{gr,Sun,E}/5 \simeq .5$ eV, which corresponds to metabolic energy quantum. Photosphere produces IR radiation with energies in the range .4-.6 eV. Therefore Europa seems to satisfy the conditions from quantum gravitational metabolism.

Just for fun, one can also look at the situation at the surface of Sun.

- 1. At the surface of the Sun, one has $z \simeq 3.0 \times 10^2$ and the metabolic energy quantum .55 eV for dark proton triplet scales to $\Delta E_{Sun} \sim .16$ keV: this is below the threshold for the nuclear fusion and below the temperature of $\sim .23$ keV of the solar corona. An interesting question is whether the X-ray radiation arriving to Earth could have some, perhaps even biological, function. TGD indeed predicts that nuclei have excitations in the keV range [L1].
- 2. For a dark electron Cooper at solar surface, the upper bound is .08 eV. The temperature of the photosphere corresponds to photon energy of .4-.6 eV, which corresponds to the metabolic energy quantum associated with the Earth's gravitational flux tubes. Could the IR thermal radiation from the photosphere serve as a metabolic energy source?

How does this model relate to the TGD inspired model for Cambrian Explosion [L85] [L173]

- ?
- 1. The TGD explanation for the sudden emergence of new phyla in Cambrian Explosion is that the radius of Earth doubled in CE in rather short time. If the end of flux tube moves along stationary orbit, the scaling formula gives for the metabolic energy quantum before the transition for the dark proton triplet the value $\Delta E_{gr} = .38 \times \Delta E_{gr,max}$, which gives $\Delta E_{gr} = .3$ eV. This is considerably smaller than .55 eV.
- 2. According to Stephen Gould (see the book "Wonderful life" about Burgess Shale Fauna [I181]), a large number of the phyla suddenly disappeared. Could this mean that they were not able to adapt to the transition increasing the value of the metabolic energy quantum? On the other hand, a rapid evolution started. Could this relate to the increased sizes of the protonic and electronic metabolic energy quanta? Solar metabolic energy quanta would not have changed.

Do Moon travellers survive in TGD Universe?

3 dark protons give the nominal value of metabolic quantum. If the naive estimates are taken seriously, terrestrial life might not be possible on Mars and Moon. Humans have however successfully visited the Moon and it is not clear whether the solar gravitational field comes to rescue.

Rather than giving up the idea, it is better to ask what goes wrong with the simplest model. The quasiclassical estimate assumes that the dark charge at the top and bottom of the gravitational flux tube has the same kinetic energy. If the kinetic energy at the top is higher, the value of the metabolic energy quantum increases. This inspires the question whether the reduction of the kinetic energy in the metabolic energy quantum can be neglected.

- 1. The simplest model for the particle at gravitational VB is as a particle in a box with kinetic energies given by $E_n = n^2 \hbar_{eff}^2 / mL^2$, L the length of the loop. If L scales like h_{eff} , the kinetic energy does not depend on h_{eff} . Therefore the scale of kinetic contribution can be estimated in a molecular length scale.
- 2. Could the system adapt to a reduction of the maximal gravitational potential at the surface of the Moon, Mars, or Venus by increasing the average value of n in the superposition of the standing waves having maximum at the top of the valence loop? The system would adapt by increasing the localization of the dark charge at the top of the loop. The reduction of the bond length would mean reduction of the superposition to n = 0 wave so that the kinetic energy would be indeed liberated.

Dark gravitational bonds and high energy phosphate bond

How could the somewhat mysterious high energy phosphate bond (HEPB) associated with diphosphates (DP) and tri-phosphates (TP) relate to the gravitationally dark hydrogen bonds (HBs)?

1. HEPB (https://cutt.ly/2FcLFJY) is identified as the bond $\dots -O - -\dots$ connecting two P atoms in ATP or ADP (https://cutt.ly/HFcLKyk). Hydrolysis involves also one H_2O molecule. The -O - P bond splits inducing the splitting of ATP to ADP and P₁. One cannot assign HEPBs to the monophosphates (MPs) associated with DNA so that the splitting of the O-P bond must play an essential role.. 2. It is best to start by listing the facts about $ATP \rightarrow ADP + P_i + 2H^+$ reaction for which the Wikipedia article (see https://cutt.ly/xFbuDet) gives both graphical representation and the overall formula for the reaction.

In the initial state 4 O-atoms of ATP have a visible negative charge. The simplest assumption is that all ions O^- actually correspond to gravitationally hydrogen bonded O...H pairs with a delocalized proton charge so one should use the notation $O^{"-"}$. O^- would be replaced with O...H - O - H such that the HB carries a gravitationally dark proton delocalized in even astrophysical scale. The negative charge would be only effective and associated with $OH"^-$ " rather than being a real negative charge of O^- . The same assumption is natural also for ADP and AMP. This would define the meaning of organic phosphates. In the final state both P_i and ADP have visible charge -3 to give a total visible charge -6.

 $2H^+$ in the final state guarantees the conservation of the visible charge in the reaction.

- 3. The $P(O^{"-"})_2$ of the third phosphate transforms to an inorganic phosphate P_i . A natural interpretation is that the gravitationally dark protons become ordinary ones. This explains $2H^+$ in the final state. This reaction would liberate part of the metabolic energy.
- 4. One H_2O molecule is used in the reaction. The natural assumption is that one hydrogen of H_2O has a dark gravitational HB with the oxygen appearing in O - P of $(O_2^{"})^*P = O) - O - P$... so that it one has $O^{"}$ visible charge -1. The bond ...P - O - ...H becomes the effective oxygen ion of $...P - O^{"}$ of P_i so that P_i would not be completely inorganic. The remaining OH of the water molecule becomes one $O^{"}$ of P of ADP. Also this reaction can liberate metabolic energy.

12.2.6 Gravitational magnetic body and the model of dark DNA

Dark DNA (DDNA) is identified in terms of dark proton triplets assigned with flux tubes parallel to DNA. Codons correspond in the original model to smaller circular flux tubes carrying the dark proton triplets. This model is modified by replacing the circular flux tubes with long U-shaped gravitational HBs. In order to avoid confusion, one must make clear that this realization of DDNA differs from that discussed in [L196] and one must check whether they are consistent and what new predictions follow from the recent, much more specific, model.

Original model of DDNA

The original proposal for DDNA was that the dark proton charge screens the negative charge of phosphates so that the charge associated with the DDNA codon would be +3. If one has dark nucleons (proton and neutron), also other charges than +3 are possible in the proposed model and would be needed for amino acid polymers (AAs) [L196].

The most recent model discussed in [L196] made the following assumptions.

1. Dark nucleotides correspond to closed loops containing a dark nucleon: both dark protons and possibly effectively dark neutrons are possible so that dark nucleon has spin and strong isopin corresponding to 4 letters of the genetic code. A dark neutron could be only effectively a neutron and could be formed from a dark proton, which has transferred its charge to a flux tube connecting it with the neighboring dark proton.

The total charge is that for dark protons as required by the condition dark DNA charge is neutralized. This conforms with the model for the formation of dark protons by Pollack effect [I110, L20, I197, I162] as transfer of ordinary protons to dark protons at flux tubes possibly forming dark codons as dark proton triplets [L20].

The flux tube could be regarded as analogous to dark π^0/π^- or dark Z^0/W^- . These two options could be dual descriptions as the conserved vector current and partially axial current hypothesis of old fashioned hadron physics suggest.

2. The loop carries angular momentum and the angular momenta of dark protons and dark nuclei sum up. The tensor product decomposition of the states obtained in this manner gives DDNA, DRNA, DtRNA, and DAA therefore unifying the counterparts of the basic biomolecules at the dark level.

3. A natural expectation is that $h_{eff} = nh$ forms the unit of angular momentum, in particular spin. This gives a very strong condition and strongly suggests that dark particle corresponds to n-particle as analog of Bose-Einstein condensate: dark 3N-protons and dark 3N-photons as representations of genes with N-codons have been indeed suggested to play a key role in TGD inspired quantum biology. Dark photons with energy of $E = h_{eff}f$ would correspond to $n_{eff} = h_{eff}/h$ dark photons forming an analog of BE-condensate.

Dark space-time sheets X^4 correspond to *n*-sheeted structures with Galois group of n-D extension of rationals. Many-sheetedness could correspond to many-valuedness of X^4 as a map $M^4 \to CP_2$ or vice versa and one can have also have n_1 - and n_2 valuedness with $n = n_1 n_2$. In fact, one has a natural factorization of the order of the Galois group to a product of integers corresponding to its decomposition to normal subgroups so that $n = n_1 n_2 \dots n_k$ is the general proposal. n_{gr} (assigned to h_{gr}), n_{em} , n_{weak} , n_{color} can have further decompositions. *n*-sheetedness with respect to CP_2 would correspond to *n* copies of a space-time sheet in M^4 , for instance parallel flux tubes forming a quantum coherent structure. For \hbar_{gr} this would be the natural option and for $n_{gr} = \hbar_{gr}/\hbar = n_{gr} \sim 10^{14}$. In this case, N-codon interpretation is not appropriate not natural, rather n_{gr} gravitationally dark DNA flux tubes could integrate to a quantum coherent parallel structure with a size about 1 mm.

The revised model of DDNA

In the model of DDNA-DNA considered here gravitationally dark HBs would define the dark codons.

- 1. The earlier model is modified by replacing the closed flux tubes associated with the dark nucleons with gravitationally dark HBs.
- 2. There is no screening now, and the negative charge of phosphates is only effective and assignable to water molecules surrounding DNA rather than phosphates directly so that DNA stability would be achieved also now.
- 3. Dark DNA has still effective charge -1 per codon and the dark proton charge would be delocalized at the dark gravitational flux tubes and thus invisible. DDNAs would be connected by quantum numbers of loopy flux tube pairs with quantum numbers π^0 or π^- connecting dark nucleons of dark DNA. A dark proton at the strong flux tubes would transform to an effective dark neutron in the case of π^- . The value of h_{eff} for these would most naturally correspond to h_{color} .

I have proposed that even the nucleons of ordinary nuclei can have dark flux tubes, which emanate from nuclei of nuclei and carry quantum numbers of pions and having size of even atomic scale. This could relate to the observed discrepancy of the radius of protons. As a matter of fact, this would mean the counterpart of dark HBs at the level of strong interactions.

4. What is new as compared to the earlier model is that there would be a composite of n_{gr} more or less parallel DNA flux tubes assignable to a volume of order 1 mm and each having a length proportional to \hbar_{gr} . Also single flux tube visiting through all the DNAs can be considered. One would have a flux tube spaghetti also assumed to be generated in the formation of astrophysical objects [L105, L116, L170].

Could the HBs associated with the base pairs of DNA become gravitationally dark?

DNA base pairs are connected by 2 (A-T) or 3 (G-C) HBs: what could this mean from the point of view of DNA energy metabolism?

1. If these strands can appear as dark gravitational strands, the maximum of 2 (3) metabolic quanta could be liberated in A-T (G-C) pairs via a transformation to ordinary HBs. Could this serve as a yet-unidentified source of metabolic energy in the replication and transcription?

- 2. Could the dark/organic mono-phosphates of the double DNA strand serve as a source of metabolic energy for DNA transferred to the HBs connecting base pairs?
- 3. Suppose that the DDNA parallel to DNA corresponds to a sequence of gravitational HBs B_{gr} as loops associated with the organic phosphates. Codon would correspond to a bound state of dark protons associated with three dark gravitational HBs.

Consider an ordinary HB A_o associated with a base pair and B_{gr} associated with the corresponding dark/organic phosphate. Can one transform A_o to A_{gr} to achieve the transfer of metabolic energy?

Two reconnections for a HB pair (A_o, B_{gr}) can transform the pair to (A_{gr}, B_o) . The gravitationally dark proton and metabolic energy would be transferred to basepair from the organic phosphate, which itself would become an organic phosphate ion P_1^- .

Note: Also the phospholipids of the cell membrane are accompanied by a monophosphate group. Also microtubules are accompanied by GMPs. Could they serve as metabolic energy sources in the cell membrane using the above described mechanism?

A quantum gravitational mechanism for the splitting of HBs associated with base pairs

The splitting of HBs associated with base pairs [?]https://cutt.ly/9FmJywe) plays a fundamental role in DNA opening necessary for DNA replication and transcription. These HBs must split during replication and transcription and many other processes such as selective recognition of DNA by proteins, regulation of RNA cleavage by site-specific mutations, and intermolecular interaction of proteins with their target DNA or RNA. Could the notion of gravitational HB provide insights about the process?

1. As the figures of (https://cutt.ly/PFmJaFr) illustrate, the base pairs of the double DNA/RNA strand have 2 or 3 HBs. HBs of type N - H...O and H - N...O and N - H...N (called imino HB) are possible. Imino HB appears for both A-T with 2 HBs and G-C with 3 HBs.

Since the hydrogen of X - H...Y is nearer to Y than X, the splitting is expected to give X + H - Y, $X, Y \in \{N, O\}$. This is indeed the case when X and Y are different. However, the imino HB N - H...N actually splits to N - H + N rather than the expected N + H - N. An exchange of a hydrogen atom is said to occur.

- 2. The temporary formation of a gravitationally dark HB could explain how this is possible. The gravitationally dark proton is at a large distance from the N atoms so that they are in a symmetric position and both outcomes for the splitting are equally probable so that the exchange rate increases.
- 3. This requires a temporary transformation of N H...N HB to a gravitationally dark HB. Could double reconnection transform the pair $(A_o, B_{gr} \text{ formed by } N - H...N$ HB and dark HB of phosphate bond to (A_{qr}, B_o) , which then splits?

Quantum gravitational explanation for the different chemistries in vivo and in vitro

If gravitationally dark hydrogen and VBs are relevant to biology, their effects should distinguish between matter in vivo, gel phase and matter in vitro. The difference should be especially clear at physiological temperatures. Is there any empirical evidence for the deviations from what is inspected on the basis of the standard biochemical intuition?

The interactions between DNA metal ions present living matter could serve as a test for the proposal. In the TGD framework, both metal ions and DNA could be gravitationally dark (in vivo or gel phase) or ordinary (in vitro phase).

1. For the DNA and metal ions as they are usually understood, the phosphate ions $(PO_4)^-$ of DNA should have interactions with metal ions and the concentrations should affect the properties of DNA. This should be true both in vivo and in vitro.

2. In the TGD framework, DNA strand in vivo and in gel phase would be accompanied by a dark DNA strand. The phosphate ions $(PO_4)^-$ would be actually pseudo-ion $(PO_4)^{"-"}$, in the sense that the ion O^- would be replaced with a gravitationally hydrogen bonded structure O...H - O - H such that the HB carries a gravitationally dark proton delocalized in a very long scale. The effective negative charge would be associated with $OH^{"-"}$ pseudo ion rather than being a real negative charge assignable to O.

Outside the physiological temperature range and in vitro, the oxygen ion would be real and the situation would be as in the standard chemistry apart from the possible effects of darkness of metal ions. The simplest assumption is that both metal ions and DNA are dark at the same temperature range only.

3. (Gravitationally) dark metal ions of type X^{++} would also have a dark valence electron at flux tube. One can speak of dark salt since flux tube bonds would connect X with H_2O_2 . Same applies to Cooper pairs of dark ions X^+ .

The phosphate of DDNA-DNA pair has Coulomb interaction with neither ordinary nor dark ions but the metal ion would interact with OH"-". This suggests that the presence of metal ions does, and ions in general, has no strong effect on the DNA properties in vivo. Besides realizing genetic code, dark DNA would shield the system from the perturbations caused by various ions.

4. Experimentally this seems to be the case. Most interactions between DNA and ions are modelled and studied experimentally in dilute water solutions. According to [I86] (https://cutt.ly/bFQ1Gla), under these conditions the DNA interaction with charged ligands, the helix-coil transition temperature, and other DNA properties are strongly dependent on the low-molecular-weight salt concentration, see [I86] and references therein. However, for condensed DNA states (fibers, gels) or in vivo, similar characteristics are often independent of or only slightly dependent on the ionic composition of the solvent.

What about amino-acids (AAs)? The proposal is that also DAA-AA pairing realizes dark genetic code. If this code is realized in terms of gravitationally dark HBs, one expects that the same should be true for AAs.

Dark proteins and quantum gravitation

What about dark proteins in the recent situation?

- 1. In the case of AA of a protein, the effective charge is assignable to the donor atom, which could be either atom of peptide backbone or of water molecule. Can one assign to a given amino acid (AA) of protein (https://cutt.ly/sFRY1WA) 3 gravitational HBs carrying a dark proton each?
- 2. In the formation of AA sequence, peptide bonding occurs, which means that (C = 0) (OH) is replaced with C=O and NH_2 is replaced with N H. (N H) (C H) (C = O) is the unit of peptide backbone (https://cutt.ly/nFRYnu4).

The *H* atom of N - H could form a gravitationally dark HB to *O* atom of water molecule, which would give $N_{"-"}$. Also *N* could form HB with *H* of water molecule: this would give $OH"^{-"}$. C = O could form a dark HB with the *H* of the water molecule so that $OH"^{-"}$ is generated but = *O* remains neutral. As in the case of DDNA-DNA pair, an effective negative charge of -3 units would be generated if one counts also the $COH"^{-"}$ as part of the peptide backbone.

12.2.7 Living systems as analogs of topological quantum computers

Topological quantum computation (TQC) has in the TGD framework a realization in terms of braids realized as magnetic flux tubes connecting subsystems [?, K7, K122]. The flux tubes carry $h_{eff} = nh_0$ phases of ordinary matter behaving in many respects like dark matter. In living matter TQC-like activities would be realized in several scales associated with the hierarchy defined by the levels of MB and one can even speculate that TGD is the basic function of living matter. This motivates a brief comparison of TGD based view about quantum computation (QC) and TQC with the standard view.

Basic distinctions from the standard view

The TGD based view about quantum computation (QC) [?, K7, K122] differs in several aspects from the standard view.

- 1. The hierarchy of Planck constants makes it possible scal the time and spatial scales of QC by realizing it using dark matter as $h_{eff} = nh_0$ as phases for ordinary matter. This is possible at quantum criticality in which long range correlations associated with quantum fluctuations are realized as $h_{eff} = nh_0$ phases, which play a crucial role in the living matter. What is favorable for QC is that for large values of h_{eff} dissipation rate is small.
- 2. The fragility of quantum entanglement is a basic problem of standard QCD. Partially it is due to the smallness of Planck constant. Number theoretic vision predicts that one can assign to quantum entanglement ordinary entanglement entropy and also p-adic entanglement entropy which is possible if entanglement probabilities belong to the extension of rationals assigned to the space-time region considered. $h_{eff}/h_0 = n$ corresponds to the dimension of extension associated with the space-time surface and is determined by the degree of the polynomial determining it at the level of M^{98} ($M^8 - H$ duality). Negentropy Maximization Principle (NMP) is the basic principle of TGD inspired theory of consciousness as a generalization of quantum measurement theory based on zero energy ontology (ZEO).

The prediction is that the quantum entanglement associated with entanglement with positive p-adic entanglement negentropies is very stable and the negentropy of the entire system tends to increase. This implies evolution as an increase of algebraic complexity accompanied by the increase of h_{eff} and quantum coherence scales.

- 3. Negentropic quantum entanglement favored by NMP satisfies strong constraints. In particular, the entanglement probabilities are rational numbers. Therefore this kind of entanglement is very rare. This solves a second basic problem of QC: there are quite too many possible quantum entanglements so that combinatorial explosion is unavoidable.
- 4. ZEO [L118, L165] [K132] allows also QCs in both time directions. In "big" state function reduction (BSFR) the computation halts and the arrow of time is changed and QC in the opposite time direction begins. At the human level the wake-sleep cycle corresponds to the periods separated by BSFRs. The saying that problems are solved, by sleeping over night, makes sense at a deeper level. During this period dissipation looks like self-organization and regeneration of structures, healing, and biological systems would apply this mechanism in all scales in order to fight against second law. One can also ask whether QC forth-and-back in time could make QC much faster.

TQC in the TGD framework

TQC is a very natural option in the TGD framework [?, K7, K122]. The basic notions are magnetic body (MB) having magnetic flux tubes and flux sheets as body parts and dark matter residing at MB.

1. ZEO replaces 3-D quantum states with superpositions of deterministic time evolutions as preferred extremals (PEs) of the basic action principle, and are analogous to Bohr orbits and realize almost ideal holography - required by the realization of general coordinate invariance, in the sense that 3-D data fix the entire 4-surface. PEs are analogous to biological functions,

behavior patterns in neuroscience, and computer programs in computer science. SFRs as acts of free will replaced these programs with new ones.

PEs would be 4-D minimal surfaces with singularities of lower dimension. PE is analogous to soap film spanned by frames defining the singularities. As in the case of soap films, the frames give rise to a finite failure of strict determinism and ideal holography. This failure would be a classical space-time correlate for quantum non-determinism, or at least what I have called cognitive non-determinism as a correlate for imagination.

In purely classical physics holography is not realized. It is easy to understand this by thinking in terms of a point-like particle (for which 3-surface is a generalization). A particle at a given point can go in any direction with any velocity. By ideal holography only single direction and unique velocity is allowed.

 Magnetic flux tubes connecting 3-surfaces give rise to networks. 3-surfaces appear as nodes of this network. An interesting possibility is that these 3-surfaces have as a good approximation 2-D projection to 3-space and therefore define membrane-like objects. All membrane like objects, such as cell membrane could be associated with this kind of 4-surfaces.

The flux tube connections are a new element not present in the standard physics. The flux tubes can be idealized as string-like entities. In 3-D space the flux tubes can get knotted and linked with each other and define in this way braids - or rather, generalizations of braids. They would define the topological space-time correlate for a TQC program,

3. Fermionic degrees of freedom (quarks at fundamental level giving rise to all elementary particles including bosons and also leptons as the bound states) define the fermionic part of TQC. Fermionic states reside at the ends of braids at the nodes of the network and more generally at the 3-surfaces from which the flux tubes begin.

An important delicacy, forced by the fact that flux tubes carry monopole flux, is that flux tubes associated with a 3-surface are tentacle-like U-shaped flux loops, and their reconnection builds flux tube pairs connecting 3-surfaces.

4. Reconnection for U-shaped flux tubes for a pair A,B of nodes forms a flux tube pair connecting A and B. The reversal of this process destroys the flux tube connection. If all flux tube connections from subsystem A to the environment disappear, A de-entangles. Thus it seems that the presence of flux tube pairs makes possible entanglement. The change of entanglement in turn has braiding as a space-time correlate.

The halting of TQC assignable to subsystems could correspond to the de-reconnection process for a subsystem. Partial de-reconnection is also possible and the notion of partial halting might make sense.

The braids are effectively 1-D and their time evolution defines effectively 2-D surfaces inside a 4-D space-time surface. They can form 2-knots as a generalization of ordinary knots which are 1-knots. The reconnection processes define the topology of these 2-knots. For higher-D space-time surface 2-knotting is not possible so that from the point of view of TQC, the dimension D=4 for the space-time is completely unique as also the dimension D=3 for 3-space.

5. Dance metaphor [?, K7, K122] is a highly useful way to see TQC in the TGD framework. One can think that the nodes of the network are like dances connected to each other by thin threads. Dancers change their partners and define a complex pattern on the dance floor. At the space-time level this defines braiding of the time-lines of the dancers. One can speak of a time-like braid.

Also the threads connecting the dancers are braided and form space-like braid determined completely by the time-like braiding once the initial state of the space-like braid is fixed. This is not quite the case if reconnections splitting or creating threads between dancers take place. One can say that the space-like braiding records the history of the dance hall as analog of akashic records. One can also speak of topological memory. 6. The evolution of the entire TGD Universe can be regarded as a fractal hierarchy of TQCs based on the fractal hierarchy of magnetic flux tubes characterized by algebraic extensions of rationals to which one can assign p-adic primes as maximal ramified primes. These in term define p-adic length scales assignable to the flux tubes. The braiding of flux tubes takes place in all scales. For instance, while moving around, we contribute to a generation of this kind of braids defining analogs of TQCs.

Biochemistry could represent especially refined analog of TQC. The basic notions of biochemistry interpreted in TGD framework correspond to those of TQC according to TGD as described above but also some new elements emerge.

1. Consider the TGD inspired view about bio-catalysis [L228]. Reconnection is the basic mechanism of bio-catalysis. According to the TGD based view about bio-catalysis, reactants find each other by using as tentacles U-shaped flux tubes and resonance mechanism.

Flux tubes can touch but this is not enough. There must be a resonance. This occurs if the cyclotron frequencies associated with the flux tubes are identical. This is possible if the flux tubes have the same radius and therefore identical magnetic field strengths and cyclotron frequencies.

If the value of h_{eff} associated with the flux tubes is reduced, the pair is shortened and forces the reactants near each other. The reduction of h_{eff} liberates energy, which in turn makes it possible to overcome the potential wall, which otherwise prevents the reaction from occurring. After the reaction the energy needed to overcome the wall is liberated and can bring U-shaped flux tubes to its original size. Note that the values of h_{eff} tend to be reduced and metabolic energy feed is to provide the energy needed to preserve the distribution of h_{eff} values.

Since reconnection takes place and reaction can produce new nodes, biochemical reactions do not reduce to the notion of gate in the generalized view of TQC.

- 2. Besides reconnection, the notion of tuning is also fundamental and brings a new element to TQC according to TGD. The change of the thickness of the flux tube as the basic motor action of the flux tube (besides reconnection and contraction) changes the cyclotron frequency. The frequency modulation makes it possible for flux tubes to search whether some objects are present in the environment. This would be the basic operation of the immune system at quantum level [K62] [L194]. The tuning of the flux tubes of MBs of the water clusters makes it possible for them to mimic the cyclotron spectrum of invader molecules and this ability explains water memory.
- 3. Bioharmony [L16] [L136, L159, L196] is a further TGD based notion. The proposal is that genetic code has two quantum realizations. The first one is based on dark nucleon sequences with a dark codon realized as a nucleon triplet. For the second realization codon corresponds to dark photon triplet. These triplets behave like quantum coherent units and are analogous to quarks as 3-quark bound states.

The binding mechanism is purely number theoretic and universal. Also genes can be regarded as dark 3N-nucleons or 3N-photons. The states of dark proton triplets correspond to all basic biomolecules DNA- ,RNA-, and tRNA-codons, as wella s amino acids (AAs).

Bioharmony defines the dark photon realization of genetic code. Communications occur by using 3-chords (or possibly even 3N-chords). The ordinary resonance between participants with the same value of h_{eff} is replaced with 3N-resonance. The allowed 64 3-chords define bio-harmony as a collection of allowed 3-chords. Music expresses and creates emotions and the natural interpretation is that bioharmony is assigned to variants of genetic code which correspond to different molecular moods. Also the energy resonant communications between dark and ordinary variants of codons must be possible and this poses extremely stringent conditions on the basic bio-molecules.

Bioharmony realizes genetic code and would become the basic code of TQC. Codons or even their sequences would serve as addresses. The signal is a sequence of these 3-chords, analog for a piece of music, and is received by resonance mechanism only by receivers which correspond to a sequence of dark nucleon triplets defining the same codons. Note that also partial resonance is possible in which case the number of possible receivers is higher. The principle is the same as in LISP. The message can be coded to the modulation of the frequency scale of chords. The cyclotron resonance peaks define a sequence of pulses making it possible to interpret the message. Nerve pulse pattern could be induced by this kind of pulse sequence.

12.3 Update of the TGD based view of nervous system

The existing TGD based view of the nervous system will be summarized first. After that the basic notions and the ideas about what happens in nerve pulse conduction are sharpened by using the quantum gravitational view about metabolism. Also the relationship between biochemistry and TGD view about quantum biology will be discussed and lead to highly non-trivial insights about the role of the basic biomolecules.

12.3.1 The recent TGD based view of nervous system

The proposal [K92, K45, K93, L149] is that the cell membrane possesses a pre-NS based on cell membranes acting as generalized Josephson junctions.

1. The oscillations of membrane potential induce Josephson oscillations as soliton sequences, which represent the ground state of the axon, and possibly also of cilium. A sequence of rotating mathematical penduli in different phases giving rise to a wave is a good analogy. Pre-nerve pulse would correspond to a perturbation of the soliton sequence in which some penduli oscillate instead of rotating, which propagates with the same velocity as the soliton sequence.

One can also consider an alternative scenario in which the roles of rotation and oscillation are changed. The soliton sequence requires more metabolic energy than its oscillatory counterpart and one might argue that the latter is more favored for this reason.

- 2. Generalized Josephson radiation gives rise to sensory communications from the cell membrane to its MB using frequency modulated generalized Josephson radiation with generalized Josephson frequencies $f_J = E_c/h_{eff}$ (and their multiples), which correspond to the energies $E_J = \Delta E_c + ZeV$, where ΔE_c is the difference of cyclotron energies for flux tubes at different side of membrane, and ZeV is the usual Josephson energy. Z denotes the charge of a Cooper pair or bosonic ion. For $h_{eff} = h_{gr}$ the generalized frequencies are in EEG range and nerve pulses appear as frequency modulations of the generalized Josephson frequencies.
- 3. The frequency modulated generalized Josephson radiation is received at MB and induces pulse by cyclotron resonance defining the response of MB as a dark cyclotron radiation. The response of MB corresponds to a sequence of resonance peaks, which induce pre-nerve pulses as propagating perturbations of the soliton sequence. The perturbation would change the rotating motion of the effective gravitational pendulum to an oscillating motion.

The pre-nerve pulse induces a nerve pulse if a quantum criticality condition stating that the magnitude of the resting potential is above the critical value is satisfied. Synaptic transmission builds a contact between pre- and postsynaptic cells and connects U-shaped flux tubes parallel to the dendrites and axon to a pair of flux tubes.

Which part of the neuron could receive the response of MB?

- 1. The original proposal [K92] was that the response of MB occurs directly at the level of the genome. This would require a network of flux tubes connecting cell nucleus and cell membrane transmitting the response from genome to cell membrane. This flux tube network would also make topological quantum computation-like processes possible [K7, K122].
- 2. One can also imagine a simpler scenario. The response would be received by the cell membrane and generate second messenger molecules, which carry a chemical signal to the cell nucleus. The response could be seen as a sensory communication with a reversed arrow of

time. The objection is that sensory and motor systems are different for vertebrates. One can however argue that the time reversal is for the combined system. If sensory and motor sub-systems have opposite arrows of time, only either of them contributes to "our" conscious experience at once.

Interestingly, in human EEG there is a clear division into quasi-stationary periods with a duration of about .3 seconds [L9] discussed from the TGD point of view in [L8]. The first half of the period looks ordered and the second half chaotic. I have proposed that these pieces are separated by BSFR at MB as a response of MB and correspond to different arrows of time.

Synaptic transmission is second key part of neural activity.

- 1. Synaptic transmission involves the transmission of a bag of neural transmitters implying that the pre- and post-synaptic cell membranes touch and fuse to a singly entity temporarily. This would imply also the fusion of the magnetic flux tubes assignable to pre- and postsynaptic axons to a single flux tube and make possible both the transfer of quantum coherence and the propagation of dark photon signals assignable to magnetic flux tubes acting as wave guides. The flux tubes could be called pre-axons.
- 2. The deeper function of neurotransmitters remains a mystery in the framework of the standard neuroscience but terms like reward and punishment are routinely used. In the TGD framework, these terms could be more than convenient metaphors.

The neurotransmitters arriving in the synaptic contact could induce a change of the local bioharmony and thus a change of the local mood so that the heuristic terminology would be justified. At the level of the basic biomolecules the epigenetic regulation based on methylation could induce similar changes [L196]. The decision making of neurons would rely on emotions created by various synaptic inputs: this is the situation also at our level!

Axonal MTs could make the conduction of nerve pulses through the myelinated portions of the axon possible. Inside myelinated portions the transfer of ions between interior and exterior of the axonal membrane is not possible. The shortening of axonal MTs involves localization of delocalized protons and electrons at gravitational flux tubes and changes the charge of the axonal interior and this in turn can take the membrane potential below the critical value and make the conduction possible. Note however that the drop of electrons and protons would take place at Bohr orbit with Earth radius. A further localization to atomic level would liberate more energy.

12.3.2 Clarification of some basic concepts

In the following I try to further clarify the basic notions used in order to identify the weaknesses of the scenario.

About the notion of dark ion

The original view was that dark ion as a whole resides at the flux tube. Later this statement became more precices: dark ion is touches the , say gravitational, dark flux tube with $h_{eff} > h$. This applies also to both gravitational, electromagnetic, weak, and color flux tubes and ordinary bonds correspond to electromagnetic flux tubes with $h_{eff} = h_{em}$ [L62].

The entire dark ion touching the flux tube would have wave function in the magnetic field of flux tube having the touching point as argument. Cyclotron states are natural.

The more precise view considered already earlier is that one has effective ion: the dark electron or Cooper pair resides at gravitational flux tube is not bound to the atom as effective ion. The predictions for dark cyclotron states are same as for the older picture and the predictions related to the dark electron or proton are new.

About the notion of electric flux quantum

What does one mean the flux tube parallel to axon?

- 1. I have talked assigned to axon a magnetic flux tube parallel to it and accompanied by magnetic flux tubes transversal to it. This would correspond to a 3-D network of flux tubes. The problem has been how to describe the membrane structure with electric field and electric flux orthogonal to the flux tube. This situation requires genuine electric flux quanta analogous to magnetic flux quanta and the time dependent deformations of the magnetic flux tube cannot give them. However, magnetic flux tubes allow very simple time dependent deformations allowing longitudinal electric flux along the tube.
- 2. Could electric flux quanta associated with a pair of lipid layers correspond to a pair of membrane-like objects having 1+2-D rather than 4-D M^4 projection connected by time-dependent deformations of transversal magnetic flux tubes carrying a longitudinal electric field?
- 3. Unfortunateluy, I did not have any candidate for an explicit solution of field equations describing 2-D membrane-like object such as cell body or axon. For some time ago I finally understood 2-D membrane-like objects in terms of 3+1-D minimal surfaces in $H = M^4 \times CP_2$. M^4 projection is 3-D and E^3 projection 2-D membrane. The basic problem is posed by the fact that 2-D closed minimal surfaces are not possible. For soap bubbles a pressure difference over the soap bubble is required and one loses minimal surface property. The solution of the problem was that the 1-D CP₂ projection of the surface is dynamical and allows 4-D minimal surface. The simplest option is that it represents rotating geodesic circle.
- 4. Therefore one can ask whether lipid bilayer could have pair of electric bodies (EBs) serving for them as a kind of template and connected by transversal electric flux tubes carrying a longitudinal rather than transversal electric field.

12.3.3 Gravitationally dark effective ions

Besides organic molecules but also metal ions are fundamental for metabolism and bio-catalysis. This led to the TGD inspired proposal that they give rise to dark ions and the recent work gives further support for the view is that gravitationally dark electrons given them their special role

1. Various bosonic effective metal ions and their Cooper pairs can get paired by gravitational flux tube with atoms of opposite total valence. The distance between paired system can become due the relative motion of the atoms considered. Also reconnections of gravitational flux tubes could cause this.

Correlations are predicted between the members of pairs. The presence of gravitational hydrogen- and valence bonds (VBs) implying the presence of effective ions could distinguish biochemistry from chemistry. Also electrolysis, and therefore organic chemistry in general, involves the ionization of atoms very difficult to understand without the notion of dark gravitational valence- and hydrogen bonds. Also the physics of water is full of thermodynamical anomalies suggesting the presence of these bonds.

2. According to standard chemistry, one has equilibrium $X(OH)_2 \leftrightarrow X^{++} + 2OH^-$ for $X \in \{Ca, Mg, Fe\}$ in water environment. Gravitational effective ionization effectively breaks charge conservation and one would obtain quantum correlated pairs formed from X^{++} connected by flux tubes H_2O_2 . Gravitationally dark electrons would not be visible. This would mean apparent charge non-conservation, which could be tested as deviation of the concentrations from the prediction $n(X^{++}) = 2n(OH^-)$.

This could happen also for water itself. $H_3 O$ ⁺ and OH^- ions are present. OH is not stable but the pairing $2(H_3 O)^+ + 2H_2O_2$ by gravitational hydrogen bonds is possible. Also $H_2O + OH^-$ pairs with one dark gravitational proton are possible. The concentrations of $(H_3 O)^+$ and OH^- would be different.

Signatures of dark effective ions

The ions X^{++} , $X \in \{Ca, Mg, Fe, Z\}$ and $X \in \{Li, Na, K\}$ would be actually effective ions with gravitationally dark VBs. Dark effective ions have special signatures, which allow to test the TGD view.

1. These effective ions effectively break charge conservation. Is the transformation of $X(OH)_2 \rightarrow X^{++} + H_2 O_2$ rather than $X(OH)_2 \rightarrow X^{++} + 2OH^-$ in question as would be if electrons become gravitationally dark. Note that hydrogen peroxide $H_2 O_2$ is a reactive oxygen species (ROS) (https://cutt.ly/NFima6X) playing a very important role in biology. ROS are produced in biological processes, in particular metabolic process such as respiration and photosynthesis. TGD view would mean that ROS are not a nuisance but an essential element of electron based metabolism.

For X^+ , $X \in \{Li, Na, K\}$ the electrons of the Cooper pair are paired with two OHs. Two XOHs forms Cooper pair of X^+ :s correlated hydrogen peroxide H_2O_2 . This would represent new physics and effective charge non-conservation.

2. Quantum gravitational correlations between H_2O_2 and X^{++} , $X \in \{Ca, Mg, Fe, Zn\}$ and between H_2O_2 and Cooper pars of X^+ , $X \in \{Li, Na, K\}$ are predicted and this prediction might be testable.

Some facts about Calcium ions

Basic facts about Ca ions allow to get idea about the implications of new metabolic quantum and the quantum gravitational realization of metabolic energy quanta.

- 1. Calcium ions (Ca⁺⁺) contribute to the physiology and biochemistry of organisms' cells. They play an important role in signal transduction pathways, where they act as a second messenger, in neurotransmitter release from neurons, in contraction of all muscle cell types, and in fertilization.
- 2. Calcium phosphate https://cutt.ly/4FimgMc appearing in bones combines effective ions possibly having gravitationally dark protons and electrons (Calcium phosphate is also considered in [L154]). Posner molecule [(PO₄)⁻³)]₆Ca₉⁺² made of 6 phosphate ions and 9 calcium ions would be the key player and has been proposed to play central role in consciousness theory [J36, J47] (https://cutt.ly/bFimzit). I already mentioned Posner molecules and a possible realization of genetic code using dark Cooper pairs of electrons. I have considered Posner molecules from the TGD point of view in [L37].
- 3. Ca⁺⁺ currents initiate action potentials. Voltage gated Ca⁺⁺ channels emerge first in the maturing of neuron and also in evolution of nervous system (already monocellular eukariotes generate action potentials). Na⁺ channels emerge later. The action potentials pulses have a longer dead time for Ca⁺⁺ than for Na⁺.

For instance, Ca⁺⁺ initiates a contraction of muscle and helps to maintain the potential difference over cell membrane, which conforms with the proposed role in electronic metabolism.

4. Ca⁺⁺ appears as a second messanger molecule. The TGD view about second messanger molecules is discussed in [L187]. Cell interior, in particular mitochondria and endoplasmic membranes contain storages of Ca⁺⁺. Mitochondria would thus involve both forms of metabolism.

Ca^{++} waves

Ca⁺⁺ waves could be effective ions due to gravitationally dark Cooper pairs.

- 1. Ca⁺⁺ waves are very important in biology and appear in cell interior and between cells. A calcium wave is defined as a localized increase in cytosolic Ca⁺⁺ that is followed by a succession of similar events in a wave-like fashion. Ca⁺⁺ waves can be restricted to one cell (intracellular) or transmitted to neighboring cells (intercellular).
- 2. Calcium waves are also associated with glial cells. Ca⁺⁺ waves are of special importance in astrocytes and other glial cells [J46]. This should relate to electronic metabolism of the primary cilia associated with both neurons and glial cells.

Calcium waves and miniature potentials would naturally relate to dark electron metabolism. Both glial cells [J32] and neurons [J31] have primary cilia acting as sensory receptors and since cilia cannot use ATP metabolis, electronic metabolism is natural.

12.3.4 About the model for the nerve pulse

Could one construct a simplified TGD based model for the nerve pulse [K92] using this kind of picture utilizing holography meaning that one can take the EBs as basic objects to which one can assign densities of various ions atoms and normal components of electric field as charge densities? Can one decompose these densities to various contribution assignable to ions or effective ions?

The basic physical picture would be as follows. The transformation of the pairs of metal atom with atoms with total valence equal to that of metal would generate gravitationally dark metal atoms, which are effective ions which correlate with the paired atoms. The valence charge of the metal atom effectively disappears and implies an effective charge non-conservation. In nerve pulse these effective ions would disappear and would look like charge non-conservation. Also effective ionic currents appear.

- 1. Josephson currents are assumed to flow along dark flux tubes connecting the two systems and electric field would be along them. Gravitationally dark protons and electrons reside at gravitational flux tubes as very long loops connecting cell interior and exterior. Dark ions are associated with these flux tubes (touch them).
- 2. What kind of dark Josephson currents could flow along them? If the two atoms are localized at the ends pf the dark gravitational valence- of hydrogen bond at the opposite sites of the membrane, the dark electron and proton Josephson currents can run along gravitational flux tube. Also effective dark ion currents can flow between interior and exterior since the gravitational VB with H₂O₂ can get stretched.

Gravitational flux tubes assignable to valence and hydrogen would connect systems such as X^{++} , $X \in Ca$, Mg, Fe and hydrogen peroxide H_2O_2 , which is a reactive oxygen species (ROS). The currents would flow between systems containing these dark ions and molecules.

3. More than 100 miniature potentials induced by Ach vesicles are needed to initiate nerve pulse in synaptic contact. The miniature potential corresponds to a liberation gravitational electronic metabolic quantum as a transformation of gravitationally dark electron to ordinary one. This critical reduction of membrane potential would induce the reduction of the membrane potential below the critical value and induce the action potential. Also protonic metabolic quanta are involved and would relate to the ordinary metabolism based on ATP machinery.

The TGD picture challenges the Hodgkin-Huxley model of nerve pulse generation (https://cutt.ly/FFiWTNA). The model for the neuronal membrane assumes that ohmic currents flow through the ion channels. What happens when a Ca^{++} initiated action potential is generated?

1. The standard description using Hodgkin-Huxley model is in terms of a rush of Ca^{++} ions to the cell interior along Ca^{++} channels. The process occurs spontaneously since the cell interior is negatively charged and does not require metabolic energy. These currents would be ohmic and dissipative. This description could make sense only in the non-myelinated portions of the axons.

Since only non-dissipative Josephson currents for dark Ca^{++} ions are possible, the rush of dark Ca^{++} dark ions does not seem plausible in the TGD picture. However, the delocalized electronic charge could end up to the hydrogen peroxide H_2O_2 paired with Ca and a genuine Ca_{++} ions would be created. The same applies to Cooper pairs of other dark metallic ions. In the myelinated portions of axon this kind of mechanism could work so that the Hodgkin-Huxley model would describe the situation.

Inside the myelinated portions of the axon, the transformation of gravitationally dark protons to ordinary protons would reduce the associated effective negative charge and make membrane potential more positive and take it below the critical value for nerve pulse generation at nonmyelinated portions.

Also pairs of dark Ca^{++} ions and dark H_2O_2 pairs from $Ca(OH)_2$ can be created, perhaps by a double (effective) ionization creating pairs of dark Ca^{++} ions and dark H_2O_2 pairs from $Ca(OH)_2$ in an electric field in the cell interior. Also dark gravitational VBs associated with Ca would be created in the cell interior and dark electron Josephson currents would be generated. The charge densities inside and/and outside the neuronal membrane would change and affect the membrane potential. This option could be realized in the non-myelinated sections of the axon in the resting state: nerve pulse would involve a transformation of dark ions to ordinary ones.

2. What looks very strange from the TGD point of view is that, although the generation of nerve pulse is spontaneous and is therefore expected to reduce the value h_{gr} , which in turn would liberate energy identified as a metabolic energy, just the opposite occurs. Can one conclude that a BSFR occurs at critical membrane potential and the arrow of time is changed. In this situation the process would be dissipative but in a reversed time direction. Later support for this interpretation will be found.

This raises a question considered from the TGD point of view in [K90]. Do the ion channels and pumps really act as channels for ionic currents or can only electronic, protonic and ionic Josephson currents flow through them?

- 1. The experimental work of Ling, Sachs and Qin [I114, I173] and other pioneers [I89, I61] 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.
- 2. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through the 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: an ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why is it so difficult to get the water out of it?

Membrane potential changes sign during the nerve pulse. The interpretation as a BSFR changing the arrow of time is suggestive and the above observation suggests the same?

- 1. If the action potential corresponds to two subsequent BSFRs as a kind of quantum tunneling event, the arrow of time temporarily changes at MB and changes the effective arrow of time at the level of the ordinary biomatter. Gel-sol phase transition in the neuron interior near neuronal membrane signals about the reduction of the quantum coherence scale.
- 2. The TGD based description for the change of the sign of the membrane potential is in terms of the model of nerve pulse describing the ground state as a soliton/oscillon sequence and mathematically equivalent to a sequence of gravitational penduli rotating/oscillating in synchrony. Can one choose between these options?

Critical membrane potential would correspond to a situation in which the rotation changes to oscillation or vice versa. The fact that the membrane potential changes sign and has original magnitude, supports the soliton model. The rotation frequency would transform to a vibration frequency, decrease further, change sign and eventually transform to a negative rotation frequency. The arrow of time would have changed. The reverse of this process would correspond to the second BSFR leading to hyperpolarization.

12.3.5 Microtubular level

TGD predicts two forms of metabolism [L181]. The ordinary metabolism relies on gravitationally dark protons originating from hydrogen bonds. For the new form of metabolism dark protons are replaced with gravitationally dark electrons or their Cooper pairs originating from metal atoms. Both dark electrons and dark electron Cooper reside at gravitational Bohr orbits with the same spectrum of radii. When they transform back to ordinary particles, they become gravitational Bohr orbits at distance defined by Earth radius and therefore liberate energy.

This metabolic mechanism could be associated with cilia and flagella having no mitochondria in their interior and could be also important in the metabolism of axonal MTs.

Could the metabolism of cilia and flagella rely on gravitationally dark electrons?

The recent work in TGD has led to considerable progress in the understanding of metabolism [L181] already discussed in the section 12.2.5. The TGD based view about metabolism involves in an essential way quantum gravity.

The observation is that the gravitational binding energy of dark protons at Bohr orbits in Earth's gravitational field for $h_{eff} = h_{gr} = Gmm/v_0$ [E1] [?, K85] [L172, L155] can correspond to metabolic energy quantum in good approximation. The proposal is that the transformation of protons of hydrogen bonds possible for electronegative atoms and occurring at least for phosphate generates gravitationally dark protons. Their transformation would liberate metabolic energy quantum.

The prediction is that besides gravitationally dark protons also similar electrons define a metabolic energy currency relating to standard metabolic currency like cent to dollar. It is proposed that the electronic metabolic currency can be applied to the purely understood metabolism of cilia and flagella (https://cutt.ly/WDkYZzx). I attach the proposal below almost as such.

According to [I185] (https://cutt.ly/EDkW2bu) the recent measurements in sea urchin sperm (length ~ 50 μ m long, diameter 0.2 μ m) show that the energy consumed per flagellar beat corresponds to $\simeq 2 \times 10^5$ ATP molecules. There is no GTP inside cilium as in the case of axonal MTs (https://cutt.ly/5DkYGB2). It is difficult to understand how ATP machinery could provide the metabolic energy feed.

This motivates the question about whether local ciliary metabolism could rely on the transformation of valence electrons of some biologically important ions to dark electrons at the gravitational MB and vice versa? The reduction of h_{gr} for electrons would provide the metabolic energy related by a factor $m_e/m_p \simeq 2^{-11}$ to the ordinary. According [I185], about 4×10^8 gravitationally dark electrons would transform to ordinary ones in a single stroke of cilium.

Electronic metabolic energy quantum would relate like cent to dollar and make possible a more refined metabolism with fine tuning. Electronic metabolism could also be an essential part of ordinary metabolism.

Consider now the idea more quantitatively.

1. What could be the electronic analog of ATP machinery. All biologically important ions can be considered as effective ions with some valence electrons at gravitational MB. In particular, the bosonic ions Ca^{++} , Mg^{++} , Fe^{++} and Zn^{++} could have Bose-Einstein condensates of gravitationally dark Cooper pairs at the gravitational MB.

 Ca^{++} waves play a key role in cellular biology, Fe^{++} is essential for oxygen based metabolism, and Mg^{++} and Zn^{++} are important in bio-catalysis: for instance, ATP must bind to Mg ions in order to become active.

2. What could be the mechanism transforming valence electrons to dark electrons? This should happen for positively charged biologically important ions, in particular for the bosonic ions Ca^{++} , Mg^{++} , Fe^{++} and Zn^{++} . The consumption of metabolic energy would correspond to a de-ionization of dark ion Ca^{++} and this might make it possible to test the proposal. For instance, Ca^{++} could accompany ciliary waves.

Where could the energy for ionization come from?

- 1. This question is also encountered in the chemistry of electrolytes [L62]. It is very difficult to understand how the external electromagnetic potentials, which give rise to extremely weak electric fields in atomic scales, could lead to ionization. The acceleration of electrons in the electric field along dark flux tubes involves very small dissipation and can easily give rise to electron energies making ionization possible.
- 2. MTs have a longitudinal electric field which by the generalization of Maxwell's equations to many-sheeted space-time (in stationary situation potential difference is same for paths along different space-time sheets) gives rise to an electric field along the magnetic flux tubes. These flux tubes need not be gravitational.

By darkness, the dissipation rate is low. Could the acceleration along flux tubes, in particular MT flux tubes, lead to the ionization? Could the electret property of linear biomolecules

quite generally serve for the purpose of generating electronic metabolic energy storages in this way?

3. Assuming opposite charges $\pm Z_{MT}$ at the ends of dark magnetic flux tube associated with the MT, one obtains a rough estimate. The length of the cilium is $L \leq .5 \times 10^{-4}$ m and its radius is $R \sim 2 \times 10^{-7}$ m. The estimate for the energy gained by a unit charge e as it travels through the ciliary MT is $E \sim Z_{MT}e^2L/R^2 \simeq Z_{MT} \times 2.85$ eV. The valence electron energy for atomic number Z with principal quantum number n (giving the row of the Periodic Table) is $E \simeq (Z/n)^2 \times 13.6$ eV. The ionization condition would be $Z_{MT} \ge (Z^2/n^2) \times 13.6/2.85$. For the double ionization in the case of Ca^{++} with Z = 20 and n = 3 this would give $Z_{MT} \ge 212$.

TGD based view about axonal and cellular microtubules

Axonal MTs and also subset of MTs in the cell body are highly dynamical critical systems changing their length continually. It seems that they are essential motor instruments of MB just like the MTs of motor cilia. Could the microtubular structures in cell soma are also analogous to supporting structures which can be rapidly deformed by making them unstable against the change of length.

1. Instability of axonal MTs and nerve pulse conduction

In the TGD framework, axonal MTs could make nerve pulse conduction in the myelinated portions of axons possible. The localization of dark proton charges in the shortening flux tube would change the charge of the MT interior and in this way affect the local membrane potential and bring it to criticality. Time reversal and BSFR could be associated with the change of the growth of the MT length to decrease or vice versa. The lengthening and shortening processes would be the same but have different arrows of time. The propagation of the wave at which arrow of time for MT changes would correlate with the conduction of nerve pulse.

The dynamic instability of the axonal and some cellular MTs (https://cutt.ly/ADzx3re) is not well-understood. Power stroke causing the decay of the MT at its end is the basic notion. Whether chemical action precedes the mechanical one or vice versa is not clear. Therefore an obvious question is whether chemistry and mechanics are enough. The following represent a possible TGD based view about the power stroke.

- 1. Gravitationally dark proton transforms to ordinary proton of a phosphate hydrogen bond in the transformation of GTP to GDP. This liberates metabolic energy quantum, serving as a power stroke. This localizes one unit of proton charge and in this manner affects membrane potential.
- 2. Assume that MT is associated with a cylindrical membrane, that is 4-D minimal surface with 3-D M^4 projection having no counterpart in GRT. M^4 projection would have the microtubular cylinder as an E^3 projection. Cylinder is not a minimal surface and the cylindrical analog of the soap bubble requires a pressure difference over the cylinder walls.

In the TGD framework, CP_2 projection as a dynamical 1-D curve, say rotating geodesic line of CP_2 would give rise to the effective pressure difference [L174]. This analog of pressure difference would increase in the power stroke and locally expand the cylinder at the position of GDP. This would push tubulin protein outwards. These kinds of power strokes would force the MT to decay and shorten.

2. Energetics of the axonal transport

The transfer of material along the MT is the basic motor activity of MTs (https://cutt. ly/TDzOePw). The transfer of protein cargoes is a very slow process even on human time scales. Therefore these processes could involve electron (Cooper pair) based metabolism in an essential way. Note however that mitochondria are present also inside MTs.

If electronic metabolism is in question, these processes are predicted to be much slower than those induced by protonic metabolic currency since the work $F\Delta x$ done by the force corresponds to metabolic energy quantum and for Δx about tubulin size, F smaller by a factor m_e/m_p than in the case of protonic metabolic quantum.

Delayed luminescence for microtubules, quantum gravitation, and the mechanism of anesthesia

Jack Tuszynksi has reported very interesting findings in Science of Consciousness 2022 (https://cutt.ly/PF60cxA). The findings are described in a popular article (https://cutt.ly/tF60hWz).

A delayed luminescence in microtubules (MTs) irradiated by laser light has been observed. This can be seen as a support for the presence of quantum coherence at least in the scale of MTs. Also it was found that the application of anesthetics (such as noble gas Xenon expected to have very weak chemical effects) shortens the delay time. This suggests the reduction of quantum coherence by anesthetics so that quantum coherence in long scales should be crucial for consciousness. One of the challenges is to understand the reason for the reduction of quantum coherence.

Delayed luminescence has been associated with bio-photons a long time ago and DNA is proposed to serve as the seat of the delayed luminescence. In particular, the group involving also Tuszynski has studied the emission of mitochondrial biophotons and their effect on electrical activity of the membrane via MTs [J43] (https://cutt.ly/XF60qLA). A TGD based view of biophotons as decay products of dark photons is discussed in [K20, K31].

To my opinion, the findings represented by Tuszynski provide support for quantum consciousness but not specifically for Orch-OR, which still remains a rather poorly defined approach since the statement that Planck scale quantum gravity effects are crucial for consciousness has no concrete content.

The TGD based interpretation of findings of Tuszynski would be as follows.

1. The laser beam serves as a metabolic energy feed increasing the value of h_{eff} and therefore the scale of quantum coherence. One can say that this metabolic energy feed creates or wakes up an analog of a conscious living organism: now at the level of microtubule MB. As it "dies" in "big" state function reduction (BSFR) involving the reduction of h_{eff} to a smaller value, not necessarily the normal value $h_{eff} = h$, the loaded metabolic energy is liberated.

This would not apply only to MTs but quite generally. For instance, biophoton emission from cut leaves, would represent a similar decay process. Biophotons would be ordinary photons resulting as decay products of dark photon BE condensates and dark photons emitted with cyclotron Bose-Einstein condensates decay.

- 2. The delocalization mechanism associated with the formation of the gravitational variants of hydrogen- and valence bonds allows effective charge densities in short scales and could have dramatic implications for the model of nerve pulse. The nerve pulse need not correspond to a generation of ohmic currents through the membrane but to effective ionization or its reverse process due to the transformation of hydrogen and valence bonds to dark gravitational bonds.
- 3. MTs could play an important role since they involve GTPs as analogs of ATPs and are thus involved with metabolism. The conduction of nerve pulse in the sense of the Hodgkin-Huxley model through myelinated sections of axons is very difficult to understand. The new view would allow the shortening and lengthening of MTs to change the effective charge density of MTs so that membrane potential would change and nerve pulse conduction in the TGD sense would be possible.

How could one understand the effect of anesthetics? I have considered this problem earlier. First one should try to understand how the critical dynamics of MTs relates to nerve pulse conduction inside myelinated regions of the axon.

1. Certainly the membrane potential should become hyperpolarized to prevent nerve pulse condition so that consciousness would be lost. In myelinated portions of axons there is only propagating perturbation of membrane potential taking it below the threshold for nerve pulse generation so that nerve pulse is generated at unmyelinated portion. In the ground state one has propagating Sine-Gordon soliton (or oscillon sequence) visualizable as a sequence of rotating (oscillating) gravitational penduli.

In the perturbation some penduli start to rotate in an opposite direction (or oscillation transforms to a rotation). Usually this would require flow of charge through the cell membrane as Josephson current. Now the variation of the effective charge densities caused by the delocalization of protons inside the axon would induce an effective Josephson current. The effective charge inside the axonal interior becomes less negative and induces at non-myelinated portions of the axon a nerve pulse describable using the Hodgkin-Huxley model.

2. A couple of comments about the arrow of time are in order. Nerve pulse is induced by ~ 200 miniature potentials of amplitude about .4 meV which could be assigned to electron metabolic energy quantum. This corresponds to energy of .8 eV, roughly 2 protonic metabolic energy quanta. This supports an interpretation in terms of a time reversed process in which two metabolic energy quanta decay to ~ 200 miniature potentials. This conforms with the proposal that nerve pulse generation is BSFR inducing time reversal.

The reconnection transforming HB (VB) to its gravitational variant or vice versa during nerve pulse propagation induces the transfer of proton (electron) to HB. Since the size scale of the gravitational bond is that of Earth, this would take time and could be too slow for protons. The problem disappears if the reconnection corresponds to BSFR changing the arrow of time. The BSFR occurs and the final state is what becomes the causal agent just as in the explanation of Libet's findings about active aspects of consciousness.

3. If the anesthetic induces the transformation of gravitationally dark HBs (VBs) to ordinary ones in the interior of the axon, the effective charge of the axon becomes more (less) negative and the axonal potential becomes more (less) negative. MTs have GTPs near their ends and GDPs in the intermediate region. Negative charges of GTPs and GDPs would naturally correspond to gravitational HBs.

The variation of MT lengths involves a transformation of GTPs to GDPs and vice versa. This would change the effective charge density of the MTs and affect the membrane potential. If gravitational HBs become ordinary, metabolic energy is liberated and vice versa. Hyperpolarization would require a generation of reconnections and a local change of the MT lengths.

The variation of the lengths of axonal MTs would induce effective negative charge near the growing end of MT. Could the moving depolarization front of the axonal membrane correspond to an increasing GDP region of an axonal MT?

4. The presence of soliton (oscillon) suggests periodic effective charge density waves in which the protons transform to gravitationally dark protons and vice versa in a periodic manner. Could this mean a periodic variation of the lengths of axonal MTs?

Also the transformation of metallic valence bonds to their dark variants and vice versa could control the membrane potential. Ca⁺⁺ waves would result in cell interior when valence electron pairs of Ca atoms or their salts become gravitationally dark. Could periodic rotation (oscillation) accompany dark electron metabolism with a much smaller energy cost?

How the presence of noble gas having very weak chemical interactions could affect the nerve pulse conduction inside the axon? One can proceed by making questions.

1. Could the anesthetic freeze the dynamics of MTs so that nerve pulse conduction would become impossible? The presence of an anesthetic should make the axonal interior more negative and induce hyperpolarization.

Could the presence of the anesthetic stabilize the MTs by minimizing the length of their GDP region? Somehow the growth of MT should be prevented means addition of tubulins and GTPs. This is achieved if the density of tubulin-GTP pairs in axonal water is reduced. The generation of GTP from GDP requires a formation of gravitational HBs from ordinary HBs. The density of ordinary HBs should be reduced.

2. Could the presence of the anesthetic reduce the density of ordinary HBs in the axonal water? HBs are associated with water clusters. How could the presence of anesthetic reduce the rate for the generation of water clusters and therefore HBs in the axonal water?

In the TGD inspired theory consciousness, the MBs of water clusters can be seen as correlates for mental images of water as a conscious entity [K62] [L194]. The level of consciousness for water would be reduced. It would be water, which is anesthetized! This would freeze the MTs so that also the axonal membrane freezes electrically.

- 3. Meyer and Overton observed that the potency of anaesthetic agents correlates with their lipid solubility. Anesthetics also seem to affect specific ion channels and receptors. One can argue that if the anesthetic is solvable to lipids, it can also enter inside the axon and somehow reduce the density of HBs assignable to the water molecule clusters accompanied by gravitational MBs. The effective charge of the axonal interior would become more negative and induce a hyperpolarization if the exterior is not affected.
- 4. How happens when water is anesthetized? A hint comes from the Pollack effect [L20]. The exclusion zones discovered by Pollack are negatively charged regions at the interfaces of hydrophilic surfaces. The TGD based interpretation could be that part of protons become dark protons at gravitational HBs. It is known that anesthetics diminish the amount of EZ water (https://pubmed.ncbi.nlm.nih.gov/27054588/).
- 5. How could anesthetics prevent the formation of EZs and thus of gravitational HBs? A metabolic energy feed is needed in the Pollack effect and is by photons as also the delayed luminescence for MTs demonstrates. How could the feed of photons needed to produce EZs be prevented by anesthetics? Energy is feeded in resonance. Could the presence of anesthetic change the energy needed to transform HB to dark gravitational HB so that the resonance condition would not be satisfied.

12.4 How multicellular without a nervous system can behave as if it had a nervous system?

In the TGD framework, the quantum models of cell membrane and nerve pulse rely on the notions of magnetic body and dark matter [K45, K92, K93, L149]. The generalization of this view leads to a notion, which could be christened as pre-neural system (PNS). Also the multi-cellulars without CNS would possess PNS.

12.4.1 Animals without the brain behave as if they had the brain

The motivations for this article came from the Quantum Magazine article (https://cutt.ly/ IDnfovQ) telling about the findings of Manu Prakash and Mathew Storm Bull. The work of Prakash and Bull is published as 3 articles [?]hat can be found in arXiv.org. In the following I summarize the findings as they are described in the popular article.

Findings of Prakash et al

Trichoplax adhaerens is a marine creature, classified as a placozoan, which has the smallest known genome in the animal kingdom. Trichoplax has thousands to few millions of cells and is between prokaryotes and eukaryotes as far complexity is considered.

Trichoplax (https://cutt.ly/SD6GGW5) is a very flat organism formed with diameter about 1 mm and thickness about 25 μ m. For cell number N in the range [10³, 10⁶] cells and for a cell approximated as a ball with radius r, this gives r in the range [2.1, 21] μ m. Despite the lack of neuronal system and muscles, the motion of trichoplax is extremely well-orchestrated and efficient.

The goal of the project of Manu Prakash and his graduate student Matthew Storm Bull was to understand how the neuromuscular system might have evolved and how the early multicellular creatures without a nervous system managed to move, find food and reproduce. Epithelial sheets formed by Trichoplax cells are studied. Trichoplax cells are monociliated that is they have only a single cilium. This simplifies the experimental study and modelling of Trichoplax.

First some basic facts.

1. Motile cilia and flagella are the analogs of muscles and primary (non-motile) ciliar serve the role of sensory organs at the cellular level. Cilia and flagella have similar structures and only their functions differ. Cilia force liquid to move with respect to the cell. Flagella make it possible for the cell to move with respect to liquid (https://cutt.ly/TDngqh0).

- 2. The force needed for the bending of the cilium is produced by the outer and inner dynein arms of the axonemal MT doublets connected to the central pair of microtubules by radial spokes. Airway cilia have components typical for motile cilia.
- 3. Beating waves as contraction waves of the axoneme induce bending of the cilium. The frequency of the beating wave is the key parameter in the dynamics of the cilium.

That the beating frequencies are in the EEG range suggests that in some respects neurons and ordinary cells have much more in common than thought. Beating frequency would take care of synchrony and one can ask whether cilia have an analog of EEG.

Popular summary of the experimental findings

I add to the summary my own comments in order to give a hint about TGD based interpretation of the findings.

1. The claim is that behavior of Trichoplax can be described entirely using the language of physics and dynamical systems.

Comment: To my understanding, a description in this sense means mathematical modelling using formalism of physics and identifying simple basic mechanical functions serving a role analogous to program modules of the software.

The nature of the living systems is very difficult to understand using only recent day physics and it is very difficult to believe that purely mechanistic description could be possible. However, the possibility to construct such a simple model is in itself a strong guideline in attempts to really understand how the motor actions of Trichoplax are possible.

2. Cilia are typically seen in the context of fluids: propelling bacteria or other organisms through water, or moving mucus or cerebrospinal fluids in a body. Therefore the expectation was that the cilia to glide over surfaces, with a thin layer of fluid separating animal and substrate. But when the researchers looked through their microscopes, they saw that the cilia seemed to walk, not swim.

The claim is that instead of hydrodynamic description, it is possible to have much simpler description in terms mechanics involving notions like friction and adhesion.

Comment: I understand that these conclusions hold true for the motion along the surface and one can wonder whether the conclusions hold true for swimming.

3. The characterization of the cilia's walking gait was taken as a goal. Only three types of basic motions: slipping, during which the cilia barely grazed the surface; walking, when the cilia adhered to the surface briefly before popping off; and stalling, when the cilia got stuck against the surface.

Comment: What is really surprising is that the motion consists of such simple basic modules somewhat like a computer program. For instance, in a general Hamiltonian system one expects Hamiltonian chaos. Bohr orbits are what comes into the quantum mind.

Mechanical models for the walking activity were developed by the authors [I152, I150, I151].

1. In the models the walking activity emerged naturally from the interplay between the internal driving forces of the cilia and the effective energy of their adhesion to the surface. The right balance between those two parameters (calculated from experimental measurements of the cilia's orientation, height from the surface and beat frequency in the EEG ranfe in the situation considered) resulted in regular locomotion, with each cilium sticking and then lifting away, like a leg. The wrong balance produced the slipping or stalled phases.

Comment: My understanding is that the driving force of the cilium serves as an input analogous to external force and chosen so that a model for a particular motion is obtained. The model is therefore not fully deterministic and autonomous. On the other hand, the reduction of hydrodynamical description to mechanical description is highly non-trivial and suggests that some new physics is involved.

2. The walking cilium can be modeled as an excitable system. In an excitable system, the signals spread and get amplified rather than progressively damping out and coming to a stop. A neuron is a classic example of an excitable system. Small voltage perturbations can cause it to fire suddenly, and above some threshold, the new stimulated state propagates to the rest of the system.

The same phenomenon seems to occur in the cilia. In the experiments and simulations, small perturbations in the height of cilium from the surface, rather than voltage, led to relatively large changes in the activity of nearby cilia. They could suddenly change their orientation, and even switch from a stalled state to a walking one.

Comment: Excitability, and self-organization in general, is in conflict with the expectations based on second law of thermodynamics. The metabolic energy feed is the way to understand the situation in non-equilibrium thermodynamics.

This behavior requires an highly non-linear mechanical system at criticality. This does not however explain why so few modes, in fact analogous to Bohr orbits, are possible. A quantum biologist could ask whether quantum criticality is involved. At classical level catastrophic theoretic description in terms of phase transitions is suggestive.

The similarities with neuronal behaviors inspire the question whether the ciliary system defines some kind of pre-neuronal system preceding the nervous system in evolution and shared by it as the fact that sensory receptors are cells with cilia.

3. It was measured how the mechanical gait of each cilium led to small, local fluctuations in the height h of the tissue. Equations for how this would 'tug' at nearby cells to affect their behavior were deduced, even as the cilia on those cells cycled through movements of their own. A convenient analogy is a network of springs tied together by tiny oscillating motors.

When the researchers modeled this dance between elasticity and activity, as they called it, they found that the mechanical interactions of cilia pushing against a substrate and cells tugging at each other transmitted information rapidly across the organism.

Stimulating one region led to waves of synchronized cilia orientation that moved through the tissue. This elasticity and strain in the physics of a walking cilium, now multiplied by millions of them in a sheet, gives rise to coherent motile behavior.

Comment: Here it is difficult to avoid the question whether the 'tug' as touching of cells (or cilia of different cells) is analogous to synaptic transmission in the neural system.

4. The synchronized orientation patterns could be complex. Sometimes the activity of the system produced vortices, with the cilia oriented around a single point. In other cases, the cilia reoriented in fractions of a second, first pointing one way and then another flocking as a group of starlings or a school of fish might, and resulting in an agility that made it possible for the animal to sometimes change direction on a dime.

Comment: Courageous quantum biologists might associate with the agility a quantum jump in multi-cellular scale.

5. It was found that the information transmission was selective. After certain stimuli, the energy injected into the system by the cilia just dissipated instead of spreading and changing the organism's behavior. As if the organism would direct its attention to particular parts of the perceptive field and react only to the changes in these parts.

Comment: Brain is able to direct its attention to particular objects of the perceptive field. Is the ciliary system able to direct its attention?

The model for the cilium and ciliary motor actions

The model starts from the model of nerve pulse and generalizes it to the case of cilium.

Concerning the understanding of the findings about the motor actions of multi-cellulars without a nervous system, this vision raises obvious questions.

- 1. MB should serve as the "boss" also for the multi-cellulars without a nervous system. The general quantal sensory communication and control mechanism should be the same as for organisms with a nervous system. Frequency modulated dark Josephson radiation should mediate sensory data to MB and dark cyclotron radiation would mediate the control commands from MB as pulse patterns as a response to sensory input.
- 2. Could the beating wave, which has frequency in EEG range, be analogous to EEG wave, membrane oscillation, and possibly perturbed oscillon/soliton sequence, which defines the ground state of ciliary membrane?
- 3. Cilia are analogous to axons. Could ciliary membrane act as a Josephson junction communicating sensory data to MB? The MTs of the motile cilia play a role analogous to that of axonal MTs as motor organs of MB. Could one consider analogs of nerve pulses for cilia inducing ciliary motor actions rather than nerve pulse patterns? No nerve pulse is involved. Could the analogs of nerve pulses be pre-nerve pulses analogous to miniature potentials of .4 meV generated in synaptic contacts for instance by acetylcholine containing vesicles (hhttps://cutt.ly/JD10NEu) and induce beating waves inducing ciliary bending? 100-200 hundred miniature potentials are needed to generate a nerve pulse.
- 4. Here the poorly understood origin of the ATP needed by ciliary motor activities [I185] serves as a guideline. Cilia and flagella cannot have mitochondria as ATP sources inside them and the diffusion of ATP from nearby mitochondria is strongly limited. The proposal discussed in [I185] is that a local generation of ATP using mechanisms, which depend on nutrients could solve the problem. It is difficult to avoid the feeling that something strange is involved with the ciliary metabolism.

TGD leads to the proposal that the standard metabolic energy quantum of about .5 eV corresponds to the change of gravitational binding energy as a proton of HB is transferred to a dark proton at at the gravitational flux tube around its Bohr orbit in the gravitational field of Earth with gravitational Planck constant $h_{eff} = h_{gr} = GMm/v_0$. Dark electrons would correspond to gravitational binding energy for a valence electron or a pair of valence electrons (Cooper pair) transferred to a gravitational flux tube.

The energy of the single electron metabolic energy quantum would be by a factor $m_e/m_p \sim 2^{-11}$ smaller than the standard metabolic quantum about .25 meV and relate to the standard metabolic energy quantum like cent to dollar. For an electron Cooper pair it would be 2 times larger and about .5 meV. Intriguingly, this energy is rather near to the Coulomb energy change assignable to the miniature potentials .4 meV (https://cutt.ly/vDRysfU)! Could the analog of nerve pulse be a propagating miniature potential induced by the dropping of an electron Cooper pair of say Ca⁺⁺ ion from the gravitational Bohr orbit back to Rydberg state with very small binding energy.

- 5. Cilium is modelled as a 2-D quantum gravitational pendulum with gravitational Planck constant controlled by MB using electronic metabolic energy quanta and the resulting model for the motion is in many respects similar to the model of nerve pulse. In the resting state ciliary penduli oscillate or rotate with constant phase difference so that a wave-like motion results.
- 6. The analog of nerve pulse transmission can be identified. Temporary fusion of pre- and postsynaptic cells takes place in nerve pulse transmission. The tugs would correspond to the adhesion of their cilia and make possible the transfer of quantum coherence and synchrony between the neighboring cells and in this way generate quantum coherence in multi-cell scale? The adhesion of cilium to the plane in which it moves is also possible.

Both kinds of adhesions spoil the synchronous oscillation of neighboring penduli. The adhesion followed by de-adhesion changes the relative phase and a further 'tug' is plausible. This leads a domino effect to an analog of nerve pulse conduction. In this process, the U-shaped flux tubes assignable to the cilia of the neighboring cells fuse to form a larger quantum coherent unit. Same would happen in the case of ordinary nerve pulse transmission [L149]. The system is quantum critical in the sense that when the cilia oscillate/rotate with a phase difference below some critical value, no touchings occur and no nerve pulses are generated. Perturbations change the situation.

12.4.2 Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal

It is useful to start with a more technical summary of the work of Prakash *et al* provided by the abstract of the article "*Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal*" [I152] by Mathew Bull, Vivek Prakash, and Manu Prakas as such.

Effective organismal behavior responds appropriately to changes in the surrounding environment. Attaining this delicate balance of sensitivity and stability is a hallmark of the animal kingdom. By studying the locomotory behavior of a simple animal (Trichoplax adhaerens) without muscles or neurons, here, we demonstrate how monociliated epithelial cells work collectively to give rise to an agile non-neuromuscular organism.

Via direct visualization of large ciliary arrays, we report the discovery of subsecond ciliary reorientations under a rotational torque that is mediated by connective tissue mechanics and the adhesion of cilia to the underlying substrate. In a toy model, we show a mapping of this system onto an "active-elastic resonator". This framework explains how perturbations propagate information in this array as linear speed traveling waves in response to mechanical stimulus.

Next, we explore the implications of parametric driving in this active-elastic resonator and show that such driving can excite mechanical 'spikes'. These 'spikes' in collective mode amplitudes are consistent with a system driven by parametric amplification and a saturating nonlinearity.

We conduct extensive numerical experiments to corroborate these findings within a polarized active-elastic sheet. These results indicate that periodic and stochastic forcing are valuable for increasing the sensitivity of collective ciliary flocking. We support these theoretical predictions via direct experimental observation of linear speed traveling waves which arise from the hybridization of spin and overdamped density waves. We map how these ciliary flocking dynamics result in agile motility via coupling between an amplified resonator and a tuning (Goldstone-like) mode of the system. This sets the stage for how activity and elasticity can self-organize into behavior which benefits the organism as a whole.

12.4.3 The analog of the nervous system at the level of multi-ciliary system

The TGD based model for nerve pulse and EEG generalizes in a rather straightforward manner to cilia.

- 1. Ciliary membranes define pre-neural system. The membranes act as generalized Josephson junctions. The modulations of the oscillation frequency of dark Josephson radiation code for the sensory input to MB. Beating waves have frequencies in EEG range and define the analogs of EEG waves as propagating oscillation patterns of the membrane potential.
- 2. The first guess is that non-motile cilia serve as sensory receptors mediating sensory input to MB as dark Josephson radiation and motile cilia as motor instruments of MB and analogs of muscle. Trichoplax has only a single cilium, which acts as a motor organ. Does it also act as a sensory receptor, or does the remaining cell membrane serve in this role?
- 3. Pre-nerve pulses at the level of animal would correspond to perturbations of the soliton sequences or their oscillatory variants: either one rotating/oscillating pendulum starts to oscillate/rotate. This transition would be induced by the response of MB and cyclotron resonance pulse. Nerve pulse/action potential would be replaced by propagating miniature potential.
- 4. The ciliary counterparts of action potentials would be analogs of miniature potentials and induced by the electronic metabolic energy quantum. They would represent the response of

MB at cilia, propagate to the basal body and proceed as chemical communications to the cell nucleus using second messangers and induce gene expression as a response.

- 5. The ciliary MBs of cells organize to a larger MB controlling the motion of cell and the MBs of cells in turn organize to even larger MB controlling the collective motion.
- 6. Synaptic transmission would be replaced with 'tug, that is the touch of neighboring cells, making possible the transfer of the beating waves between the cells. If the touch reduces to the touch of the cilia, the connection with the model of nerve pulse transmission would be even closer. Note however that there is only one flagellum per Trichoplax cell. The orbits of straight ciliar define cones, which correspond to 2-D space-times in 4-D space-time.

The intersection of these surfaces consist of discrete points in the generic case. If the neighboring cilia rotate with the same frequency and are in the same phase so that the minimal distance between ciliar remains constant, they cannot touch. Above some critical phase difference touching can take place and the touching can occur and the neighboring cilia drop from the phase synchrony.

7. The quantum coherence extended in the fusion of the ciliary MBs generated in the touching of cells or individual cilia. Does also the transfer of local bioharmony take place in the touch. Are the analogs of transmitters involved and affect the bioharmony of the MB of the receiving cell just like nerve transmitters are proposed to do?

12.4.4 TGD based intepretation of the findings of Prakash *et al*

The findings described in the articles [I152, I150, I151] have made it possible to develop a TGD based picture about the situation.

Homeostasis in the TGD Universe

In biology the balance between sensitivity and stability modelled by Prakash *et al* is known as homeostasis. In biological view, homeostasis is based on a complex many-layered control hierarchies analogous to those used in computation as if a master programmer had written these programs. But can these kinds of control hierarchies really emerge in standard physics?

The proposal of the model of Prakash *et al* is that the 'active-elastic' resonator as a relatively simple mechanical system can at least mimic homeostasis. The model for the epithelial sheet of the animal as a set of oscillators representing cilia coupled by strings. The direction of the cilium defines an effective spin. A resonant coupling of this spin to an external torque represents the control of the motion and parametric resonance allows energy cascades creating collective responses.

In the TGD framework, homeostasis emerges spontaneously via the second law of thermodynamics in reverse time direction.

- 1. In zero energy ontology (ZEO), biological self-organization and homeostasis involve in an essential manner the possibility of time reversal occurring in "big" (ordinary) state function reduction (BSFR) occurring in long length scales. Time reversal changes repellers to attractors so that homeostasis as an ability of the system to stay near the critical point becomes possible by performing BSFRs.
- 2. Dissipation of energy is a process in which the coherence scales of excitation decreases. Time reversed periods mean dissipation with a reversed arrow of time and in the model of Prakash *et al* they would correspond to energy cascades proceeding from short to long length scales.

Parametric amplification and a saturating nonlinearity can be seen as the mathematical model for the BSFR inducing time reversal.

1. 'Spikes' mean amplification and in ZEO they could correspond to BSFR changing the arrow of time at the level of MB so that the amplification process would reduce to dissipation with a reversed arrow of time.
2. I have proposed that the interpretation of nerve pulse as a pair of BSFRs temporarily changing the sign of resting potential. An analogous interpretation could make sense now.

Cilium as a quantum gravitational pendulum

The findings of Prakash *et al* makes it possible to consider a concrete TGD inspired model for a single cilium and its dynamics.

- 1. The observed sub-second time scale for the ciliary reorientations conforms with the interpretation of beating waves are analogs of EEG waves transformed to mechanical waves as longitudinal contraction waves of cilium causing the bending. These waves would be induced by the membrane potential waves of ciliary membrane and in TGD corresponds to waves associated with the Josephson junction defined by the membrane communicating data to the MB of the system characterized by $h_{eff} = h_{gr} = GMm/v_0$.
- 2. In the first approximation, one can idealize the cilium/flagellum as a rigid linear object of radius $r = .2 \ \mu m$, length $l = 100 \ \mu m$, and with a density not far from the density of water of $10^3 \ \text{kg/m}^3$. The presence of gravitational Planck constant suggests that one can model cilium as a gravitational pendulum with a mass independent oscillation period $T = 2\pi \sqrt{l/g}$, which corresponds to a sub-second time scale $T \simeq .2$ s for $l = 100 \ \mu m$.

The values of l vary in a wide range. For $l = 20 \ \mu \text{m}$ mentioned as an upper bound for the length of flagellum, one has $T \sim .1$ corresponding to 10 Hz EEG resonance frequency. The range $l = 2 - 4 \ \mu \text{m}$ was mentioned in [I49] as a lower bound for the length of beating cilium, corresponds to 25-36 Hz frequency range. In the same source, 10-12 μm was reported as normal cilium length: it corresponds to pendulum frequency 15.8 Hz. Furthermore, the beating frequency was reported to depend only weakly on l so that the beating frequency and pendulum frequency cannot be identified.

The estimates for the period of the cilium as gravitational pendulum correspond to EEG frequencies as also in the frequency range of beating waves. For $h_{eff} = \hbar_{gr} = GMm/v_0$ and m equal to proton mass, the corresponding transition energies are in the eV scale of biophotons for protons. What puts the bells ringing is that for electrons the energy scale is the same as that of the electronic metabolic energy quantum.

3. As a 2-D gravitational pendulum cilium can also rotate. Angular momentum is quantized as units $h_{eff} = h_{gr}$. Electronic metabolic energy quanta can induce transitions between the harmonic oscillator states of the cilium. The transitions between the states of the quantum gravitational pendulum changing angular momentum would serve as the quantum counterpart for the torque in the models of Prakash *et al.* They would represent the quantum control by MB by using the transformation of gravitationally dark electrons to ordinary electrons.

Correlation between the height of the tissue and membrane potential of cilium

The height h of the tissue is interpreted as a parameter analogous to membrane potential.

- 1. TGD suggests that the membrane potential of cilium is proportional to the h. The critical height h_{cr} would correspond to a critical value V_{cr} of the ciliary membrane potential for the generation of miniature potential reducing V_{cr} .
- 2. Cilium as a gravitational pendulum is free when its distance from the surface is larger than the pendulum length l so that $h_{cr} = l$ is a natural identification. When the adhesion occurs MB induces a burst of miniature potentials $\Delta V = .5$ meV feeding electronic metabolic energy quanta to the cilium to achieve de-adhesion.

What happens in the adhesion and de-adhesion?

The key step of the process is the adhesion of cilia to the substrate and its reversal. The probability for the adhesion depends on the tissue height h and obviously vanishes for h > l, l the length of cilium. For very small h the cilium sticks on the surface. Part of the cilium would stick to the surface horizontally. Effective adhesion energy is assumed to be in a crucial role. The control action of the cell (animal) is modelled as an external torque on cilium.

Adhesion can also mean that two neighboring cilia moving in opposite direction stick together.

1. In the TGD framework, the de-adhesion could be induced by a transformation of a suitable number of electronic metabolic energy quanta about $E_c = .25$ meV associated with single electron (cilia do not have mitochondria) to the kinetic energy of the cilium as a gravitational pendulum.

One can estimate the velocity v if the de-adhesion induced by a receival of single metabolic energy quantum E_c from $mv^2/2 = E_c$. This gives $v \simeq 60 \ \mu$ m/s. The estimate looks rather reasonable. For the standard metabolic energy quantum .5 eV, one would be $v \simeq 2.7$ mm/s.

2. If momentum is conserved, the change of the horizontal momentum component for the cilia as a pendulum is compensated by the recoil momentum of the entire cell. This gives an estimate for the change ΔV of the velocity of the cell as $\Delta V \sim (m_c/M) \times v$.

Adhesion energy and de-adhesion as precedessor of nerve pulse generation

What the notion of effective adhesion energy could mean in the TGD Universe (note that adhesion energy as a term is misleading since it actually corresponds to adhesion energy per surface area).

- 1. A very naive order of magnitude estimate used in the modelling of wetting of a surface by water approximates adhesion energy density with the surface tension σ_W for water: $\sigma_w \simeq 7210^{-3}kg/s^2$. This corresponds to an energy density per unit area $\epsilon = .5 \times 10^{-11} \text{ eV}/(\mu \text{ m})^2$. For the cilium with radius $r = .2 \mu$ m attached vertically this would give $W = sigma_W \pi r^2 \simeq .7 \times 10^{-12} \text{ eV}$. This is extremely small energy and looks unrealistic.
- 2. For instance, if chemical or other kinds of bonds are formed with the surface, the adhesion energy can be even in the eV range. TGD suggests the formation of flux tube bonds between cilia and surface is what comes into mind and the adhesion energy would correspond to the reduction of energy when the bond is formed and shortens by the reduction of h_{eff} as in the basic step of bio-catalysis.
- 3. The thermal stability of adhesion would suggest that the adhesion energy is of the order of thermal energy, which is of the order .05 eV, which is about 10 percent of the standard metabolic energy quantum. If this is the case, the size of .5 meV for the metabolic energy quantum of electron Cooper pairs implies that at least 100 dark gravitational electrons must transform to ordinary ones to liberate the cilium, which has stuck vertically. Recall that cilia can also stick to each other and the same estimate holds also now as a lower bound coming from the thermal stability of adhesion.
- 4. Intriguingly, the number of miniature potentials generated by acetylcholine vesicles needed to generate action potential is 100-200 (hhttps://cutt.ly/JD10NEu)! This suggests that the de-adhesion process is a precedessor for the generation of nerve pulse in the postsynaptic neuron. This conforms with the view that the ciliary membrane is a precedessor of axon.
- 5. Nerve pulse transmission connects the pre- and postsynaptic flux tubes to longer flux tubes and generates larger quantum coherent units. 100-200 miniature potentials generate an action potential after the connection has formed. What could be the counterpart of this at the level of cilia?

Intriguingly, the de-adhesion from the surface requires at least 100 miniature potentials in the model of cilium as a gravitational pendulum. Also the cilia of the neighboring cells can stick together if they move in opposite directions. De-adhesion would require roughly the same energy. Both mechanisms would generate the analog of nerve pulse.

Could the preneural system have transformed to a neural system by the evolution of single flagellum to axon? Could primary cilia have evolved to dendrites? Did flagella having even rather long lengths start to form permanent almost-contacts with the primary cilia of the neighboring cell or even more distant cells, which then developed to synaptic contacts. This would have required the evolution of cilia with radius below .5 μ to axon with radius about 2.5 μ m, and containing axonal MTs instead of axonemal MTs. ATP based metabolism in the interior would have emerged besides electron based metabolism, and besides miniature potentials also action potentials and critical membrane potential would have emerged.

Do 'spikes' correspond to real spikes?

Spikes induced by a driving of an 'active-elastic' resonator define a key notion in the models of Prakash *et al.* The intuitive picture of the resonator is as a collection of cilia as motors connected by strings. The 'spikes' would be analogs of nerve pulses. 'Spikes' correspond to tugs inducing flocking and in neuroscience induce formation of larger coherent units of neurons.

In the TGD based model for nerve pulse, spike corresponds to a perturbation coming from MB and transforming the motion of a single pendulum from rotation to oscillation or vice versa. Same should be true now if the cilium is the precedessor of the axon.

- 1. The active-elastic resonator could correspond to cilia as quantum gravitational penduli and the temporary formation of flux tube connections between the MBs of the penduli could be a counterpart for the formation of strings.
- 2. A direct touch of cells is not necessary for a 'tug'. The touching of neighboring cilia might be enough and could be regarded as one particular case of adhesion and would be analogous to touch of pre- and postsynaptic cells mediated by the neurotransmitter vesicle. Since the distances between cells are measured in micrometers and if the ciliar lengths are about 100 μ , this is possible.

In the TGD framework, one can consider the option that cilia do not even touch. Since quantum coherence is at the level of MBs, and what is needed in the TGD framework, is a reconnection of the U-shaped flux tubes associated with the cells: this is assumed to take place also in the synaptic contact in which neurons fused temporarily.

- 3. The probability for the reconnection of flux tubes (for the touching of cilia) increases as the cells approach each other and could lead to a fusion of several cellular MBs to a larger MB inducing a flock behavior controlled by the larger MB. This would take place when two neighboring ciliary gravitational penduli are in opposite phase with large enough amplitude so that they approach each other.
- 4. The propagation of nerve pulse would be a domino effect in which the adhesion of neighboring cells or adhesion of cell to surface followed by de-adhesion, which spoils synchronous motion locally and inducies new adhesion. A multiple collision generating quantum coherent at the flux tube level would be in question.
- 5. In the collective mode the metabolic quanta E_c from cells would arrive in synchrony (but with time lapse to give rise to a wave) so that the cells would walk in synchrony. The rotation of the cilia as gravitational penduli with a constant phase difference gives rise to a wave. In this macroscopic gravitational quantum state Trichoplax would walk. Walking involves gravitation in an essential manner so that the appearance of quantum gravitation is not surprising.

The generation of propagating waves

The model for the generation of propagating waves is very much analogous to the model of axonal membrane as Josephson junction [K92, K45, K93] [L149, L155]. The oscillating waves for the phase differences of the Cooper pair wave function over Josephson junction define a dynamics analogous to that to a sequence of gravitational penduli. This model could apply as such at the level of ciliary membrane serving as a pre-axon.

The local motion could correspond to oscillation or rotation and the analog of nerve pulse would mean local transformation of oscillation to rotation or vice versa generating soliton or defect of soliton sequence locally. Also waves that propagate at the level of the entire animal are involved and can be associated with a system of genuine gravitational penduli forming a planar structure. There would also be a propagating wave at the larger MB induced by the temporary fusion of MBs of cilia.

1. The local oscillation of the cilium takes place with the frequency $f = \sqrt{g/l/2\pi}$ of the gravitational pendulum. For the propagating wave $u = \omega t$ is replaced with $\omega(t - x/V)$. The rotation of the pendulum in a vertical rotation plane does not make sense but there are also modes in which the pendulum rotates in plane and have angular momentum which is large since one has $h_{eff} = h_{gr}$ serves as the unit of angular momentum. These modes would be crucial for the control of the motion.

The speed V of the wave would be analogous to a conduction velocity of nerve pulse. The first guess for the velocity would be as the velocity $V \sim (m_c/M) \times v$, where v is the horizontal velocity gained by the cilium de-attachment already estimated, and m_c and M are the masses of cilium and cell.

2. If one or more metabolic energy quanta E_c feed energy to a single pendulum, the pendulum ceases to be in phase with its neighbors. If the same takes place for MBs, they might reconnect. Could a phase transition initiated by a seed at the level of MBs generate a larger quantum coherent unit analogous to a moving vortex? Energy cascade would correspond to BSFR with time reversal.

Flocking as a generation of quantum gravitational coherence

What could the formation of collective modes, flocking, mean in the TGD framework?

- 1. The modes of a single cilium correspond to a sticking to the plane without motion, rotation around a roughly elliptical orbit in plane, and rotation without motion. If a single cilium behaves as a solid body, one has a vortex- like structure rotating like a rigid body. Note however that Trichoplax can be very far from a rigid body: it can even split into two parts.
- 2. The quantal description of the cilia as a quantum gravitational pendulum combined with the conservation of angular momentum suggests that the angular momentum for the center of mass motion of the Trichoplax and the total angular momentum of the ciliary oscillators sum up to zero. This would explain the nearly circular motions. Linear motion of Trichoplax would correspond to a common vertical rotation plane without rotation.

In fact, both momentum and angular momentum generation could rely on conservation laws and reduce to exchanges of these conserved quantities between MB and system. This seems to be the only option since metabolic energy quanta with $h_{eff} = h$ cannot create forces and torques in the scale of an organism.

It deserves to be mentioned that the generation of angular momentum of astrophysical objects such as galaxies is poorly understood in the general relativistic framework and the TGD proposal is that the angular momentum of visible matter is accompanied by opposite angular momentum of dark matter and magnetic bodies of astrophysical objects [L105].

- 3. This model would realize the fractal aspect of holography: the ciliary motion would correspond to the motion of the entire animal. Second aspect of holography is that 3-D data fix the time evolution in the sense that the orbits are analogous to Bohr orbits. In TGD, this is forced by the realization of the general coordinate invariance, and means that the 3-D surface of $H = M^4 \times CP_2$ is almost uniquely determined by a 3-D surface without any data about its 4-D tangent space. Also this aspect of holography is realized and could explain why such an extremely simple model can describe the motion of Trichoplax.
- 4. Moving vortex-like defects could correspond to the formation of quantum coherent states in which cilia as gravitational penduli are in the same quantum state with non-vanishing angular momentum and non-trivial center-of-mass motion. There is also an analogy with the decomposition of the rotational motion to vortices in super-fluidity.

How could a living system direct its attention?

Prakash *et al* [I152, I150, I151] also found that Trichoplax can also react in a selective manner to perturbations as if it could direct its attention.

According to the TGD inspired theory of consciousness, a metabolic energy feed to the target of attention serves as a correlate for the directed attention. The target corresponds to a mental image of the MB of the system. Mental images have correlates at the level of the space-time surfaces. Space-time surfaces are minimal surfaces with singularities analogous to soap films with frames [L174]. At the frames the dynamics fail to be completely deterministic so that they naturally serve as space-time correlates of mental images. The non-determinism is also finite.

This mental image 'wakes up' in a BSFR separating it from the environment and the superposition of 4-D soap films is reduced so that a single alternative from a finite number of time evolutions is selected. This explains the mysterious looking discovery that during intensive discussion almost anything can happen in the background and remain unnoticed. Sensory input does not lead to a wake up of mental image. The behaviour of the Trichoplax is completely analogous to the behaviour of higher life forms.

12.4.5 Possible implications of the notion of pre-CNS

The notion of pre-CNS is very general and it is interesting to consider the most obvious implications.

Can organisms without CNS learn?

In [I129] the question whether learning without the nervous system is impossible is considered. Computers are left out of consideration and this restricts the discussion to organic matter. One can consider several definitions for learning. If the change in behaviour is taken as a signature of learning, one ends up to the conclusion that there are large classes of organisms without nervous systems, which are able to learn: paramecia, bacteria and plants are three large classes of this kind of organisms.

There is evidence that multi-cellulars have evolved from the colonies of mono-cellulars, and it is known that colonies of bacteria learn [I138] (https://cutt.ly/zD0vhuN). For instance, E. Choli colonies can anticipate changes in the environment by associating higher temperatures with a lack of oxygen. This is the basic type of learning in neural systems and interpreted in terms of changes of synaptic strengths.

Animals with ciliary systems have pre-CNS in the proposed sense, and could learn by essentially the same mechanisms as neuronal networks. Associative learning involves a strengthening of synaptic contacts increasing the probability for the formation of transmitter vesicles. Now this would mean the increase of the probability for the formation of a 'tug' contact and this would lead to the analogs of sub-neural networks.

The model of genetic code based on bioharmony [L16, L136, L159, L196] leads to the proposal that the basic mechanism of learning emerge already at the level of basic biomolecules DNA, RNA, tRNA, and amino acids (AA). Bioharmonies define different moods and the learning by conditioning involves in an essential manner moods affected by the stimulus already at the molecular level. The basic moods would be realized already at the level of basic biomolecules X=DNA, RNA, tRNA, AAs, or rather, the pairings DX-X where DX is the dark analog of X identified as dark nucleon sequence [L196]. Epigenetic mechanisms could stabilize the bioharmonies as correlates for the moods.

There is experimental evidence for this kind of learning (https://cutt.ly/6SuLNqk). When the RNA of an animal, which has learned a conditioned behavior, is scattered on the neurons of the animal that has not learned the behavior, the neurons so the signatures of learned behavior. Somehow the RNA transmits the conditioning based on negative or positive emotions generated by the stimulus. The explanation terms of DRNA-RNA pairing carrying the mood infecting the neurons with the conditioned behavior is discussed in the TGD framework in [L86, L107].

Also plants have senses and motor actions

Also plants have senses (https://cutt.ly/mDOA9Zo) and motor actions (for instance, sun flower orients itself towards Sun) and can learn (https://cutt.ly/sDOPUZo).

Can the proposed general model for pre-CNS explain these findings?

1. Microtubules are essential for cilia and axons. In general, plant cells do not have centriole or flagella: the motile, freely swimming sperm cells of some plants are an exception.

Plants however have root hair (https://cutt.ly/JDOA7rc) consisting of epidermal cells having lateral tubular extensions resembling cilia. Their radius varies between 17-17 μ m and the length varies between 80-1,500 μ m so that their scale is roughly 100 times larger than that of cilia. The basic function of root-hair cells is to collect water and nutrients from the soil.

2. The MBs of root-hair cells controlling them must be able to receive sensory input from roothair cells and control their activities. Essentially the same general model seems to work as in the case of axons and cilia.

The membranes of root-hair cells could serve as sensory receptors using Josephson radiation to communicate the sensory input to MB. Root hair cells do not contain chloroplasts nor do they perform photosynthesis, which suggests that also now the electronic variant of metabolism is involved. The miniature potentials would appear as analogs of nerve pulses.

Some parts in the stem of the plant can be surrounded by hairy extensions which consist of a single cell or are multicellular structures. Also these could serve as sensory receptors. Note that the hairy geometry would maximize the sensory area.

- 3. What about the counterpart of the neuron network? Although plant cells are covered by cell walls composed of cellulose, hemicelluloses and pectin, they are not completely isolated. Plasmodesma (https://cutt.ly/9D0Sraf) are gap junction-like connections between neighboring plant cells, which allow the transfer of molecules. Plasmodesma could also act as analogs of permanent synaptic contacts, something which brings in mind a meridian system. Note that plasmodesma also have MTs as components.
- 4. Plants communicate with each other [I71] (https://cutt.ly/PDOSies), for instance via their roots send signals to each other under the soil by using chemical secretions.

In the TGD Universe, the communications mediated by dark photon signalling via the layers of MB could make indirect communications possible. Plants form communities (https://cutt.ly/eDOSfOF). One can even ask whether for instance a crop field or wood resembling a ciliary community covering a cell membrane could give rise to a higher level nervous system of some kind.

Talking fungi

After having written this article I learned of a fascinating discovery of Andrew Adamatsky [I45], who has studied sponges and found that they show electrical activity sequences of analogs of action potentials ('spikes').

The abstract of the article gives an overview about the findings.

Fungi exhibit oscillations of extracellular electrical potential recorded via differential electrodes inserted into a substrate colonised by mycelium or directly into sporocarps. We analysed electrical activity of ghost fungi (Omphalotus ni- diformis), Enoki fungi (Flammulina velutipes), split gill fungi (Schizophyllum commune) and caterpillar fungi (Cordyceps militari). The spiking characteristics are species specific: a spike duration varies from one to 21 hours and an amplitude from 0.03 mV to 2.1 mV.

We found that spikes are often clustered into trains. Assuming that spikes of electrical activity are used by fungi to communicate and process information in mycelium networks, we group spikes into words and provide a linguistic and information complexity analysis of the fun- gal spiking activity. We demonstrate that distributions of fungal word lengths match that of human languages. We also construct algorithmic and Liz-Zempel complexity hierarchies of fungal sentences and show that species S. commune generate most complex sentences

The amplitude of spikes varies in the range .03- 2.1 meV. The analogs of miniature potentials correspond to energy .4 meV. The prediction of the TGD based model for the metabolic energy quantum for electron triplet is .51 meV. The solar gravitational metabolism associated with photosynthesis would correspond to the upper bound of 2.5 meV for the metabolic energy. The natural question is whether this kind of communication is specific to fungi or occurs also in preunoral and neuronal systems in general.

The language hypothesis conforms with the TGD based view that the dark variants of genetic code realized using as codons dark photon triplets analogous to 3-chords defining what I call bioharmony serving as a correlate for emotional state and fundamental level [L159, L196]. Dark 3N-photons as representation of for instance genes, define analogs of music pieces. For the TGD based view of the emergence of human language see [K133]. Genetic code would have number theoretic and geometric origin and would be universal. It would have several realizations and be realized also in other than biological systems.

Dark 3N-photons are analogous to Bose-Einstein condensate of 3N-photons and correspond to so-called Galois singlets, whose formation would rely on a universal number theoretical mechanism for the formation of bound states. The sequence of dark codons selects the receiver, which must possess the same sequence of dark nucleon triplets to achieve resonance. If the frequency scale is modulated, the reception generates a sequence of 3N-pulses analogous to nerve pulse sequence and in this way transforms information coded to frequency modulation to a pulse sequence.

12.5 Are space-time boundaries possible in the TGD framework?

One of the key ideas of TGD from the very beginning was that the space-time surface has boundaries and we see them directly as boundaries of physical objects.

It however turned out that it is not at all clear whether the boundary conditions stating that no isometry currents flow out of the boundary, can be satisfied. Therefore the cautious conclusion was that perhaps the boundaries are only apparent. For instance, the space-time regions correspond to maps $M^4 \to CP_2$, which are many-valued and have as turning points, which have 3-D projections to M^4 . The boundary surfaces between regions with Minkowskian and Euclidean signatures of the induced metric seem to be unavoidable, at least those assignable to deformations of CP_2 type extremals assignable to wormhole contacts.

There are good reasons to expect that the possible boundaries are light-like and possibly also satisfy the $det(g_4) = 0$ condition and I have considered the boundary conditions but have not been able to make definite conclusions about how they could be realized.

1. The action principle defining space-times as 4-surfaces in $H = M^4 \times CP_2$ as preferred extremals contains a 4-D volume term and the Kähler action plus possible boundary term if boundaries are possible at all. This action would give rise to a boundary term representing a normal flow of isometry currents through the boundary. These currents should vanish. 2. There could also be a 3-D boundary part in the action but if the boundary is light-like, it cannot depend on the induced metric. The Chern-Simons term for the Kähler action is the natural choice. Twistor lift suggests that it is present also in M^4 degrees of freedom. Topological field theories utilizing Chern-Simons type actions are standard in condensed matter physics, in particular in the description of anyonic systems, so that the proposal is not so radical as one might think. One might even argue that in anyonic systems, the fundamental dynamics of the space-time surface is not masked by the information loss caused by the approximations leading to the field theory limit of TGD.

Boundary conditions would state that the normal components of the isometry currents are equal to the divergences of Chern-Simons currents and in this way guarantee conservation laws. In CP_2 degrees of freedom the conditions would be for color currents and in M^4 degrees of freedom for 4-momentum currents.

3. This picture would conform with the general view of TGD. In zero energy ontology (ZEO) [L118, L165] phase transitions would be induced by macroscopic quantum jumps at the level of the magnetic body (MB) of the system. In ZEO, they would have as geometric correlates classical deterministic time evolutions of space-time surface leading from the initial to the final state [L104]. The findings of Minev et al provide [L104] lend support for this picture.

12.5.1 Light-like 3-surfaces from $det(g_4) = 0$ condition

How the light-like 3- surfaces could be realized?

1. A very general condition considered already earlier is the condition $det(g_4) = 0$ at the lightlike 4-surface. This condition means that the tangent space of X^4 becomes metrically 3-D and the tangent space of X^3 becomes metrically 2-D. In the local light-like coordinates, $(u, v, W, \overline{W}) guv = g_{vu}$ would vanish $(g_{uu} \text{ and } g_{vv} \text{ vanish by definition.})$

Could $det(g_4) = 0$ and $det(g_3) = 0$ condition implied by it allow a universal solution of the boundary conditions? Could the vanishing of these dimensional quantities be enough for the extended conformal invariance?

2. 3-surfaces with $det(g_4) = 0$ could represent boundaries between space-time regions with Minkowskian and Euclidean signatures or genuine boundaries of Minkowskian regions.

A highly attractive option is that what we identify the boundaries of physical objects are indeed genuine space-time boundaries so that we would directly see the space-time topology. This was the original vision. Later I became cautious with this interpretation since it seemed difficult to realize, or rather to understand, the boundary conditions.

The proposal that the outer boundaries of different phases and even molecules make sense and correspond to 3-D membrane like entities [L174], served as a partial inspiration for this article but this proposal is not equivalent with the proposal that light-like boundaries defining genuine space-time boundaries can carry isometry charges and fermions.

3. How does this relate to $M^8 - H$ duality [L127, L128]? At the level of rational polynomials P determined 4-surfaces at the level of M^8 as their "roots" and the roots are mass shells. The points of M^4 have interpretation as momenta and would have values, which are algebraic integers in the extension of rationals defined by P.

Nothing prevents from posing the additional condition that the region of $H^3 \subset M^4 \subset M^8$ is finite and has a boundary. For instance, fundamental regions of tessellations defining hyperbolic manifolds (one of them appears in the model of the genetic code [L159]) could be considered. $M^8 - H$ duality would give rise to holography associating to these 3-surfaces space-time surfaces in H as minimal surfaces with singularities as 4-D analogies to soap films with frames.

The generalization of the Fermi torus and its boundary (usually called Fermi sphere) as the counterpart of unit cell for a condensed matter cubic lattice to a fundamental region of a tessellation of hyperbolic space H^3 acting is discussed is discussed in [L176]. The number of tessellations is infinite and the properties of the hyperbolic manifolds of the "unit cells" are

fascinating. For instance, their volumes define topological invariants and hyperbolic volumes for knot complements serve as knot invariants.

This picture resonates with an old guiding vision about TGD as an almost topological quantum field theory (QFT) [K64, K14, K130], which I have even regarded as a third strand in the 3-braid formed by the basic ideas of TGD based on geometry-number theory-topology trinity.

- 1. Kähler Chern-Simons form, also identifiable as a boundary term to which the instanton density of Kähler form reduces, defines an analog of topological QFT.
- 2. In the recent case the metric is however present via boundary conditions and in the dynamics in the interior of the space-time surface. However, the preferred extremal property essential for geometry-number theory duality transforms geometric invariants to topological invariants. Minimal surface property means that the dynamics of volume and Kähler action decouple outside the singularities, where minimal surface property fails. Coupling constants are present in the dynamics only at these lower-D singularities defining the analogs of frames of a 4-D soap film.

Singularities also include string worlds sheets and partonic 2-surfaces. Partonic two-surfaces play the role of topological vertices and string world sheets couple partonic 2-orbits to a network. It is indeed known that the volume of a minimal surface can be regarded as a homological invariant.

3. If the 3-surfaces assignable to the mass shells H^3 define unit cells of hyperbolic tessellations and therefore hyperbolic manifolds, they also define topological invariants. Whether also string world sheets could define topological invariants is an interesting question.

12.5.2 Can one allow macroscopic Euclidean space-time regions

Euclidean space-time regions are not allowed in General Relativity. Can one allow them in TGD?

- 1. CP_2 extremals with a Euclidean induced metric and serving as correlates of elementary particles are basic pieces of TGD vision. The quantum numbers of fundamental fermions would reside at the light-like orbit of 2-D wormhole throat forming a boundary between Minkowskian space-time sheet and Euclidean wormhole contact- parton as I have called it. More precisely, fermionic quantum numbers would flow at the 1-D ends of 2-D string world sheets connecting the orbits of partonic 2-surfaces. The signature of the 4-metric would change at it.
- 2. It is difficult to invent any mathematical reason for excluding even macroscopic surfaces with Euclidean signature or even deformations of CP_2 type extremals with a macroscopic size. The simplest deformation of Minkowski space is to a flat Euclidean space as a warping of the canonical embedding $M^4 \subset M^4 \times S^1$ changing its signature.
- 3. I have wondered whether space-time sheets with an Euclidean signature could give rise to black-hole like entities. One possibility is that the TGD variants of blackhole-like objects have a space-time sheet which has, besides the counterpart of the ordinary horizon, an additional inner horizon at which the signature changes to the Euclidean one. This could take place already at Schwarzschild radius if g_{rr} component of the metric does not change its sign.

12.5.3 But are the normal components of isometry currents finite?

Whether this scenario works depends on whether the normal components for the isometry currents are finite.

1. $det(g_4) = 0$ condition gives boundaries of Euclidean and Minkowskian regions as 3-D light-like minimal surfaces. There would be no scales in accordance with generalized conformal invariance. g_{uv} in light-cone coordinates for M^2 vanishes and implies the vanishing of $det(g_4)$ and light-likeness of the 3-surface.

What is important is that the formation of these regions would be unavoidable and they would be stable against perturbations.

- 2. $g^{uv}\sqrt{|g_4|}$ is finite if $det(g_4) = 0$ condition is satisfied, otherwise it diverges. The terms $g^{ui}\partial_i h^k\sqrt{|g_4|}$ must be finite. $g^{ui} = cof(g_{iu})/det(g_4)$ is finite since $g_{uv}g_{vu}$ in the cofactor cancels it from the determinant in the expression of g^{ui} . The presence of $\sqrt{|g_4|}$ implies that the these contributions to the boundary conditions vanish. Therefore only the condition boundary condition for g^{uv} remains.
- 3. If also Kähler action is present, the conditions are modified by replacing $T^{uk} = g^{u\alpha}\partial_{\alpha}h^k\sqrt{|g_4|}$ with a more general expression containing also the contribution of Kähler action. I have discussed the details of the variational problem in [K21, K14].

The Kähler contribution involves the analogy of Maxwell's energy momentum tensor, which comes from the variation of the induced metric and involves sum of terms proportional to $J_{\alpha\mu}J_{\mu}^{beta}$ and $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}$.

In the first term, the dangerous index raisings by g^{uv} appear 3 times. The most dangerous term is given by $J^{uv}J^v_v\sqrt{|g|} = g^{u\mu}g^{v\nu}J_{\alpha\beta}g^{vu}J_{vu}\sqrt{|g|}$. The divergent part is $g^{uv}g^{vu}J_{uv}g^{vu}J_{vu}\sqrt{|g|}$. The diverging g^{uv} appears 3 times and $J_{uv} = 0$ condition eliminates two of these. $g^{vu}\sqrt{|g|}$ is finite by $\sqrt{|g|} = 0$ condition. $J_{uv} = 0$ guarantees also the finiteness of the most dangerous part in $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}\sqrt{|g|}$.

There is also an additional term coming from the variation of the induced Kähler form. This to the normal component of the isometry current is proportional to the quantity $J^{n\alpha}J_l^k\partial_\beta h^l\sqrt{|g|}$. Also now, the most singular term in $J^{u\beta} = g^{u\mu}g^{\beta\nu}J_{\mu\nu}$ corresponds to $J^{u\nu}$ giving $g^{u\nu}g^{vu}J^{u\nu}\sqrt{|g|}$. This term is finite by $J_{u\nu} = 0$ condition.

Therefore the boundary conditions are well-defined but only because $det(g_4) = 0$ condition is assumed.

- 4. Twistor lift strongly suggests that the assignment of the analogy of Kähler action also to M^4 and also this would contribute. All terms are finite if $det(g_4) = 0$ condition is satisfied.
- 5. The isometry currents in the normal direction must be equal to the divergences of the corresponding currents assignable to the Chern-Simons action at the boundary so that the flow of isometry charges to the boundary would go to the Chern-Simons isometry charges at the boundary.

If the Chern-Simons term is absent, one expects that the boundary condition reduces to $\partial_v h^k = 0$. This would make X^3 2-dimensional so that Chern-Simons term is necessary. Note that light-likeness does not force the M^4 projection to be light-like so that the expansion of X^2 need not take with light-velocity. If CP_2 complex coordinates are holomorphic functions of W depending also on U = v as a parameter, extended conformal invariance is obtained.

12.5.4 $det(g_4) = 0$ condition as a realization of quantum criticality

Quantum criticality is the basic dynamical principle of quantum TGD. What led to its discovery was the question "How to make TGD unique?". TGD has a single coupling constant, Kähler couplings strength, which is analogous to a critical temperature. The idea was obvious: require quantum criticality. This predicts a spectrum of critical values for the Kähler coupling strength. Quantum criticality would make the TGD Universe maximally complex. Concerning living matter, quantum critical dynamics is ideal since it makes the system maximally sensitive and maximallt reactive.

Concerning the realization of quantum criticality, it became gradually clear that the conformal invariance accompanying 2-D criticality, must be generalized. This led to the proposal that super symplectic symmetries, extended isometries and conformal symmetries of the metrically 2-D boundary of lightcone of M^4 , and the extension of the Kac-Moody symmetries associated with the light-like boundaries of deformed CP_2 type extremals should act as symmetries of TGD extending the conformal symmetries of 2-D conformal symmetries. These huge infinite-D symmetries are also required by the existence of the Kähler geometry of WCW [K64, K34, K97] [L169, L197]. However, the question whether light-like boundaries of 3-surfaces with scale larger than CP_2 are possible, remained an open question. On the basis of preceding arguments, the answer seems to be affirmative and one can ask for the implications.

1. At M^8 level, the concrete realization of holography would involve two ingredients. The intersections of the space-time surface with the mass shells H^3 with mass squared value determined as the roots of polynomials P and the tlight-like 3-surfaces as $det(g_4) = 0$ surfaces as boundaries (genuine or between Minkowskian and Euclidean regions) associated by $M^8 - H$ duality to 4-surface of M^8 having associative normal space, which contains commutative 2-D subspace at each point. This would make possible both holography and $M^8 - H$ duality.

Note that the identification of the algebraic geometric characteristics of the counterpart of $det(g_4) = 0$ surface at the level of H remains still open.

Since holography determines the dynamics in the interior of the space-time surface from the boundary conditions, the classical dynamics can be said to be critical also in the interior.

- 2. Quantum criticality means ability to self-organize. Number theoretical evolution allows us to identify evolution as an increase of the algebraic complexity. The increase of the degree n of polynomial P serves as a measure for this. $n = h_{eff}/h_0$ also serves as a measure for the scale of quantum coherence, and dark matter as phases of matter would be characterized by the value of n.
- 3. The 3-D boundaries would be places where quantum criticality prevails. Therefore they would be ideal seats for the development of life. The proposal that the phase boundaries between water and ice serve as seats for the evolution of prebiotic life, is discussed from the point of TGD based view of quantum gravitation involving huge value of gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ making possible quantum coherence in astrophysical scales [L178]. Density fluctuations would play an essential role, and this would mean that the volume enclosed by the 2-D M^4 projection of the space-time boundary would fluctuate. Note that these fluctuations are possible also at the level of the field body and magnetic body.
- 4. It has been said that boundaries, where the nervous system is located, distinguishes living systems from inanimate ones. One might even say that holography based on $det(g_4) = 0$ condition realizes nervous systems in a universal manner.
- 5. I have considered several variants for the holography in the TGD framework, in particular strong form of holography (SH). SH would mean that either the light-like 3-surfaces or the 3-surfaces at the ends of the causal diamond (CD) determine the space-time surface so that the 2-D intersections of the 3-D ends of the space-time surface with its light-like boundaries would determine the physics.

This condition is perhaps too strong but a fascinating, weaker, possibility is that the internal consistency requires that the intersections of the 3-surface with the mass shells H^3 are identifiable as fundamental domains for the coset spaces $SO(1,3)/\Gamma$ defining tessellations of H^3 and hyperbolic manifolds. This would conform nicely with the TGD inspired model of genetic code [L159].

12.6 Krebs cycle from TGD point of view

This section was inspired by the YouTube video (https://cutt.ly/7XTY1Cc) in which biologist Nick Lane talked of Krebs cycle, also known as citric acid cycle, (https://cutt.ly/kXTY9B5). The title of the video was "How the Krebs cycle powers life and death?". I am grateful for Marko Manninen for the link.

12.6.1 Lane's view of the role of Krebs cycle in the emergence of life

Lane's talk starts with a picture about the network of metabolic reaction pathways of an animal cell. Its complexity is absolutely stunning. In the network nodes correspond to various biochemical compounds and edges between them to reactions catalyzed by biocatalyst.

This huge complexity shows how magnificent work biochemists have done but also forces, at least me, to ask whether there should exist a description relying on deeper principles and involving something beyond chemistry.

Before continuing, I can of course reveal the cards already now and tell that I have been working for roughly two decades with what I could call TGD (Topological Geometrodynamics) [L169] inspired quantum biology. Quantum gravitation in the TGD sense and phases of ordinary matter, which can be quantum coherent in arbitrarily long length scales and behave in many respects like dark matter, play a crucial role in this model. The model challenges the vision of life as nothing but biochemistry.

Krebs cycle

In the middle of the illustration of the metabolic network stands the Krebs cycle. There is in fact also another cycle found by Krebs: readers can try to identify it from the picture of the video.

- 1. The input of the cycle is glucose C_6H_{12} produced in previous reactions splitting carbohydrates, proteins and lipids. Glucose is first split into pyruvate involving 2 carbon atoms. This produces carbon dioxide CO_2 , which can be said to be a waste product. Second output of the cycle is water H_2O .
- 2. The Krebs cycle has two basic functions. The first function is to build precursors of various biomolecules like amino acids, nucleotides, and lipids for further processing in the other parts of the reaction pathway network.

Second function is to liberate the metabolic energy of the pyruvate. Mitochondria, where Krebs cycle takes place are both power stations and molecular factories of the cell building the basic building blocks constructed in other parts of the cell.

3. Although CO_2 and H_2O can be said to be the outputs of the aerobic Krebs cycle, Lane prefers to talk about 2H as the output. The pairs 2H react with NAD^+ to give $NADH + H^+$. The reaction liberates energy kicking the proton H^+ over the potential wall defined by the membrane voltage.

Eventually the proton falls back and gains energy by acceleration in the electric field: the energy of the proton makes possible the energization of ADP by phosphorylation: $ADP \rightarrow ATP$ adding one phosphate P_i to ADP. $ATP \rightarrow ADP$ in turn takes care of the further distribution of the metabolic energy. One can say that ATP serves as a basic metabolic currency and all biological processes use this standard coin. Note that Krebs cycle has both aerobic and anaerobic variants and only the last step involves oxidative phosphorylation.

NADH , which has taken hydrogen and one electron e^- of 2H carries the electron to electron chain in which electrons are transferred in a stepwise manner along the mitochondrial membrane and gradually gives up its energy and end up to oxygen and ADP.

4. Krebs cycle is indeed a cycle. At the first step it transforms pyruvate involving two C atoms to a compound with 6 C atoms and and at the first half of the cycle it is transformed to a compound with 4 C atoms going through 4 steps being eventually transformed to the compound with 6 C atoms.

Reverse Krebs cycle

In the reverse Krebs cycle (https://cutt.ly/HXTY5RR, CO_2 and 2H and energy are the inputs and pyruvate is the output. Also reactions like $NAD^+2H \rightarrow NaDH + H^+$ are reverted so that a time reversal at some level is suggestive. Instead of production of ATP, ATP is used to get energy in absence of some other energy source such as solar radiation. The symmetry between the two halves of the Krebs cycle allows the production of the precursors of various biomolecules also in the reverse Krebs cycle.

- 1. Reverse Krebs cycle is obviously a natural predecessor of the Krebs cycle, which appears when animals use the energy stored chemically by photosynthesizing organisms. Instead of photons, the reverse Krebs cycle can also use biochemical energy. Even electron energy can be used.
- 2. Photosynthesis relies on the reverse Krebs cycle used by plants and some other photosynthesizing organisms (algae living in oceans). Energy comes from photons of solar radiation and is stored in various biomolecules and ATP produced in the reverse Krebs cycle. The biomolecules storing energy are then used by animals using the Krebs cycle.
- 3. In the archaea and bacteria H_2O as input of reverse Krebs cycle can be replaced with H_2S . This can occur even in mammalian mitochondria under stress conditions, when oxygen supply is reduced (https://cutt.ly/qXTUe4j)
- 4. The Krebs cycle can be reversed under some conditions such as cancer. Lane argues that the reverted Krebs cycle is favourable for cancer cells since it produces basic precursors of the basic biomolecules. But also the Krebs cycle does this: maybe the reverse Krebs cycle does this more effectively. In any case, the reverse Krebs cycle does not liberate metabolic energy so that it has disastrous effects.
- 5. Some primitive life forms can use both Krebs cycle and reverse Krebs cycle, be animal- or plant-like, one might say.

The importance of charge separation

Lane emphasized the importance of charge separation. The interior of the cell is negatively charged and the outside positively charged. This charge separation is very common in living matter. For instance, DNA is negatively charged: one unit of negative charge per nucleotide associated with phosphate. Earth's interior is negatively charged and exterior positively charged.

Pollack effect [I110, I111, L20, I162, I197] generates negatively charge regions of water, exclusion zones with effective stoichiometry H_2O and layer like hexagonal structure consisting of hexagons. Clearly, the Pollack effect produces OH^- from H_2O molecules.

Pollack effect is induced by the irradiation of water in a presence of gel at visible or IR wavelengths and induces charge separation. This effect is poorly understood in the standard chemistry framework and its explanation involving new physics is a central element in the TGD based view of living matter [L20].

Krebs cycle takes care of the charge separation requiring energy feed metabolic energy storage in the pyruvate.

The proposal for the evolution of life

Lane also discusses evolution of life starting from the idea that the primitive form of reverse Krebs cycle preceded the recent forms of life. It was discovered in 1966 that photosynthetic bacteria living in anaerobic environments use the reverse Krebs cycle to produce basic biomolecules and to store energy.

1. Margaret Dayhoff was the mother of bioinformatics. On the basis of the evolution of the present day form of enzyme ferredoxin, which has simple inorganic active site and has a key role in photon energy utilization, Dayhoff suggested that its prototype was incorporated into metabolism very early in biological evolution, even before genetic code existed(!). Ferredoxin was evolved by a doubling of a shorter protein, which would have evolved only 8 the simplest amino acids. This shorter ancestor in turn involves only amino acids alanine, proline, serine, and glycine.

For instance, methanogens (archaea) and acetogens (bacteria) use a simple analog of Krebs cycle to grow from H_2 and CO_2 by using a so-called COA pathway.

Reverse Krebs cycle is associated with anaerobic photosynthetic bacteria and since photosynthesis makes chemical energy storage possible, reverse Krebs cycle must have appeared first. Its analog can also use chemical energy of inorganic molecules. 2. Bill Martin proposed that so-called LUCA living in hydrothermal vents is the ancestor of bacteria and archaea (https://cutt.ly/hXTUoZ6). LUCA would have lived 4 billion years ago. LUCA was autotrophic and made all its biomolecules from the inorganic molecules of the environment containing hydrogen, CO_2 and nitrogen turning them to organic compounds like ammonia. It lived in the dark and there was no oxygen so that it would have obtained its metabolic energy from some other source than recent plants and animals.

It would have used the primitive version of the reverse Krebs cycle with H_2S and CO_2 as inputs to build basic biomolecules. This process is an analog of photosynthesis storing energy as chemical energy. Inorganic molecules would have replaced photons as the source of metabolic energy.

The genes of LUCA would have been very simple. The first naive guess is that the genes of LUCA are shared by archaea, prokaryotes, and eukaryotes and this gives constraints on the speculations concerning their genome. This gives however quite too high a number of candidates. The lateral transfer of genes must be taken into account. It implies that the common genes need not be possessed by LUCA. The outcome was a proposal involving 355 genes for LUCA. For instance, the genes responsible for the synthesis of nucleic acids and amino acids were missing. Also the genes needed to code complete ribosomes were missing.

3. Deborah Kelley discovered alkaline hydrothermal vents with charge separation between interior containing. They are rich in hydrogen gas. Hydrothermal vents were predicted by geologist Mike Russel based on the study of what looked like fossilized mineral sponges. The pores of this inorganic structure would have had OH^- ions in the interior and protons in the exterior. The walls would have contained FeS.

Lane suggests that inorganic pores inside the hydrothermal vents represent a candidate for a proto cell.

- 1. Lane emphasized the importance of the charge separation. The interior of both proto cell and its modern version must have been negatively charged (alkaline) whereas the exterior was positively charged. Lane notices that a similar charge separation also characterizes Earth interior and exterior: the electric field of Earth is made possible by this charge separation. What is amusing and thought provoking is that the strength of the electric field in lightning is the same as through the cell membrane! Could one see Earth itself as a giant cell? Did life proceed from long scales to short scales or vice versa?
- 2. A primitive predecessor of reverse Krebs cycle using perhaps H_2S and CO_2 instead of water would have generated the building bricks of chemical life. Oxidation of inorganic compounds such as iron ions could have served as the source of the metabolic energy.
- 3. Lane discusses a proposal for the steps leading to pyruvate from which the Krebs cycle starts from. Bound methanol from CO_2 . From this to pyruvate containing two carbons. This is realized in the lab. Also lipids would have been generated leading to the emergence of cell membranes.

It should be noticed in passing that in the experiments producing the basic biomolecules UV light is often needed: this is understandable since the scale of molecular energies is in visible and UV. The problem is that the recent life forms do not however utilize UV light.

4. These life forms would have lived in hydrothermal vents and would have disappeared as life based on photosynthesis generating oxygen emerged. All plant-like life forms not using photosynthesis would have disappeared in CE if they existed at all.

Oxygen based life would have been the winner since reverse Krebs cycle for photosynthesis is much more effective than for the variant of Krebs cycle using chemical energy. Also aerobic Krebs cycle is much more effective than that based on fermentation. The monocellular life forms, possibly using H_2S based metabolism, would have disappeared in CE when the oxygen levels in oceans would have increased dramatically.

5. Note that the same proposal for the proto cell could work if H_2O replaces H_2S if it is available. One can also make "What if?" question. Can on imagine that photons and oxygen were in some mysterious way available from the beginning.

6. The next revolution according to Lane would have been the emergence of photosynthesis as analog of reverse Krebs. H_2O would have replaced H_2S from water. $CO_2 + H_2 \rightarrow CH_2O + O_2$ became the basic reaction making possible the storage of metabolic energy to carbon compounds and producing the basic building blocks of biomolecules.

The Great oxidation event (GOE), estimated to have occurred for 2.4-2.2 billion years before the Cambrian explosion (CE), would have initiated a very slow oxidation of oceans and amplified in CE dramatically. This would explain why the fossils of life forms utilizing oxygen based photosynthesis are absent before CE.

The scenario however has problems.

1. The proposal is that metabolism came first. However, metabolism requires biocatalysts and their generation requires genes. If metabolism was miraculously possible without genes, how genes emerged from metabolism? All nothing-but-chemistry based views of the origin of life have hen-egg problems. Did the cell membrane emerge first? Did proteins or genes emerge first? Did proteins, DNA or RNA emerge first?

All these need each other in recent life, which leads to asking whether something much deeper emerged first or was present from the beginning at the level of fundamental physics. Could this something relate to the difference between in-organic and organic matter and to the incredible efficiency and precision of bio-catalysis? Does biophysics involve something totally new, not yet identified?

- 2. Did the GOE really happen? What is known of fossils suggests that it occurred in CE but how is this possible? Did oxygen rich oceans appear out of nowhere just like the complex multicellulars. Could one think that this somehow occurred and multicellular cells replaced the possibly existing life forms in hydrothermal vents at the surface of Earth using chemical energy as metabolic energy?
- 3. As Lane emphasizes, charge separation is crucial. Pollack effect induces it. We do not understand the Pollack effect in the standard biochemistry framework.

These objections give a good motivation for developing a TGD based view about Krebs cycle. This view is based on some basic ideas of TGD inspired quantum biology, quantum gravitational views of metabolism [L183] and evolution of life [L178], the TGD inspired view about how Pollack effect induces charge separations leading also to a view of genetic code realized in terms of both dark proton and dark photon triplets, the TGD proposal for what happened in Cambrian explosion in which oxygenated oceans and highly developed multicellulars emerged apparently out of nowhere [L85, L173, L156].

12.6.2 TGD view of Krebs cycle and early life

The TGD based view of life could have emerged from the problems of the view of Lane.

1. Brief overview of quantum TGD

TGD and TGD inspired theories of consciousness and quantum biology rely on a new view of space-time and quantum theory [L169].

1. In the original form TGD was proposed to be a geometrization of classical physics: the gauge fields of standard model and gravitational fields are geometrized in terms of the geometry of 8-D space $H = M^4 \times CP_2$ in which space-times are 4-D surfaces.

The new view of space-time leads to notions like topological field quantization. Maxwellian fields are replaced by topological field quanta such as magnetic flux quanta (tubes and sheets) and electric flux quanta which correspond to space-time surfaces of finite spatial size in H.

2. Later the geometrization program was extended to include entire quantum physics and was based on the notion of the "world of classical worlds" (WCW) consisting of 4-D surfaces identified as space-time surfaces in H, which are preferred extremals of action principle analogous to Bohr orbits.

Preferred extremal/Bohr orbit property leads naturally to holography which is not quite exact, which has important implications for quantum biology and understanding of cognition. This in turn leads to zero energy ontology (ZEO). Quantum states are not superpositions of 3-D surfaces but of 4-surfaces.

They are therefore quantum variants for analogs of deterministic time evolutions: functions, behaviors of computer programs. The notion of function is central in biology and neuroscience and would be also a central notion in fundamental quantum physics.

ZEO leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory solving its basic problem due to the conflict of the determinism of unitary time evolution with non-determinism of state function reduction. Quantum jump replaces the entire superposition of space-time surfaces with a new one rather than violating the deterministic time evolution of a given space-time surface. There are two causalities: this solves the basic problem of quantum measurement theory. There are also two times: the geometric time of a physicist and the subjective time as a sequence of quantum jumps.

This in turn leads to a new view about state function reductions (SFR): in ordinary "big" SFR the arrow of time changes whereas in "small" SFR as an analog of weak measurement it is not changed. The findings of Minev et al [L104] provide direct support for ZEO [L104]. Also the views about thermodynamics must be modified since the arrow of time can change. The implications are especially profound in biology.

3. Later came a generalization of the physics based on real numbers to what I call adelic physics [L66, L67]. Adeles are fusion of reals and p-adic number fields identified as correlates of cognition and intention. p-Adic number fields are completions of rationals just like real numbers. They allow an infinite number of extensions induced by algebraic extensions of rationals.

It is natural to interpret the hierarchies of extensions of rationals as evolutionary hierarchies and one can assign to extensions the value of effective Planck constant $h_{eff} = nh_0$ determined by their dimension. Also biological evolution reduces to the increase of algebraic complexity in a sequence of quantum jumps replacing zero energy state with a new one.

This framework led to $M^8 - H$ duality, which generalizes the momentum-position duality of wave mechanics. This duality provides two views of physics. The complexification M_c^8 of M^8 , as analog of complexified8-D momentum space, has an interpretation as complexified octonions. At the level of M^8 the counterparts of 4-surfaces are determined by the roots of monomial polynomials P of a real argument and having integer coefficients. The roots of Pcorrespond to, in general complex, mass squared values defining mass shells H^3 (hyperbolic spaces) in momentum space $M_c^4 \subset M_c^8$. The roots are algebraic numbers in an extension of rationals defined by P and the Galois group of P acts as symmetries of the theory.

These 3-D objects are continued by holography to 4-surfaces. The holographic dynamics is dictated by the condition that the normal space of the 4-surface is associative, that is quaternionic. The second condition is that the normal space contains commutative space (analogous to complex numbers). This guarantees that the normal space corresponds to a point of CP_2 and makes it possible to map these associative 4-surfaces to space-time surfaces in H.

Some basic ideas of TGD inspired quantum biology

Consider now some aspect of TGD inspired quantum biology relevant for what follows.

1. Dark matter and quantum biology

Basic prediction of the number theoretic vision of TGD is a hierarchy of dark matter phases labelled by $h_{eff} = nh_0$, where n is the dimension associated with the extension of rationals.

1. Dark matter in the TGD sense residing at monopole flux tubes is central for the TGD view of life. Also the electric flux quanta, which correspond to deformations of minimal surfaces of H with 2-D membrane-like projection to E^3 are expected to be important and accompany for instance, the lipid layers of cell membrane and boundaries between two phases. For instance, molecules could be accompanied by these kinds of membranes involving $h_{eff} > h$ phases. Dark variants of protons and electrons and perhaps also ions reside at the field equanta.

- 2. Large value of h_{eff}/h would mean high algebraic complexity and high "IQ" so that the magnetic body (MB) would naturally use the biological body as a motor instrument and sensory receptor.
- 3. There are reasons to believe that the value of h_{eff} correlates with the interactions mediated by the flux tubes. Gravitational Planck constant $\hbar_{hr}/=GMm/\beta_0$, where $\beta_0 = v_0/c \leq 1$ defines a quantize velocity parameter, M corresponds to either Earth's or solar mass and m is mass of a particle, is determined by Equivalence Principle and would characterize gravitational flux tubes. \hbar_{gr} must be used in the condition $\hbar_{gr}/\hbar \geq 1$ is satisfied. This notion was originally introduced by Nottale [E1] and discussed from the TGD point in [K101, K84, K85].

This proposal generalizes to other interactions. The gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0 = r_S/2\beta_0$, where r_S is Scwartshild radius. For Earth this gives $\Lambda_{gr} = .45$ cm. This should be a fundamental biological and also hydrodynamical length scale [L178, L168] besides the corresponding length scale associated with the Sun.

4. Large values of h_{eff} , in particular \hbar_{gr} , mean the presence of long range quantum fluctuations serving as correlations for quantum criticality, which in the TGD Universe would accompany ordinary criticality. In living matter these fluctuations would be associated with the criticality with respect to melting/freezing and boiling/condensing.

There would also be criticality around physiological temperature especially relevant to biological life [L178]. In these transitions, large density fluctuations take place and this leads to the TGD view about the role of quantum gravitation in biology and theory of conscious experience. Quantum gravitation would not be relevant in Planck scale but for Planck mass scale and appear in macroscopic scales longer than Λ_{gr} and even in the scale of Earth and even Sun.

- 5. One ends up with a quantum gravitational view of metabolism [L183] based on the proposal that both hydrogen bonds and valence bonds are accompanied by magnetic flux tubes and be characterized by even \hbar_{gr} and therefore can have very long lengths giving rise to quantum coherence in long scales. The delocalization of dark protons at gravitational flux tubes by the absorption of dark solar photons would be a central element and one can say that the gravitational flux tubes serve as gravitational batteries with the metabolic energy stored in the reduction of the gravitational binding energy. One also ends up with a vision of how the neural system evolved [L183].
- 6. Pollack effect [I110, I111, L20, I162, I197] is a central element in the TGD view of living matter [L20, L47, L129, L39]. What would happen is that in the presence of a gel phase, the irradiation by visible or IR light would generate the negatively charged exclusion zone (EZ) by kicking protons of H_2O to the flux tubes of the MB of water where they could form sequences of dark protons.

Pollack effect would thus explain charge separation occurring for cell and DNA and even for Earth and would be absolutely central for TGD. A feed of metabolic energy would be necessary to preserve the charge separation requiring dark protons. An alternative interpretation is that preservation of high level of cognitive consciousness, measured by the value distribution of h_{eff} as analog of IQ, requires metabolic energy feed

- 7. Dark proton triplets or dark nucleon triplets [L196] at monopole flux tubes would provide a realization of the genetic code, and give rise to dark variants of DNA, RNA, tRNA and amino acids already at the level of water. Since also metabolism is involved.
- 8. The realization of the genetic code in terms of dark photon triplets would be essential for communications. The biochemical realization would be a secondary realization of the genetic code and would emerge later.

9. Number theoretic vision leads to a proposal that genetic code is universal [L159, L196]. Even the cell membrane could realize the genetic code. The key notion would be so-called icosatetrahedral tessellation at the hyperbolic space H^3 (mass shell and its counterpart in H) allowing realization of genetic code which would induce realizations at the space-time level. Also higher than 1-D realizations, such as realization at the level of cell membrane.

This picture would solve the hen-egg problems of the nothing-but-chemistry approach [L181]. All the basic building blocks necessitating each other emerge simultaneously. The TGD based view of space-time also strongly suggests that membrane-like structures are universal at the space-time level [L174] and are associated with cell membranes and various boundary layers.

2. Zero energy ontology

Zero energy ontology (ZEO) [L118, L165, L177] [K132] is also important for the TGD view of life.

- 1. "Big" or ordinary SFRs (BSFRs), would reverse the arrow of time and the interpretation of BSFR could be interpreted as a universal counterpart of death. BSFR would however mean reincarnation with an opposite arrow of time.
- 2. Sleep-awake cycle could be due to BSFRs at some level of MB. At the level of bio-molecules analogous cycles are also present. During the sleep period, dissipation occurs with a reverse arrow of time and this looks like healing when looked from the opposite time direction.

Since MB controls biological matter with f $h_{eff} = h$, the change of the arrow of time in BSFRs at the level of the magnetic/field body would induce effective time reversal at the level of the ordinary biomatter. The arrow of time for ordinary matter would change in a very short time scale since BSFRs would occur with a high rate.

An attractive conjecture is that Krebs cycle and its reversal are time reversals of each other at some level of MB. If so, the appropriate levels of MBs of animals and plants tend to live in opposite time directions. As noticed, the Krebs cycle can change to its reversal, say in cancer, and the interpretation would be that the analog of cell death followed by a reincarnation with an opposite arrow of time occurs.

Expanding Earth hypothesis, Cambrian explosion, and emergence of oxygen rich oceans

The TGD proposal is that life and photosynthesis and higher chemical life emerged in underground oceans. Oxygen is needed and oxidation of the underground oceans would have taken place by photosynthesis by reverse Krebs cycle and been based on water instead of H_2S .

1. Evolution of life in underground oceans

Consider now the TGD picture.

1. Life would have evolved in underground oceans shielded from meteoritic bombardment and cosmic rays. The radius of Earth increased rapidly by a factor of about 2 during the Cambrian explosion (CE). The multicellular life utilizing photosynthesis bursted to the surface of Earth and formed recent oceans.

There would have been no oceans before the CE. Hydrothermal vents could have existed. The possible lifeforms were very simple bacteria, which photosynthesized using H_2S since there was now water and oxygen.

Earth was like Mars now: Mars has no oceans and no oxygen. There are indications of underground reservoirs of water and signs of simple life forms.

2. Cosmic expansion in GRT predicts astrophysical objects to expand smoothly. This does not happen. In the TGD Universe, the expansion would be a quantum phenomenon and take place in rapid jerks and such a jerk would have induced CE.

I got interested in the Expanding Earth hypothesis after watching a video [F2] by Neal Adams. The video is very impressive artwork but in the lack of references skeptics probably

cannot avoid the feeling that Neal Adams might use his highly developed animation skills to cheat the reader. I found also a polemic article [F1] of Adams but the references were lacking. The basic argument was that the Wegener hypothesis generalizes. If the radius of the Earth were 1/2 of the recent radius, the whole Earth would be covered by continents fitting together along their boundaries.

2. Expanding Earth hypothesis

This leads to Expanding Earth Hypothesis (EEH) [L85, L173, L156].

- 1. EEH stating that the radius of Earth increased rather rapidly by a factor of about two in Cambrian Explosion and underground oceans serving as seats for highly evolved photosynthesizing life bursted to the surface and forming oceans.
- 2. Highly developed multicellular animals and photosynthesizing algae bursted to the surface. Note that algae are responsible for the production of most oxygen also in the recent oceans. If hydrothermal vents contained sulphur based life it disappeared because the generation of the basic building blocks of biomolecules was too slow.

Interestingly, the radius of Mars is roughly 1/2 of that for Earth. Could Mars have underground oceans teeming with life? When does the radius increase by factor two?

- 3. There is however a problem. How is photosynthesis possible underground? It is dark there! The basic proposal is that solar photons with energies in the visible and possibly infrared range arrive as dark photons along monopole flux tubes, which extend above the Earth and carry dark matter. The strength of the magnetic field would be about .2 Gauss and fraction 2/5 of the nominal value of the Earth's total magnetic field involving also a non-monopole part.
- 4. Also dark photons from the interior of Earth propagating along the flux tubes or associated with them could have served as an energy source. The temperature in the Earth's inner core (with radius about 20 percent of the Earth's radius) corresponds to about 5,500 K, which corresponds to a thermal energy scale of about .55 eV, which corresponds to the nominal value of the metabolic energy quantum.

The energy at the maximum of the energy distribution is roughly 3 times larger than this energy and would be around 1.65 eV. The energy at the maximum wavelength of thermal energy distribution is 5 times higher and about 2.75 eV, which is the upper bound for the energy range 2-2.75 eV of visible photons.

If the temperature of the inner core before CE has not differed appreciably from that now, which could hold true if the inner core was already before CE in the expanded state as also water containing regions, the idea about dark photons from the inner core as a metabolic energy source, which would make possible the evolution of photosynthesis in underground oceans, makes sense.

3. A model for the growth of the Earth radius by factor 2

The idea about relatively fast growth of the Earth radius by factor 2 raises the eyebrows of standard physicists. How can such a large change of density make sense? It seems safe to exclude the possibility that the mass of Earth has increased roughly by a factor of 8 (mass should have arrived from dark magnetic flux tube structure to which the core of Earth is associated as a tangle).

Monopole flux tube spaghetti should determine the structure of the ordinary condensed matter making Earth. One can consider several possibilities by allowing a fractal behaviour of the matter density induced by the structure of the flux tube spaghetti if it does not fill the entire volume [L173, L156].

The increase of the radius of Earth by factor about 2 means that the average density decreases by a factor 1/8. I have considered several options for what this could mean.

1. Quantum gravitation plays a key role in the TGD view of the emergence of life [L178] and brings in a completely new element. Density fluctuations at quantum criticality associated with the density changing phase transitions, such as freezing and evaporation, affect gravitational binding energy dramatically in long scales. This leads to a view how life could have evolved from this kind of quantum criticality. If the density fluctuations correspond to local scalings, they affecte all gravitational binding energies in the same manner by reducing them.

Quantum gravitational Compton length $\Lambda_{gr}GM/\beta_0$ using the definition $\hbar_{gr} = GMm/\beta_0$ defines the key parameter. This suggests a considerable flexibility since the transition could be induced from the level of quantum gravitational flux tubes and leave the details for what happens in scales below Λ_{gr} open.

2. Both the necessity of local scalings and energy conservation in the transition give further constraints. In the scaling of the radius of Earth by factor 2 induced by local scalings, the gravitational binding energy is reduced dramatically. There must be a way to compensate for the increase of the energy. Energy must be liberated in some degrees of freedom and condensed matter degrees of freedom in atomic scales are a natural candidate here.

For protons the gravitational binding energy is below .5 eV and for nucleus with mass number A it is below .5A eV. The reduction of the gravitational binding energy per particle in the phase transition would be of this order of magnitude. Encouragingly, this energy corresponds to a typical energy scale for the interactions energies between atoms.

3. The electronic size of an atom is inversely proportional to $n^2 h_{eff}^2/Z^2$, where *n* is the principal quantum number for valence electrons and *Z* is the charge of the atomic nucleus. The electronic binding energies are proportional to $Z^2 n^2/h_{eff}^2$ so that the transition would require energy feed if scaling occurs in electronic degrees of freedom. Energy is not liberated. Furthermore, the electronic size of the atom cannot be affected in the transition.

Note however that the experiments of Randell Mills [D7] provide support for the possibility of h_{eff} smaller than h for valence electrons [L41]. The TGD inspired model for chemical bonds [L62] suggests that the value of h_{eff} characterizes valence bonds.

4. Second possibility is that the energy is liberated in atomic size scales defined in terms of the size lattice constant a defining the unit cell of the atomic lattice, which is rather constant. The atomic p-adic length scale defining a would increases by factor 2 or the value of h_{eff} assignable to the atomic p-adic length scale (the p-adic length scale L(137) is a good guess) increases by a factor 2 from h/2 to h. Note that before the transition the value of h_{eff} assignable to a cannot be the same as the value assignable to the atomic electrons, since the latter cannot change in the transition.

The reduction of the gravitational binding energy should correspond to the liberated interatomic interaction energy depending on a which would increase by a factor 2. If this interaction energy can be regarded as positive interaction energy of positively charged atoms without conduction electrons, it is positive, and would decrease in the transition and could compensate for the reduction of the gravitational binding energy.

5. The phase transition would have been local and occurred gradually. The regions of water containing the photosynthesizing life forms and multicellular animals would have been in the recent phase already before CD. Water atoms behaved like dark matter since h_{eff} was twice its value for other atoms (as unit cells).

The same could apply also to the inner core serving as a source of dark photons providing the metabolic energy. Indeed, the radius of the inner core is roughly 1/5 of the radius of Earth, so that the possibility that also the inner core was in the ordinary phase looks realistic: the doubling of the Earth radius would be replaced with a scaling by factor 10/6.

Only the mantle would have been in the exotic phase. Of course, also the uppermost layers could have been also in the ordinary phase as the recent situation on Mars would suggest. The phase transition would have gradually proceeded in the mantle during the period when the radius of Earth was doubled.

6. The arguments of [L156] based on the idea that CP_2 length scale corresponds actually to Planck length scaled by factor $\sqrt{h/h_0}$ led to a speculation that $h_{eff} = h$ could be proportional to integer $n_0 = (7!)^2$ defining the order of Galois group for the number theoretic ground This suggests that the order of the Galois group was given by $n = n_0/2 = 7!^2/2$ before CE and was replaced with $n_0 = (7!)^2$ in CE. The Galois group would have been $S_7 \times A_7$, where A_7 is an alternating group, which is simple. Z_2 is the only normal subgroup of S_7 .

Can one imagine any evidence for an analog of the exotic phase in the framework of known physics? In the case of water, superionic ice [D8] (https://cutt.ly/uXUIkUQ and https://cutt.ly/3XUIWhX) existing at extreme pressures is a possible candidate for the exotic phase of water. Superionic ice is proposed to appear in the mantles of giant planets such as Uranus and Neptune and in [L173, L156] the possibility that it could occuring the Earth's mantle was considered. The density of superionic ice is slightly less than 4 times the density of ordinary ice. The reduction of h_{eff} with factor 2 ($n = n_0/2 = (7!)^2/2$) would given a density, which is 8 times the density of ordinary ice. The increase of the density by factor 2 would require effective 2-dimensionality but superionic ice is 3-D.

4. Quantum gravitational metabolism

Consider first the quantum gravitational metabolism at Earth in the recent situation. In [L183], I discussed the following vision.

1. The long gravitational monopole flux tubes with $\hbar_{eff} = \hbar_{gr} = GM_E m/\beta_0$, $\beta_0 = v_0/c \leq 1$, have lengths much longer than gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$ does not depend on the mass *m* of charged particle, now proton at the dark hydrogen bond. Λ_{gr} is about .45 cm for $\beta \simeq 1$ using $\hbar_{gr} = GMm/\beta_0$. There are several pieces of evidence suggesting that Λ_{gr} is a fundamental scale of hydrodynamics [L168, L178].

The length of long dark hydrogen bond flux tubes should be of order Earth size scale. For the recent life forms they would extend from the surface of Earth to the atmosphere.

The dark photons of sunlight are absorbed by these flux tubes and this would increase the length if the energy reduces the gravitational binding energy. These flux tubes would serve as quantum gravitational batteries just like cell membranes as electromagnetic batteries.

2. Skeptics can of course wonder how it is possible that extremely weak gravitational interaction of gravitation and photons allows the transfer of dark photon energy to gravitational degrees of freedom. As a matter fact, quantum coherence means that gravitational interaction is actually extremely strong!

In ordinary quantum theory one should use $\alpha_{gr} = GMm/\hbar$ as a coupling strength. It is larger than unity for Mm larger than Planck mass squared and the perturbation series fails! The introduction of \hbar_{gr} saves the perturbation theory! As a matter of fact, the original motivation for h_{eff} was that the Universe is theoretician friendly and the increase of \hbar means a phase transition making perturbation theory possible.

One can characterize dark gravitational interaction by a dimensionless coupling parameter $\alpha_{gr} = GMm/4\pi\hbar_{gr} = \beta_0/4\pi$, which depends on β_0 only and is $1/4\pi$ for $\beta_0 = 1$ and therefore by a factor $1/e^2$ larger than fine structure constant and still of the same size as strong coupling strength α_s !

- 3. The upper bound for the gravitational binding energy of a proton in the Earth's gravitational field is of the order of . 5 eV metabolic energy quantum. If the dark proton at the long flux tube is localized at the surface of Earth, its gravitational binding energy increases and energy is liberated as metabolic energy. The flux tube can be given the original length by the absorption of a dark photon of solar radiation. The order of magnitude of energy is around metabolic energy quantum if 3 protons are localized simultaneously [L183]. ATP machinery indeed involves 3 protons which could have formed dark 3-proton.
- 4. The model also predicts a new metabolic energy currency associated with electrons. It is by the ratio $m_e/m_p \simeq 2^{-11}$ smaller than the standard metabolic energy quantum with the nominal value .5 eV.

5. The situation before CE

Consider now the situation before CE, when oceans were underground. One can imagine several options depending on whether dark solar radiation, dark photons from the Earth's core, or both provide the metabolic energy in the primordial photosynthesis.

1. For the simplest option involving only dark photons from the Earth's core, the dark flux gravitational flux tubes extending downwards to the interior of Earth would be spontaneously formed and their formation would have liberated metabolic energy given by the increase of the gravitational potential. If the flux tube extends down to the surface of the inner core with radius of $2R_E/5$, the metabolic energy released for the hydrogen bond would be about 1.5 eV to be compared with metabolic energy quantum of .5 eV. The absorption of a dark photon with energy of 2 eV would leave .5 eV of metabolic energy.

One can ask whether the ADP molecule could have contained this kind of long dark hydrogen bond and whether it could have shortened in ADP \rightarrow ATP transition by absorption of a dark photon before CE.

One can also imagine that the dark cyclotron state of the dark proton was excited by the dark solar photon and was liberated as the metabolic energy in the interior as the dark proton was localized.

2. Could the dark photons from the Earth's core be involved with the metabolism of recent life forms? Say those living underground? Could the increase of the radius of Earth by a factor of 2 have reduced the rate for the increase of the length of dark hydrogen bonds so that this mechanism became insignificant? Could one imagine that the Earth's mantle still contains life forms utilizing the core of Earth as a metabolic energy source? I have suggested this half-jokingly for more than 2 decades ago [K42, K43].

The next question concerns the identification of the primordial photosynthesizers.

- 1. They would have been the underground counterparts of the recent plants. Dark magnetic flux tubes emanating from them would have formed a kind of magnetic forest.
- 2. They did not have roots, leaves, nor flowers and lived in underground oceans and did photosynthesis. Algae https://cutt.ly/9XTBTE0) living in oceans satisfy these conditions. They include cyanobacteria (red and green algae) and glaucofytes. They or their predecessors (at least cyanobacteria) should have lived in the underground oceans and have evolved to the recent algae and plants after CE. Interestingly, algae produce most of the oxygen of Earth also in the recent biosphere. Cyanobacteria living in endosymbiosis with algae are the first known organisms that have produced oxygen.
- 3. This picture also solves the problem of how the oceans were oxygenated. They were oxygenated from the beginning and only bursted to the surface of Earth in CE.
- 4. This picture also conforms with the proposal of Lane that Earth and cell are very much analogous and makes this idea very concrete. The TGD variant of this proposal suggests that lightnings are actually analogs of action potentials possible even for unicellular organisms.

12.6.3 Appendix: A Corrected physical interpretation of the parameter β_0

Writing of this article led to an observation an apparent paradox, which resulted from a wrong interpretation of the parameter β_0 in Nottale's formula.

1. As already discussed, the quantum gravitational phase transition reducing the value of β_0 by factor 2 was involved with CE and led to the increase of the radius of Earth by factor 2.

There are indications that the recent value β_0 is $\beta_0 \simeq 1$ and thus near to the maximal value [L168, L178]. This however leads to the conclusion that $\beta_0 = 2$ was true before CE. This leads to a contradiction if one assumes that $\beta_0 = v_0/c$ is consistent with special relativity.

2. The resolution of the apparent contradiction is based on the fact that the definition of the parameter β_0 in the Nottale's formula is actually not unique and determined only by scaling without further inputs such as the condition $\beta_0 \leq 1$. Therefore one can replace the formula $\hbar_{gr} = GMm/\beta$ with the formula $\hbar_{gr} = GMm/2\beta_{0,ph}$ if one defines $\beta_{0,ph} = \beta_0/2$. For this option, the value of $\beta_{0,ph}$ would have decreased from $\beta_{0,ph} = 1$ to $\beta_{0,ph} = 1/2$ in CE. The value of Λ_{gr} after CE would be $\Lambda_{gr} = GM/2\beta_{0,ph} = r_s/2$ just as proposed earlier [L168, L178].

12.7 About the mechanism of the energy transfer in photosynthesis

I learned about very interesting results related to photosynthesis. A popular article on the BigThink page (https://rb.gy/phb4c) tells about an article published in the journal PNAS [I188] (rb.gy/9zppa).

The basic mystery of photosynthesis is extreme energy efficiency. Up to 95% of the photon's energy is transmitted in a medium that would seem to be as inhospitable as possible for energy transmission with almost no dissipation. The use of very low temperatures, the shooting of monochromatic photons into a lattice, and superconductivity are out of the question. The incoming photons also have a wavelength distribution, which does not facilitate the energy transfer either.

12.7.1 Some facts

Consider first a summary of the basic findings and conclusions.

- 1. Chlorophyll is the basic structure involved with photosynthesis. Its basic function is to gather solar energy and transfer it to the reaction center where the energy is stored to various biomolecules. There are 2 wavelength bands, corresponding to 430 nm in blue and 662 nm in red, where the absorption is especially strong. The so-called LH2 proteins act as antennas absorbing photons. In the reaction center LH1 proteins perform photosynthesis by building biomolecules to which the solar energy is stored.
- 2. It has been observed that the lower limit of the size of the so-called light-absorbing LH2 antenna proteins is 2.5 nm. It is also the minimum distance between LH2 proteins. The proposal is that the LH2 antenna network could somehow make the transfer of energy almost without dissipation.

It is believed that the disorganization of the proteins might explain this. However, in the popular article there was no intuitive argument as to why this is so. The claim is made on the basis of computational models and empirical facts gained by studying the transfer process. I find it difficult to imagine how the irregular positions of proteins could promote the process.

3. The proposed interpretation of the findings is as follows. A photon enters and excites the electron of the LH2 protein. When the electron is de-excited, one or more photons are generated which in turn excite the electrons of the next LH2 proteins. Finally, the generated photons excite the electrons of the reaction center and these electrons are used in the photosynthetic process to produce sugar molecules.

12.7.2 The TGD based model

The findings seem to resonate with two key views of the TGD inspired quantum biology.

- 1. Photosynthesis involves at least a temporary storage of solar energy to quantum gravitational energy batteries [L183, L178].
- 2. There is dark variant of the genetic code and realization of dark DNA double strand base on the icosahedral tessellation [L199] of the hyperbolic 3-space H^3 , which is realized both as a mass shell in $M^4 \subset M^8$ and light-cone proper time=constant 3-surface in $M^4 \subset M^4 \times CP_2$.

Icosa-tetrahedral and possible other hyperbolic tessellations would be associated, not with the biological body, but with the magnetic body (MB) of the biosystem carrying dark matter identified as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0$. The location of dark matter at the field body would explain why dark matter has not been found in various searches.

Basic questions

What are the questions waiting for an answer?

- 1. Why would the dissipation be so low? Quantum coherence in a scale of at least the order of tens of nanometers could guarantee this. Dark matter as phases with a large value of h_{eff} indeed implies a long quantum coherence scale. Also a regular crystal structure is a natural prerequisite for a low dissipation. The dissipation is minimized if the energy, or possibly the electrons, are transferred through the hyperbolic tessellation of the MB carrying dark matter.
- 2. The minimum distance between LH2 proteins is about 2.5-4 nanometers, which corresponds to the DNA codon size scale. In the TGD based model for genetic code, the dark realization of the genetic code and the DNA double helix are connected to an icosa-tetrahedral honeycomb in hyperbolic 3-space H^3 assigned with the MB [L199]. Could the crystalline structure be realized by using the same icosa-tetrahedral tessellation as associated with the dark DNA and dark genome controlling the ordinary genome.

If the transfer of energy to the reaction center occur at the MB as a transfer of dark electrons, the dissipation could be very small since there would be no direct interaction of the dark electrons with the ordinary matter if the interaction vertices can involve only particles with the same value of h_{eff} , as seems natural.

Quantitative data

Consider next the quantitative data.

- 1. The distance between LH2 proteins is in the range 2.5-3.1 nm. This scale corresponds to the DNA codon size scale and to the cell size of the fundamental region of the icosa-tetrahedral tessellation, which has Platonic solids as cells [L199]. There are 12 icosahedrons, 20 tetrahedrons and 30 octahedrons forming a region of size 10 nm, which corresponds to the p-adic length scale L(151) (associated with a p-adic prime $p \simeq 2^k$, k = 151) appearing as a characteristic length scale in bomatter. This region corresponds to 10 DNA codons for which the total twist along the DNA strand is 6π that is 3 full turns.
- 2. The size of the structure involved with the photosynthesis would be naturally cell size scale? The wavelength of the red light gives a length scale of order .5 μ m and serves a natural lower bound. Note that cell nucleus size is about 1 μ m.
- 3. The time τ required for the energy transfer between adjacent antenna proteins varies from 5.7 to 14 ps. In time τ , the distance traveled by the light is L = 1.71 4.2 mm. Interestingly, for Earth the gravitational Compton wavelength $\Lambda_{gr}(E) = GM_E/\beta_0(E)$ is for $\beta_0(E) = v_0/c = 1$ equal to $\Lambda_{gr}(E) = 4.5$ mm. Gravitational Compton frequency is $f_{gr}(E) = 67$ GHz and corresponds to a time of about $T_{gr}(E) = 15$ ps, the upper limit for the estimated time.

 f_{gr} corresponds to a photon energy of $E_{gr} = .27$ meV. The electronic metabolic energy quantum in the case of the Earth would be related by a factor m_e/m_p the protonic metabolic energy quantum identifiable as standard metabolic energy currency. The model for the findings of Andrew Adamatsky [I45] suggests that sponges have a language based on membrane potential oscillations with membrane potential variations of order mV. The TGD based model suggests the existence of metabolic energy quantum of this order of magnitude [L183]! meV is also the energy associated with the miniature membrane potentials. Could τ be identifiable as the gravitational Compton time T_{gr} at which the dark matter at the MB would oscillate?

How could the electrons be transferred to the reaction center as dark electrons?

Could the process at the level of LH2 antenna proteins correspond to the propagation of the dark electron and the hole associated with it? The dark electron would hop between the sites of the tessellation perhaps by quantum tunneling, which in TGD Universe corresponds to a pair of "big" (ordinary) state function reductions (BSFRs) changing the arrow of time temporarily. The dark electron current would be analogous to super current and the system "hole + dark electron" would be analogous to a Cooper pair.

- 1. The duration τ of a single step should correspond to the oscillation period $\tau \sim T_{gr}$. If so, the oscillation would play the role of EEG resonance oscillation coordinating the transfer by induces the pairs of BSFRs.
- 2. The first guess is that electrons are converted to dark electrons with a large value of the gravitational Planck's constant $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0(M)$ [E1] located at the gravitational MB of the Earth or Sun. They would be transferred to the U-shaped monopole flux tubes and the reduction of the binding energy of the electron would be equal to the energy of the incoming photon absorbed by it.

The reduction of the binding energy cannot be however purely gravitational. For electrons, the maximal gravitational binding energy in the case of the Earth is about $E_{gr}(Earth, e) = .25$ meV whereas the incoming photon has energy $E \simeq x \times .5$ eV, where x is in the range 4 to 6 in the wavelength range considered. For the Sun the maximal binding energy E_{gr} is reduced by the ratio $[M(Earth)/M(Sun)] \times [R(Sun)/R(Earth) = .071$. In the case of protons with $E_{gr}(Earth, p) = .5$ eV this gives to $E_{gr}(Sun, p) = .14$ eV, which happens to be roughly twice the energy assignable to membrane potential. For electrons this gives $E_{gr}(Sun, e) = 1.8 \ \mu \text{eV}$.

For the energy transfer in photosynthesis, the energy of the solar photon cannot therefore correspond to the change of gravitational binding energy in the case of electrons. Rather, the energy must be identified as the change of electromagnetic binding energy as an atom is effectively ionized when an electron becomes a dark electron at the MB. This MB need not be gravitational and could also correspond to a relatively small $h_{eff} > h$.

- 3. What comes to mind are dark unpaired valence electron states of atoms in which the h_{eff} of an unpaired electron increases so that binding energy is scaled down by $1/h_{eff}^2$. The binding energy spectrum of the dark electron states is obtained by scaling the ordinary binding energy spectrum and these states are analogous Rydgerg states in that the radius of Bohr orbits is scaled up by h_{eff}^2 . If the valence electron becomes gravitationally dark $(h_{eff} = h_{gr})$, the atom effectively suffers ionization to a state with vanishing energy and positive charge. Dark ions could correspond to this kind of states.
- 4. How could the energy transfer to the reaction center take place? The simplest mechanism could be the following. One can charge the solar energy batteries by transforming ordinary electrons to dark electrons at the MB of the Sun. At the reaction center the dark electrons drop back and transform to ordinary electrons and are available for the photosynthesis proper, storing the energy to biomolecules.

The experimental findings could be consistent with the assumption that the pairs formed by a dark electron and hole move to the reaction center, and the movement of the dark electron is analogous to a conduction in a lattice by hopping. The lattice could correspond to the tetra-icosahedral tessellation assignable also with DNA and genetic code. The time for one transition would correspond to $T_{gr}(Earth) \sim 15ns$. This supports the view that the MB of the Earth is present.

5. Why would the dropping down to Earth take place in the reaction center? The holes have an effective positive charge because the dark electrons have a large distance to the surface of Earth. If the reaction center has a negative charge, it attracts the positively charged holes. The holes move towards the reaction center and the dark electrons and gravitational monopole flux tubes and dark electrons follow. The electrons transform to normal ones and holes disappear. The predicted negative charge of the reaction center serves as a test for the proposal. 6. How this negatively charged region in the reaction center could be generated? Pollack effect [I110, L20, I197, I162], discussed from the TGD point of view in [L20], is caused by (say) IR radiation in the presence of gel phase, and indeed generates negatively charged exclusion zones. The exclusion zones could be due the transfer of protons of water molecules to dark protons at the flux tubes of the MB, which is however not gravitational. Both cells and DNA represent examples of negatively charged objects. Pollack effect is indeed a key element of the TGD inspired view of living matter. There it is natural to assume that the exclusion zone is present also in the reaction center.

If the energies of dark electrons and holes are separately conserved, they can annihilate to the ordinary electron in the reaction center. Can this be true?

- 1. Why would the energy of the dark electron be conserved in the hopping along the tessellation? Single step would correspond to a motion under the magnetic Lorentz force, which conserves energy since force is orthogonal to the velocity.
- 2. What about the dark electron-hole interaction? This interaction is present if the flux tube follows the motion of the hole-dark electron pair. This pair would form a bound state analogous to the Cooper pair and its energy would be conserved if its scattering would reduce to the magnetic scattering of the dark electron. The situation would be very much like in the case of superconductivity.
- 3. If the hole corresponds to a transition of an unpaired valence electron to a large h_{eff} analog of a Rydberg state with a very large size, the binding energy and energy of the state is very near to zero. The ionization energy scale for valence electrons is measured in electron volts just like for the photons from the Sun.

The energy scale for icosa-tetrahedral honeycomb scaling like $\hbar_{eff}^2/(2m_eL^2)$, L the size of the fundamental region, gives an estimate for the unit of energy quantization, which does not depend on \hbar_{eff} . The energy scale is 10^2 eV for L = L(151) = 10 nm. This scale is expected to be very large as compared to the energy gap so that transitions are not possible. The situation would be like in superconductivity and superfluidity.

4. What about energy conservation in the motion of the localized valence hole? Valence electron hole can be replaced with the valence electron of a neighboring atom and this makes possible its movement towards the negatively charged reaction center. The energy of the valence hole in the center of mass system of the atom is not changed but the ionized atom or the molecule containing it would experience the Coulomb force assumed to be associated with the reaction center and its center of mass energy can change.

How is it possible that the attractive Coulomb field between the hole and the reaction center does not affect the energy of the valence hole? The question is well-motivated The Coulomb energy between the hole and the reaction center is expected to be much larger than the energy gap. For instance, for distance of 1 μ m the Coulomb energy between unit charges is of order 10^{-2} eV.

What prevents the valence hole from accelerating and getting more energetic? The U-shaped gravitational magnetic flux tube has a string tension and the lengthening of the flux tube could compensate for the Coulomb force. The Coulomb energy would be transformed to elastic energy of the flux tube. In the reaction center the flux tube would contract and the dark electron could fuse with the hole having the same energy.

Is this picture consistent with the quantum gravitational storage of metabolic energy?

Is this picture consistent with the earlier proposal for the metabolic energy storage, which is based on the notion of gravitationally dark protons [L183] and also predicts electronic metabolic energy currency of about .25 meV for which there is some evidence [I45]?

1. The motivation for the proposal is that the gravitational potential energy of a proton at the surface of Earth is .5 eV: this happens to be the nominal value of metabolic energy quantum. Of course, since the electromagnetic binding energies in molecular scale are measured using

eV as units, this might be a pure accident. The weaker optimistic interpretation is that this co-incidence makes possible interaction between quantum gravitational and quantum electromagnetic degrees of freedom.

When the distance from the surface of Earth in the direction of the Sun, the gravitational forces of Sun and Earth are identical. This condition gives an upper bound for the distance r(Earth) of the particle from the Earth in the direction of Sun as $r(Earth)/AU - r(Earth) = \sqrt{M(Earth)/M(Sun)}$ giving $r(Earth) \simeq 100R(Earth)$ to be compared to the distance of Moon about $r(Moon) \simeq 60R(Earth)$. The value of the gravitational potential difference as is 99% of the maximal one.

The proposal [L183] is that the transformation of protons of water molecules to gravitationally dark protons could serve as a mechanism for the storage of metabolic energy.

If the metabolic energy quantum is determined *solely* by the gravitation of Earth, this mechanism does not work at large distances from the surface of Earth. The fact that Moon travellers have survived does not favor a purely gravitational mechanism but the fact that molecular binding energies are of the same order, might save the mechanism. A more imaginative option is that the gravitational MB of the Moon traveller is still associated with Earth and makes it possible to store metabolic energy to the gravitational MB of Earth.

- 2. Dark protons triplets could serve as a storage of metabolic energy in the case of ATP (high energy phosphate bond) and maybe even in the case of biomolecules. This is supported by the appearance of 3 protons as a kind of basic unit in ATP \rightarrow ADP metabolic machinery.
- 3. In the Pollack effect, IR radiation effectively ionizes water molecules and produces effective stoichiometry $H_{1.5}O$ inside a negatively charged exclusion zone. The decrease of the electronic binding energy per water molecule in the Pollack effect could be naturally given by the energy of the IR photon and would be rather small. If the Coulomb binding energy quantum E = .5 eV, the reduction of the gravitational binding energy in the transfer of dark proton triplet to the gravitational MB would be given by E and would lead to a zero energy state. Could one the build-up the energy carrying bio-molecules by transferring dark proton triplet to the gravitational magnetic bodies of the biomolecules by using the energy liberated by dark electrons as they drop down and transform to ordinary electrons in the reaction center?

12.8 Appendix: Basic facts about cilia and flagella

Intermediate filaments, actins and microtubules (MTs) are basic structures of cytoskeleton. MTs are associated with centrosome, cell membrane protrusions known as cilia, flagella, and axons (https://cutt.ly/FDnfEVP). Axonal MTs and part of MTs in the cell interior are dynamical and have a varying length. Actins are protrusions of the plasma membrane protrusions known as microvilli (https://cutt.ly/HDRaxxf) are analogous to cilia.

Cilia, flagella, axons, and microvilli are involved with motor activities of some kind. In the case of MTs and actins, contractions and lengthenings define the basic element of dynamics. Actin dynamics relates to the gross motion of the cell. The dynamics of axonal MTs might also relate to the nerve pulse conduction. Axonal MTs are not organized into regular structures like the other MTs.

Motile cilia and flagella are precedessors of muscles and motor system. Primary cilia function as antennas and act as mechanical, chemical, and thermal sensory organs.

12.8.1 Structure and function of cilia

Cilia start from the basal body. One can distinguish between primary and motile cilia (https://cutt.ly/IDnfKAB). Unlike motile cilia, primary cilia do not beat and dynein arms and other structures needed for motion are missing. These cilia act as antennas and sensory receptors. All sensory cells have cilia playing the same role so that cilia could be seen as cellular sensory and motor organs.

- 1. Cilium is a cylindrical protuberance of the plasma membrane. Its radius is about $.1 \ \mu$ m to be compared with axonal radius radius about $.25 \ mum$. The length of cilium varies in the range 1-30 μ m.
- 2. Inside cilium is its cytoskeleton known as axoneme. For motile cilia the MTs of the axoneme have 9+2 structure and for primary cilia they have 9+0 structure. For the basal bodies the structure consists of a ring of 9 MT triplets without central MTs. Vertebrates can also have other types of cilia.
- 3. The 9 pairs of the ring are partially overlapping, which makes it possible for them to glide with respect to each other: this induces the bending of the motile cilium. The tubulins of these pairs are horizontally connected by nexin bonds to form a ring-like structure. Radial spokes and outer and inner dynein arms force the gliding motion.

The pairs or rings consist of two kinds of MTs. The MT of type A has 13 tubulin protofilaments and MT of type B has 10 protofilaments. In motile cilia and flagella, structures essential for motility, such as axonemal dyneins, radial spokes, and the nexin dynein regulatory complex (N-DRC), are arranged on DMTs with a 96-nm repeating unit.

4. The members of the central pair are non-overlapping MTs connected by a bridge. The center MTs are involved with the control of the ciliary motion induced by the gliding.

Stabilization of cilia MTs is by inner lumen proteins. The structure and protein composition of motile cilia and flagella are well conserved among eukaryotes.

12.8.2 Beating waves

Cilia and flagella have similar structures and only their functions differ. Cilia force liquid to move with respect to the cell. Flagella make it possible for the cell to move with respect to liquid (https://cutt.ly/TDngqhO). The force needed for cilia beating is produced by the outer and inner dynein arms of the axonemal microtubule doublets connected to the central pair of microtubules by radial spokes. Airway cilia have components typical for motile cilia.

- 1. Motile cilia and flagella beat in a synchronized pattern. This coordination is achieved by metachronal rhythm, in which a wave of simultaneously beating groups of cilia moves from the anterior to the posterior end of the organism. The motions of cilia along the cell surface have different phases so that the motion looks like a wave: mexican wave (https://cutt.ly/iDRUehV) is a good example of this. The waves in the crop field induced by wind serve as a good example.
- 2. The cilia on the same line perpendicular to the direction of the effective stroke are synchronized and thus have the same phase, and adjacent rows of cilia parallel to the direction of the effective stroke beat with a phase difference.

Beating corresponds to a contraction wave and here the dynein arms are in an essential role. Orientation, beating frequency, wavelength, amplitude parametrize the motion of cilium.

- 3. Waves begin from cilia rather than the basal body so that the obvious idea that the cell would initiate the motion, need not be correct. Various wave forms such as plane waves and non-symmetric waves cause the bending.
- 4. The beating frequency varies in EEG range, which need not be an accident. Some sources report beating frequencies in the range 4-10 Hz. Some sources report 20-60 Hz frequency (https://cutt.ly/uDngfy0).

Chapter 13

Comparison of Orch-OR hypothesis with the TGD point of view

13.1 Introduction

Diosi-Penrose variant of the Orch-Or [J18] model constrains the range of the separation parameter R, also called the resolution scale of matter density, and predicts that weak em radiation accompanies Orc-OR, which are not predicted by the original Penrose model [J41]. Two years ago experiments by Donadi et al carried out in Gran Sasso underground laboratory failed to detect the predicted radiation [D5] (see https://cutt.ly/JJ569SI or arXiv version https://cutt.ly/ZJ56482).

These conclusions have been strengthened in a theoretical article by Diosi et al [J14] (https: //cutt.ly/8J6qdD8) inspired by these experimental findings. The authors represented theoretical arguments leading to the conclusion that D-P theory theory is highly implausible with reasonable values of the scale parameter R.

According to the abstract of [J14], partial separation, applying at the microtubular (MT) level, requires the brain to maintain coherent superpositions of tubulin of such mass, duration, and size that vastly exceed any of the coherent superposition states that have been achieved with state-of-the-art optomechanics and macromolecular interference experiments. The conclusion is that none of the scenarios discussed in the article (with a possible exception to the case of partial separation of tubulins) are plausible. There is also a popular article (https://cutt.ly/KJ6qrPp) briefly summarizing these conclusions.

In the sequel Penrose view about gravitational state function collapse, Penrose-Hameroff (P-H) model (P-H model) and Diosi-Penrose (D-P) model are discussed from the TGD point of view.

13.1.1 Penrose theory

It is appropriate to briefly summarize the assumptions of the original Penrose theory [J41] for quantum gravitationally induced state function collapse.

1. Quantum superpositions for masses in different configurations have different gravitational energies. Also gravitational fields must appear in quantum superposition. However, since a theory of quantum gravitation is lacking, it is not clear how to mathematically formulate this intuition.

The description of the two states with different self-interaction energies relies on a classical non-relativistic description of gravitation. When two configurations in the superposition are known, it is in principle straightforward to calculate the difference E_g of self-interaction energies.

The basic hypothesis is that the superpositions of gravitational fields of different configurations are unstable against collapse. For simplicity a superposition of two configurations is assumed.

2. An intuitive estimate for the duration of the state ending with collapse is based on Uncertainty Principle:

$$au \sim \frac{\hbar}{E_g}$$
 .

 τ inversely proportional to E_g . τ is suggested to correspond to a typical time scale of human consciousness via the formula $\tau = \hbar/E_g$. The value of E_g is extremely small, which makes gravitational quantum coherence extremely vulnerable.

3. One must somehow characterize the states appearing in the superposition. The notion of separation distance R characterizes ΔE_g . The value of R must be guessed. This is not easy since the very definition of R remains unclear, at least to me. One could take R only as a phenomenological parameter characterizing the resolution scale.

Alternative identification would be as a separation distance. Separation would mean creation of a superposition of two classical configurations for which internal gravitational energies differ. As if the distance between nucleons of nuclei or between nuclei of atoms had changed by length R. For nuclei (atoms) R would correspond to the nucleon (nuclear) size scale.

Coherence is required in the sense that the change of gravitational energies tends to be of the same sign for all particles. Otherwise the change E_g of the gravitational self-interaction energy is expected to be vanishingly small to give short enough $\tau \simeq \hbar/E_q$.

4. Since the change of gravitational interaction energy for all particle pairs must be of the same sign, the replacement of R as a scaling parameter comes into mind: different configurations would differ by a scaling.

13.1.2 Penrose-Hameroff theory of consciousness

Penrose's view about gravitational state function reduction [J41] is part of the Orch-OR proposal of Penrose and Hameroff [J28, J24, J27]. The duration of the quantum gravitational coherence must last long enough, of the order of the typical time scale of conscious experience or possibly time between two conscious experiences. Perturbations should not induce a too fast decorence: in standard quantum theory this looks unavoidable.

- 1. Microtubule (MT) hypothesis states that MTs are systems able to appear in quantum gravitational superpositions. Why this should be the case, remains unclear to me.
- 2. Superpositions of MT configurations must last long enough. τ could correspond either to the duration of conscious experience or time between two moments of consciousness. τ should be long enough and is estimated to be in the range 5 sec- 10^{-2} seconds. $\tau = \hbar/E_g$ gives an estimate for E_g , which is extremely small, of order 10^{-13} eV for $\tau = .1$ seconds corresponding to 10 Hz frequency in alpha band. Extremely small energies (in comparison to metabolic energy quantum of about .5 eV) are involved and one can argue that electromagnetic interactions unavoidably spoil the gravitational quantum coherence in standard quantum physics framework.
- 3. The separation scale R appearing as a basic parameter must be estimated or rather, guessed. The problem is that the definition of R does not have clear geometric meaning. Atomic separation of order nuclear or nucleon size scale for Carbon atoms is assumed as a working hypothesis. The rate for a collapse in the case of a single Carbon atom can be estimated from the dimensional estimate for the change of the gravitational energy as $E_g \simeq Gm^2/R$. The change is assumed to have the same sign for all Carbon atoms so that this estimate is multiplied by the number of Carbon atoms. $\tau = 25$ ms is assumed from a 40 Hz synchrony time scale. The gravitational quantum coherence of $N \sim 10^{11}$ tubulins is required with this assumption.

Tubulin has a mass of 50 kDa, and Da corresponds to proton mass. This makes a mass of $5 \times 10^{16} m_p = 3.9 \times 10^{-4}$ Planck masses. The length of a structure containing 10^{11} tubulins forming a cylinder of parallel 13 MTs, each consisting of 13 tubulin units of length about 10 nm, would be of order 15 m so that a single axon cannot satisfy the constraints. Empirical inputs restrict the value of R. Shifts of the nuclei would be measured in femtometers:R = 2.5 fm. 1 nm scale separations for electrons would be required.

The following items summarize what I found difficult to understand.

- 1. The changes of gravitational interaction energies should have the same sign in order to guarantee that τ is not too large. Scalings would satisfy this constraint. The notion of separation scale does not code for this intuition.
- 2. What about the changes of electromagnetic energies induced by the separation? Can they be the same for the states of superposition so that only gravitational energy would be liberated in Orch-OR?
- 3. Why would microtubules be so special? Why not for instance axonal membranes or DNA?
- 4. The idea that consciousness consists of moments identifiable as quantum jumps is attractive but in conflict with the idea that conscious experience has a duration. This has been a decades-long headache also in the TGD framework. Could the quantum jump be the beginning of a conscious experience and the next quantum jump the end of it? Could one have a kind of holography of consciousness with quantum jump as analog of the 3-D boundary of space-time coding the information determining the contents of conscious experience: this is the most recent TGD view [L192]. Also self hierarchy as analog of various geometric hierarchies of TGD would conform with the idea that the structures for the physical world and conscious experience reflect each other. A category theorist might speak of a functor between physics and consciousness.

13.1.3 Diosi-Penrose theory

Diosi-Penrose (D-P) theory involves the additional prediction that Orch-OR involves also weak emission of electromagnetic radiation. This emission is argued to take care of energy conservation, which both Penrose and Diosi, regard as an unphysical feature.

It must be emphasized, the loss of classical conservation laws defines the basic problem of general relativity since the isometries of Minkowski space-time are lost and Noether's theorem cannot be used to derive the existence of energy, momentum and angular momentum. It was just this problem, which led to TGD.

I must confess that I really do not understand the mechanism of energy liberation proposed by Diosi. The following is only my humble attempt to understand.

1. One would have a superposition of two states with different gravitational self-interaction energies. In a non-relativistic Newtonian mechanics, one can in principle assign well-defined energies to them. Also changes of electromagnetic interaction energies and kinetic energies of particles must be taken into account. The changes of both gravitational and electromagnetic interaction energies and changes of particle energies can be computed classically if the two configurations are specified precisely.

This is because the separation scale R, whatever it might mean, does not induce only a change of gravitational energy but also of electromagnetic interaction energies and kinetic energies. Stationarity assumption simplifies the situation.

In short scales, the changes of electromagnetic interaction energies have a completely different order of magnitude than gravitational interactional energies and this does not add to the plausibility of quantum gravitational coherence. In longer scales electromagnetic interaction energies are expected to compensate each other. Since gravitation is not screened, the situation can be and, in the case of MTs, should be different for gravitation.

A solution of the objections might be based on a precisely defined notion of scale hierarchy allowing to separate gravitational and electromagnetic interactions.

2. The predictions depend on the resolution scale R of mass density identified also as a separation distance R. R can correspond a) to tubulin protein scale (partial separation),
b) atomic nuclei (R ~ 2.5 Fermi for Carbon atoms), or c) its nucleons. By estimates, R should be of order nuclear size scale or even of nucleon size (b) and c)).

The interpretation of the R has remained unclear for me. The illustrations of popular talks suggest an interpretation as a distance between copies of the system at different positions self-interaction energies for two configurations differing by a shift are the same.

If the shift occurs in the relative radial coordinates for the parts of the system and if one stays in the framework of general relativity, it is difficult to avoid the interpretation as scaling. Both local and global scalings could be considered. It however turns out that TGD allows a more elegant view [L183].

3. What about the total energies of the superposed configurations? If the state with a higher energy is less probable, the collapse tends to lead to a less energetic state and the collapse liberates energy.

The amount E_g of liberated gravitational binding energy liberated would be extremely small for $\tau = \hbar/E_g \sim .5 - 10^2$ sec, which corresponds to energy $E_g \simeq 10^{-12}$ eV. Here $E_g = N \times e$ refers to the total liberated energy. The total liberated energy would be proportional to the number of basic units in quantum coherence. For $R = \hbar/m_p$ and proton as a basic unit, this would give $e = Gm_p^3 \sim 10^{-38}m_p$. Roughly $N = 10^9$ protons would be required.

It would seem that in the Diosi-Penrose model the liberated energy must be be essentially electromagnetic and kinetic energy. It is difficult to make any estimates without a detailed model. In any case, the electromagnetic energy would dominate at least in short enough scales.

- 4. The collapse is assumed to be a Poisson process: this reduces its description to a single particle level corresponding in scale R. Momentum changes should be random so that only dissipation visible as an increase of temperature should result. Temperature change is the measured observable.
- 5. Despite the incoherence for em interactions, the changes of gravitational self-interaction energies at single particle level should add up coherently. It is not easy to understand how gravitational coherence in long scales is possible if everything reduces to a single particle level and electromagnetic energy dominates. The existence of length scale hierarchy suggests a possible solution to this problem. The separation of electromagnetic and gravitational degrees of freedom however requires new physics.

To sum up, if the superposed states differ by scaling instead of R, the changes of both gravitational and em interaction energies could be estimated in the general relativistic framework from their scaling behavior and one obtains simple expressions. The estimate for the changes of kinetic energies requires some assumptions.

In the TGD framework scaling hypothesis is not necessary and for the already proposed mechanism of metabolism [L183] the space-time surfaces in the superposition do not differ by a scaling. However, it turns out that scaling induced density fluctuations could play an important role also in the TGD based view about quantum gravitation.

13.1.4 Empirical test of Diosi-Penrose theory

D-P model has been empirically tested by Donade et al [D5] (https://cutt.ly/qKszmNC). Authors estimate the rate for the emission of radiation predicted by the D-P model, which is faint but detectable. Also a dedicated experiment at the Gran Sasso underground laboratory to measure the emission rate is reported. The null result sets a lower bound on the effective size of the mass density of nuclei, which is about three orders of magnitude larger than previous bounds. This rules out the natural parameter-free version of the Diosi-Penrose model.

1. The weak radiation would relate to the change of electromagnetic energy induced by the change of gravitational self-interaction energy of charged particles. The radiation is assumed

to be a single particle phenomenon occurring spontaneously as a Poisson process in short scales even without the quantum coherent superposition of gravitational fields. Therefore it is argued that a gravitational long length scale quantum coherence need not be present and non-biological systems can be used in the test. As explained, this hypothesis remains rather unclear to me since no detailed mechanism is proposed: only the existence of the radiation is proposed.

One must consider a system exhibiting quantum coherence in a long enough scale. This quantum coherence is assigned with conduction electrons. A shielded germanium detector is used.

- 2. The mathematical treatment, discussed in the Appendix of [D5], is based on the evolution equation for the density matrix containing operator terms representing matter Hamiltonian and gravitational self-interactions. The collapses at single particle level give rise to diffusion as charged particles liberate energy in gravitational collapse.
- 3. No emission was detected within the wavelength range corresponding to nuclear-atomic length scale range and therefore photon energies in the range $10 10^5$ eV. Note that the large energy scales suggested by Uncertainty Principle suggest that something is badly wrong with the model. If quantum gravitational coherence in biological scale is involved, this is not expected.

The separation scale R should be longer than atomic scale but this is excluded theoretically because the rate of spontaneous collapse would be quite too slow so that decoherence caused by other interactions would prevent long enough coherence time τ for Orch-OR.

In the sequel TGD based view of how quantum gravitation is present in quantum biology [L183, L189] is briefly summarized and compared with the ideas and models of Penrose, Hameroff and Diosi.

13.2 Comparison with TGD based approach

Quite recently, the role of quantum gravitation in the biology of the TGD Universe has been considerably clarified [L183, L189]. This includes quantum gravitational models of metabolism, biocatalysis, and the analog of topological quantum computation.

The TGD view about quantum gravitation differs in many aspects dramatically from that of Penrose. What is common is the vision about quantum coherent superpositions of space-times, now space-time surfaces, as also the proposal that MTs might have a special role as also water. The reason would be quantum criticality making possible long length scale quantum fluctuations, which can be described in terms of the effective Planck constant h_{eff} labelling phase of ordinary matter behaving like dark matter [K38, K39, K40, K41]. By its huge value, $h_{eff} = h_g r = GMm/v_0$, introduced originally by Nottale [E1], would be most important for biology and consciousness at brain level [K85, K18] [L171, L168].

For these reasons, it is interesting to find how the TGD view relates to P-H and D-P models.

13.2.1 TGD inspired quantum gravitational view about metabolism and nerve pulse conduction

A considerable progress in the understanding of quantum gravitational aspects of quantum biology in the TGD framework has taken place recently [L183, L189].

1. The TGD based view about cell and neuronal membrane, nerve pulse and EEG assumes pre-neural level, which is quantal. In this view, cell membranes act as Josephson junctions and communicate sensory input to the magnetic body (MB) of the system as dark Josephson radiation. MB in turn controls the cell by dark cyclotron radiation produced as pulses as MB receives frequency modulated Josephson radiation resonantly.

Number theoretic vision implies the notion of Galois confinement [L157], which inspires the notion of a dark N-particle, which consists of N dark particles as an analog of the color confined state of quarks. Dark 3N-protons and dark 3N-protons as fundamental representations

of genetic code are central for the TGD inspired quantum biology [L136, L159]. Cyclotron 3N-resonance for dark 3N-photons makes possible targeted communications and control with gene defining the address of the receiver like in LISP and frequency scale modulation defining the signal transformed to N-cyclotron resonance peaks.

2. Gravitational MB of Earth, which consists of very long U-shaped tentacle like flux tube loops with a scale of the Earth radius with gravitational Planck constant \hbar_{gr} introduced by Nottale [E1] explains the findings of Blackman [J7] and others about physiological and behavioral effects of ELF radiation in EEG rane, is of special interest and assumed to play a key role in metabolism. Gravitationally dark protons would be associated with very long gravitationally dark hydrogen bonds (HBs) so that hydrogen is effectively negatively ionized.

Gravitationally dark electrons or their Cooper pairs would in turn accompany gravitationally dark valence bonds connecting metal atoms or their Cooper pairs with molecules of opposite valence (hydrogen peroxide H_2O_2). Also the metal atom is effectively ionized. This provides a more accurate view of dark metal ions assumed to play a central role in the TGD inspired quantum biology.

3. The estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary is of a correct order of magnitude. A more precise model predicts correctly the nominal value of metabolic energy quantum for proton triplets which appear also in the generation of ATP.

For triplets of electron Cooper pairs, the same mechanism predicts an upper bound of the electronic metabolic energy quantum, which corresponds to the so-called miniature potential of few meV. This raises the question whether the letters of genetic code could be realized by the 4 states of electron Cooper pairs and whether the Posner molecule could realize it [L183].

- 4. Electronic metabolism would solve the problem due the lack of ATP machinery inside cilium and near it. This picture leads to a rather detailed model of the role of phosphate in metabolism and also to a detailed model for the pairing of DNA and dark DNA (DDNA) and forces to modify the earlier model somewhat.
- 5. Also the gravitational MB of Sun could be involved, and the prediction is that the energy range for the metabolic energy quanta corresponds to the range of visible energies so that photosynthesis could use photon energy to kick dark protons and dark electrons to the gravitational MBs of Earth and Sun to serve as metabolic energy storage.

The quantum gravitational view about metabolism leads also to a modification of the views about nerve pulse conduction [L183].

- 1. In the quantum model, the cell membrane acts as a *generalized* Josephson junction for biologically important dark metal ions. These ions are identified as gravitationally dark effective ions with gravitationally delocalized electron Cooper pairs.
- 2. The delocalization of protons and possibly also electrons to gravitational bonds provides a concrete realization of the Josephson junction model in which the ground state of the axon corresponds to a soliton sequence, which has a sequence of rotating gravitational penduli as a mechanical analog [K92]. Action potential would correspond to a soliton (or several solitons) with an opposite direction of rotation. One cannot exclude the option that the ground state corresponds to a propagating wave of small oscillation and the nerve pulse to a soliton or several solitons.
- 3. The conduction of neural signals through the myelinated portions of the axons, where nerve pulse is impossible, remains a still unsolved problem of neuroscience. The formation of dark hydrogen- and valence bonds leads to an effective ionization, which takes membrane potential below critical value for the generation of nerve pulse, which is generated in the unmyelinated sections.

The critical dynamics of microtubules (MTs) involves variation of MT length relying on $GDP \rightarrow GTP$ transition, which involves the change of MB to gravitational MB and vice

versa changing the local membrane potential. Therefore MT dynamics makes possible the propagation of the action potential. The effect of anesthetics can be understood in terms of reduced density of HBs preventing the formation of gravitational HBs so that MTs and the axonal potential freeze.

4. A model of the pre-neural system [L183], based on the gravitational MB and the predicted electronic metabolic energy quantum, is developed in order to explain how animals without a nervous system behave as if they had the brain. These animals move using cilia/flagella, which have no mitochondria inside them or in their vicinity. This suggests that the electronic metabolism could replace the usual metabolism.

Quantum gravitation in the TGD sense also provides insights about bio-catalysis and topological quantum computation-like processes [L189, L195].

Dark-electron hole pairs as a signature of gravitational metabolism

An intriguing resemblance between the physics of electron-hole pair Bose-Einstein condensates at very low temperatures and photosynthesis have been discovered. The findings are described in a popular article at (https://rb.gy/fnv3j). The original article of Schouten et al [I179] can be found at https://rb.gy/b982c. It has been observed that electron-hole pairs as quasiparticles form Bose-Einstein condensates at very low temperatures. They behave very similarly as in living matter where temperature is much higher and these Bose-Einstein condensates should not exist.

1. TGD predicts dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ (*n* integer, $h_0 < h$) residing at field body (in particular, at the monopole flux tubes of the magnetic body (MB)) defining the TGD counterpart for classical em fields in TGD as collection of space-time sheets carrying classical fields.

The large value of h_{eff} makes these phases macroscopically quantum coherent and analogous to Bose-Einstein condensates. This leads to a variety of predictions. In particular, the magnetic body (MB) would be in a key role in living matter controlling the ordinary biomatter and forcing it to behave coherently. The very large value of gravitational Planck constant $h_{eff} = h_{gr} = GMm/\beta_0, \ \beta_0 = v_0/c \leq 1$, makes possible gravitational quantum coherence at the gravitational MB and the classical gravitational fields of Sun and Earth play a key role in quantum biology: this is reflected by many magic numerical co-incidences [L178].

- 2. The strange effects in the brain (the quantal effects of ELF em fields in the brain) originally led to the TGD view of dark matter, which is also predicted by the number theoretical vision of TGD. For instance, superconductivity and analogous phenomena are possible at room temperatures at MB of the system. The TGD based model of high Tc superconductivity relies on them [K89, K90, L153].
- 3. One interesting structure is a pair of a dark electron and the hole created as the electron becomes a dark electron at MB. The quantum numbers of holes and dark electrons are in 1-1 correspondence, and this could make possible a kind of quantum holography mapping the state of holes to that of dark electrons. This would provide representations of biological body (BB) at MB as kinds of sensory perceptions about the state of BB [L203].
- 4. The transfer of electrons to dark electrons can cause electronic charge fluctuations in ordinary matter due to the transfer of electrons to dark electrons at MB. For strange metals, these fluctuations have been observed: it is difficult to understand them as being caused by the attachment of electrons to atoms of strange metal since the time scale is too long (https://rb.gy/ws51f).

The reported experimental findings about a connection between electron-hole pair BEcondensates at low temperatures and photosynthesis can be seen as a support for the TGD view of dark matter and living systems. In particular, the TGD view would be important for understanding photosynthesis and other proposals for how quantum physics could be relevant for biology. For instance, the model for the ability of birds to navigate by utilizing the magnetic field of Earth suffers from a problem that the ordinary Planck constant is too small by a factor of order 1/100.

- 1. The TGD explanation of the new findings is in terms of the hierarchy of Planck constants labelling dark matter as phases of ordinary matter. Gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$, $\beta_0 \leq 1$, labels a levels of hierarchy, which are of special importance in the TGD based model of living matter.
- 2. In TGD, one could have Bose-Einstein condensates of hole-dark electron pairs. Dark electrons would reside in a very long gravitational flux tube and would be kicked to height of order Earth radius by solar photons during photosynthesis. They would serve as a metabolic energy resource: gravitational batteries would be loaded in photosynthesis. When dark electrons drop down and transform to ordinary ones, they liberate energy which can be stored or used. ATP-ADP process could involve this dropping down.

Also dark protons could be transferred to magnetic fux tubes. This would take place in Pollack effect in which irradation of water in the presence of gel phase leads to the formation negatively charged regions with effective stoichiometry $H_{1.5}O$. Part of protons goes somewhere and one possible place could be gravitational MB but also much shorter flux tubes for which dark proton corresponds to the size scale of DNA nucleotide are possible and would be important for the reaization of dark genetic codon. Perhaps the most plausible option is that triplets of dark protons and electrons are involved in the case of metabolic energy storage.

13.2.2 The P-H theory and TGD

One could end up with the analog of Orch-OR in the TGD framework via the following arguments.

1. Gravitation is an unscreened long range interaction. Therefore it is plausible that it should allow quantum coherence in arbitrarily long scales. The first guess for the coherence scale in the presence of a large mass is as Schwartschild radius $r_s = 2GM$: the analog of the quantum gravitational Compton length is indeed proportional to it. This however requires large values of Planck constants and leads to the TGD view of dark matter as $h_{eff} = nh_0$ phases of ordinary matter.

Note that in the P-H model the gravitational self-interaction energy was in a crucial role. In the proposed TGD based model for metabolism, for genetic code, and for the role MTs in the propagation of action potential, the interaction of dark electrons and protons with gravitational fields of Earth and Sun is in a key role. This suggests a strong dependence of life on the planetary environment [L183], which is not a good news for space travellers. The metabolic mechanisms relying on self-interactions would avoid this dependence.

2. One can indeed generalize the notion of gravitational metabolism to gravitational self-interactions for quantum critical systems of which MTs and water at physiological temperature range provide basic candidates. At quantum gravitational criticality these systems would define quantum superpositions of gravitational MBs with different values of $\hbar_{gr} = GMm/v_0$ and gravitational Compton length $\Lambda_{gr} = GM/\beta_0$, $\beta_0 = v_0/c$. β_0 is expected to have a discrete spectrum by number theoretic constraints and $\beta_0 = 1/n$ is the simplest option.

Also now the presence of a large mass M (planet, star or both) is needed in order to have large enough value of gravitational Compton length Λ_{gr} , which defines a lower bound for the quantum gravitational coherence scale.

- 3. The crucial finding is that binding energy of protons in the Earth's gravitational field is of order of the metabolic energy quantum .5 eV. A more precise model [L183] leads to the conclusion that metabolic energy quantum corresponds to 3 protons: the transfer of 3 protons through the cell membrane indeed takes place in ATP-ADP process. Also electrons give rise to metabolic energy quantum. Also the solar gravitational field gives rise to metabolic energy currency and this currency would be important in photosynthesis.
- 4. Intriguingly, the mass of a water blob of radius 17 μ m, the size of a neuron, equals the Planck mass. This suggests that Planck mass, rather than Planck length, is important in biology. The estimate for the gravitational energy of this water blob gives energy which is of the same order of magnitude as Coulomb energy ZeV = 0.05Z eV associated with the membrane potential. Could a cell define a gravitationally quantum coherent structure and could the
changes of the gravitational self-interaction energy serve as metabolic energy quanta? The changes seem to be too small if they correspond to scalings.

Furthermore, in the case Earth, the Schwartschild radius is .9 cm, which is a biological length scale and one has $\Lambda_{gr} = r_s/cv_0 = GM/v_0 = .45cm(c/v_0)$. One has $\beta_0 = v_0/c \simeq 1$ in a good approximation.

5. There are indications that β_0 is quantized to rational values. The space-time surfaces in the superposition would correspond to different values of β_0 and Λ_{gr}

Could different space-time surfaces assignable to MBs in the superposition correspond to different values of β_0 ? $\beta_0 = 1/n$? For n = 2, Λ_{gr} would be scaled up by factor 2. This need not imply scaling at the level of ordinary matter but could imply it at the level of MB. $\beta_0 = 1 - 1/n$ would allow arbitrarily small scalings of Λ_{gr} .

In the TGD framework, the space-time surfaces in the superposition need not be scaled variants of the ground state space-time surface. The gravitational binding energy of long gravitational flux tubes accompanying the gravitational HBs and VBs is reduced and would serve as a local metabolic energy resource. Could the number of potential metabolic energy quanta as the number of these bonds to the integer n appearing in v_0 ?

P-H hypothesis involves the assumption that MTs are quantum systems.

1. There is indeed evidence for MTs as quantum coherent systems [J1, J24] discussed from the TGD point of view in [L19]. In TGD the quantum coherence would be due to metabolic energy feed taking care that dark particles decaying back to ordinary ones can be re-created [L153]. Quantal flow equilibrium would be in question.

In TGD, a related crucial element is the hierarchy of dark matters labelled by $h_{eff} = nh_0$. The gravitational Planck constant GMm/v_0 would correspond to the top of this hierarchy and make possible gravitational quantum coherence in long scales.

- 2. In the TGD framework, one expects that MTs define an important level in the hierarchy of consciousness. The criticality of axonal MTs in the sense that their lengths are continually changing could be actually quantum criticality at the level of the MB of MT. This could make MTs special since quantum criticality makes a system an ideal sensory receptor and controller. The increase of h_{eff} in turn increases the cognitive resources of the system since algebraic complexity increases.
- 3. The transfer of protons from MTs to dark protons at its MB can indeed explain why the conduction of action potentials through the myelinated sections of the axon is possible. The charge of the MT region changes and this changes membrane potential and gives rise to action potential.
- 4. The inclusion of self-gravitation could add the ability of water to serve as a metabolic energy source gravitational self-interaction energy as a metabolic energy. One might hope that this allows us to overcome the dependence of metabolism on planetary gravitational fields. In fact, only water is able to do this.

Could the following picture make sense?

- 1. Superpositions of geometries are replaced in TGD with superpositions of space-time surfaces with quantum gravitationally important modifications assignable to the gravitational magnetic body. There would be no problems with energy conservation and the new view about space-time allows us to identify also MTs as and their MBs as space-time surfaces, which are minimal surfaces with singularities analogous to soap films with frames.
- 2. A lot of new physics emerges: number theoretical physics and geometric physics related by $M^8 - H$ duality, number theoretical h_{eff} hierarchy labelling dark matter as phases of ordinary matter; gravitational Planck constant $\hbar_{gr} = GMm/v_0$ characterizing particle of mass touching gravitational flux tube; and zero energy ontology (ZEO).

3. The crucial point is that the huge value of \hbar_{gr} would allow to avoid the loss of quantum gravitational coherence otherwise caused by the other interactions.

For $\hbar_{gr} = GMm/v_0 > \hbar$ one must replace \hbar with \hbar_{gr} meaning that $GMm > v_0\hbar$. The TGD based quantum gravitation becomes visible for particles of mass m in the gravitational field of large mass M at flux tubes with $GMm/v_0 > \hbar$. The gravitational Compton length $\Lambda_{gr} = GM/v_0 = r_s/2v_0$ does not depend on m and for Earth one has $\Lambda_{gr} = .45 \ cm/(v_0/c)$, which is a biological scale. Cyclotron frequencies for a charged particle with mass m are also independent of m. Josephson frequency $f_J = ZeV/\hbar_{gr}$ is dramatically smaller than for ordinary \hbar and corresponds to ELF frequency in the case of cell membrane.

- 4. Gravitational variants of hydrogen bonds (HBs) and valence bonds (VBs) as long U-shaped flux tubes are part of picture. Liberation of metabolic energy as an increase of gravitational binding energy as very long dark gravitational HB or VB becomes short. Metabolic energy quanta come as protonic and electronic variants differing by factor m_p/m_e . The masses of Earth and Sun have a central role. Also other masses involved but the proportionality of \hbar_{gr} to M means that these are the most important ones.
- 5. Gravitational energy difference would be roughly $\Delta GMm/R$ for a long gravitational flux tube associated with dark HB (VB) and short tube and corresponds to metabolic energy associated with the long HB (VB). A rough guess for the metabolic energy would be about .5 eV for proton. This would give time of order 10^{-14} sec corresponding to an energy of IR photon. For electron the metabolic energy in the meV range. A more careful estimates increase the number of protons and electrons to 3.

This would suggest that the space-time surfaces in the superposition correspond to spacetime surfaces with various numbers of potential metabolic energy quanta. These space-time surfaces are *not* scaled versions of the ground state space-time surface as in the GRT picture but analogous to the deformation of the surface of Earth by the presence of biosphere such as plants and trees. By fractaility. this kind of magnetic forests of U-shaped flux tubes would appear in all scales and first emerged in the model of atomic nucleus carring quarks.

In order to get some grasp on the new idea, one can play with numbers.

1. One can consider the analog of the P-H hypothesis $\tau = \hbar/E_g$ as $\tau = \hbar_{gr}/E_g = \hbar/R$ in the case of the gravitational flux tubes of Earth with size scale R determined by Earth radius R_E .

The time scale corresponding to dark proton flux tube of length of order Earth radius $R_E \sim 6.37 \times 10^6$ m would be $R_E/(v_0/c)$ and would give $\tau = 21$ ms for $\beta_0 = v_0/c = 1$. The time scale of nerve pulses is a few ms.

2. Also gravitational Compton time should have relevance. For $\beta_0 = 1$ one has $\tau = GM/c = r_s/2c$. For Earth this would give $\tau = 1.7 \times 10^{-11}$ s. For ordinary Planck constant this corresponds to an meV energy scale. So called miniature end plate potentials .4 mV (https://cutt.ly/HSJIn76) have this scale.

13.2.3 Could the space-time surfaces in the superposition correspond to different scalings?

The change of gravitational interaction energy should not be random and should be such that the changes of gravitational energy are of the same sign for all particles. The interpretation of the parameter R as a shift does not look plausible.

This does not leave many options in the GRT framework. The change of the gravitational interaction energy could be induced by a scaling also in TGD framework, but most naturally at the level of gravitational MB as scaling of magnetic flux tube thickness, whose thickness is naturally proportional to \hbar_{gr}/\hbar . This would conform with the underlying scaling invariance of TGD so that R should be replaced by a dimensionless scaling parameter $\Lambda - 1$.

1. Scalings are indeed natural in the TGD framework, where the analog of time evolution is assigned with scaling rather than time translation and p-adic thermodynamics with conformal weight rather than energy so that a discrete superposition of scaled variants of space-time surface would make sense. One option is that scalings correspond to different p-adic primes , perhaps near to each other. Scalings by say powers of 2 suggested by p-adic length scale hypothesis could make sense at the level of visible matter in critical situation involving large density fluctuations (as in the evaporation). In this case the quantum criticality of MB could induced criticality of the ordinary matter.

The scaling of flux tube thickness could correspond to that for the universal particle independent gravitational Compton length $\Lambda_{gr} = GM/v_0$ induced by the change of the velocity parameter as $\Delta v_0/v_0 \Delta \Lambda$. Small scalings would be possible and they would be realized for dark particles at gravitational flux tubes. Note that this requires the presence of a heavy astrophysical object such as a star serving also as a metabolic energy source.

- 2. The scale change would be proportional to the change of the scaling parameter $\Lambda 1 = \Delta \Lambda$. In the P-H model, the estimates for the separation scale R, whose interpretation seems to be as a shift, vary between nucleon size scale and size scale of tubulin protein (10 nm).
- 3. A simple estimate shows that for 10^{11} tubulins assignable 10 m long axon containing 13×13 tubulins per length of about 10 nm, the scale of gravitational self-interaction energy is of order 10^{-16} eV so that the interpretation of a reduction of gravitational binding energy for an analog of Orch-OR as a potential metabolic energy is excluded. The mechanism proposed in [L183] is the only possible mechanism involving only MTs (plus the gravitational field of Earth to make Λ_{qr} large enough).
- 4. For the TGD based quantum gravitational model of metabolism E_g has a scale of metabolic energy quantum and is many orders of magnitude larger than allowed by the constraint if it defines a time scale in a range 5 sec- 10^{-2} sec. For ordinary Planck constant, one would have $\tau \sim 10^{-13}$ sec. In the TGD framework $h_{eff} = \hbar_{gr}$ implies $\tau = h_{gr}/E_g$. For the Earth's mass, the time scale would be the desired one. This supports the hypothesis that cell interiors consisting of ordered water define gravitationally quantum coherent regions and the surfaces in the superposition differ by the number of gravitational HBs and VBs.

The metabolic mechanism based on gravitational HBs and VBs imply the dependence of life on planetary gravitational fields. However, metabolic autonomy could be of high relevance for the life on other planets and also for space travel (this is discussed from the TGD point of view in [L183]). Also the possible proto cells in interplanetary space could use a metabolism based on gravitational self-energy. The presence of a nearby star seems however necessary to guarantee that the quantum gravitational coherence scale $\Lambda_{gr} = GM/v_0$ is long enough. For biological systems, such as cells, it is extremely small.

Could the gravitational self-interaction energy of water serve as a source of metabolic energy and allow to circumvent this dependence?

1. Consider first the cell scale. Water blob of Planck mass $M_{Pl} = 2.2 \times 10^{-8}$ kg has size $R \simeq 1.74 \times 10^{-4}$ m, which corresponds to the size of a large neuron. In this case, one has $E_g = \Delta E = [\lambda - 1)/lambda]E_g$, $E_g \simeq GM^2/R \sim 7$ meV. Maximum energy gain is 3.5 meV, which is roughly 10 times the energy scale of miniature potentials and is by a factor of 10 smaller than the Coulomb energy scale $\sim .05$ eV assignable to the membrane potential. The energy scale corresponds however to the difference of Coulomb energies of cell membrane for opposite values of membrane potential.

If the system is critical so that large density fluctuations inducing the scaling of R and preserving M are possible, the scaling parameter $\Delta\Lambda$ characterizing the possible changes of water volume can be large. In this case, one could consider the possibility that some kind of metabolic energy needs could be satisfied.

2. Could larger water blobs, say those assignable to muscles, which indeed experience scale changes, help? For the entire body of mass of 50 kg and size scale of R = 1 m, the estimate for gravitational self-interaction energy is of order 6.4×10^{12} eV, which is about 10^{-6} J: lifting a weight of 1 kg to a height of 1 m requires 10 J. This option does not look realistic. Note also that the liberated metabolic energy feed cannot be targeted in a precise way.

3. Just for fun, one could also consider the entire biological body with (say) size R = 1 m and mass M = 50 kg and regard cells with mass of order Planck mass m_{Pl} as the dark particles at the flux tubes of its MB. The flux tubes connecting cells to each other would be stretched to gravitational flux tubes of length of roughly body size R. This option would allow a targeting of the metabolic energy by transforming the dark cell back localized to the biological body.

The estimate for the order of magnitude of a metabolic energy quantum $E = GMM_{Pl}/R$ for MB flux tubes of size R would be $E \sim .25$ eV, one half of the value of the metabolic energy quantum. As will be found, the change of the sign of the membrane potential involved with an action potential requires energy of 3.5 meV and this energy could be generated already by a mass $M \sim .5$ kg.

13.2.4 Could the TGD analog of Orch-OR make possible an action potential for protocells?

The idea about gravitational superpositions of space-time surfaces related by scalings looks interesting since the scalings could relate to the scaling of the parameter β_0 in $\hbar_{gr} = GMm/v_0$ and in Λ_{qr} in the case that the flux tubes correspond to the mass of Earth or Sun.

For the masses M of say living organisms Λ_{gr} is extremely small. The presence of a stellar object, having a gravitational field characterized by $\hbar_{gr} = GMm/v_0$ and $\Lambda_{gr} = GM/v_0$, is needed in order to have quantum gravitational coherence in biologically interesting scales.

Quantum gravitational phase transitions of water blobs as the TGD counterpart of Orch-OR?

Instead of Orch-OR, quantum gravitational phase transitions are suggestive in the TGD framework. The quantum gravitational superpositions would be associated with quantum phase transitions changing Λ_{gr} and perhaps also inducing a scaling of the system consisting of ordinary matter. This scaling would mean large density fluctuations affecting the gravitational self-interaction energy.

1. Ordered water forming a gel-like phase in the presence of biomolecules is a natural guess for what gravitationally quantum coherent phase could be. A membrane-like object separating proto-cell from environment is needed to create a volume of water with quantum gravitational coherence.

2-D membrane-like objects with 1+2-D M^4 projection, possibly pairs of them forming double membranes, appearing in these scales could serve as templates for membrane-like objects, which could have preceded cell membrane and also for the recent cell membrane. Their presence could have led to the emergence of lipid layers, which involve only hydrocarbons. These membrane-like objects form a fractal hierarchy and could accompany both galactic and planetary planes as walls and also the biosphere at the surface of Earth serving as analog of the cell membrane.

- 2. p-Adic length scale hypothesis and the number-theoretically miraculous appearance of 4 Gaussian Mersenne primes $L(k) \simeq 2^k$, k = 151, 157, 163, 167, between the cell membrane length scale and cell nucleus scale suggests that gravitational quantum coherence in these scales is involved.
- 3. Protocell as a pair of 2 membrane-like objects and as a template of cell membrane could define electric flux quantum as a counterpart of magnetic flux quantum. It would have carried an electric field as an analog of capacitor plates.

If the electric voltage is absent, only mechanical work is possible. The energy scale in mechanical thermodynamic degrees of freedom is however huge as compared to the energy scale in gravitational self-interaction energy degrees of freedom so that the change of gravitational self-interaction energy to mechanical work in the cellular scale is not possible.

Pollack effect [L20] caused by the stellar radiation could have generated the negative charge to the interior of the inner membrane. In principle, this requires the presence of only water.

- 4. One can imagine that the value of \hbar_{gr} characterized by the value of β_0 and associated with the stellar gravitational flux tubes, fluctuates locally and generates scaled variants of gravitational flux tubes in turn inducing density fluctuations and the thermodynamical criticality of water. Fluctuations would produce water regions with a reduced density analogous to a vapour phase.
- 5. The liberated self-interaction energy would be $E_{gr} \simeq (\lambda 1)GM^2/R$, where R is the size of the water blob, and scales like R^5 . λ is the scaling inducing also the scaling of $\Lambda_{gr} = GM/v_0 \rightarrow \lambda \Lambda_{gr}$.

At quantum criticality, assumed to induce thermodynamic criticality, the change of the free energy would be very small for the values of scalings in the superposition. The first guess is that by the quantization of $\beta_0 = 1/n$, one has $\lambda = n$. n = 2 gives 2-adic scaling and p-adic length scale hypothesis favoring $p \simeq 2^k$ could relate to these phase transitions. This picture makes sense if the criticality is analogous to that of boiling water.

For a water blob of Planck mass with $\beta_0 = 1/n$, the gravitational metabolic energy gain is below 3.5 meV, which corresponds to the miniature potential.

6. As already found, the gravitational self-interaction energy cannot be used to perform mechanical work in practice. Since the energy gains are in the meV range, a more promising option is that the energy goes to a creation of a pre-neuronal action potential. By the arguments of [L183], the metabolic energy quantum for electron based metabolism is of order .25 meV and miniature potentials about .4 meV. Action potentials are possible already for mono-cellulars and one can ask whether even a proto-cell could generate the analog of an action potential without the ATP-ADP machinery.

The scaling of the volume as a phase transition at quantum criticality could be present also in recent biology and one can wonder if the swelling of cells during infection could relate to this process.

Could the generation of gravitational self-interaction energy give rise to action potential?

The generation of gravitational self-interaction energy of a water blob with Planck mass liberates energy. Could it have given rise to an analog of action potential?

1. The gravitational self-interaction energy is of order $E_{gr} = GM^2/R$ and as a function of R scales like R^5 so that it is rather sensitive to the value of R. Already the scaling of R from 10^{-4} m by factor 3.1 transforms metabolic energy quantum of 3.5 meV to .5 eV.

For a fixed M, E_{gr} scales as 1/R. The analog of Orch-OR would be following. A superposition of different scalings of a water blob would be created much like in evaporation. After that a phase transition leading to a less dense state with definite scaling would take place. This requires metabolic energy provided by a near enough star. The phase transition back to the original situation takes place and liberates the metabolic energy.

2. When an action potential is generated, the membrane potential changes sign. In ZEO this could correspond to two BSFRs, each of which changes the arrow of time. The change for the arrow of time corresponds naturally to the sign change of V.

The change of energy in this process is $2QV = 2e^2V^2S/d$, eV corresponds to the Coulomb energy of membrane potential, Q = ES = VS/d is the charged assumed to be conserved in the transition, $S = 4\pi R^2$ corresponds to the area of cell membrane. Charge conservation gives V = d/S. The natural scaling is $d \to \lambda d$ and $S \to \lambda^2 d$, which gives $V \to V/\lambda$.

For $R = 10^{-4}$ m corresponding to Planck mass (large neuron size), d = 10 nm, and V = .05 V, the change of Coulomb energy of the membrane would be $\Delta E \simeq 6.3$ meV. The upper bound for the change of the gravitation binding energy was 3.5 meV corresponding to a scaling of 2. It would seem that the gravitational phase transition as a 2-fold scaling and its reverse could induce a proto version of the action potential.

13.2.5 How water blobs could have evolved into living organisms?

Quantum gravitational criticality could be assigned to water blobs. In interstellar space the possible metabolism would not depend on the planetary gravitational flux tubes but would depend on the mass M of the nearest stellar object. Stellar gravitational fields are indeed necessary for large enough gravitational Compton length GM/v_0 .

Important facts about water

Consider a water blob of radius R. The phase diagram of water (https://cutt.ly/EKx9nGX) allows to understand how thermodynamic criticality under normal conditions and during the prebiotic period could differ. There are two different situations to consider. When the pressure is above tricritical pressure P_{cr} , water allows liquid phase. Below P_{cr} , only solid and vapour phases are possible.

1. The normal physiological situation with normal pressure $P_{phys} = 1$ atm (101.325 kPa) in the vicinity of physiological temperature around $T_{phys} = 37$ C, which is between the freezing point and evaporation point. This kind of criticality could have been present for pressures above the tricritical pressure along a critical line.

The numerous thermodynamic anomalies of water suggest that it is quantum critical at the physiological temperature range between solid-liquid phase transition and liquid-gas phase transition. The temperature for this range is above T = 0 C. Quantum criticality would give rise to superposition of phases with different density and differing by scaling above the tricritical point.

Solid-liquid critical curve would naturally correspond to quantum criticality. Could some kind of life forms be associated with this criticality?

2. Below the tricritical point, the liquid water phase is absent so that the counterpart of the physiological quantum criticality is not possible. If the pressure is below $P_{cr} = 611.657$ Pa $\simeq .006P_{phys}$ and temperature below $T_{cr} = 0.01$ C, only solid and vapour phase are possible and criticality would be associated with the curve at which sublimation of ice takes place.

In particular, the situation with $T \simeq 30$ K would correspond to a very early prebiotic phase, when the age of the Universe was about 1 Gy and the cosmic temperature was about 30 K. In this situation, quantum criticality could relate to the sublimation and the density fluctuations associated with it and would involve a superposition of scaled variants of H_0^2 blob.

Snow flakes, Emoto effect, and Pollack effect: life at quantum criticality?

Suppose that solid-liquid solid-vapour critical curves correspond to quantum criticality. Could some kind of life forms be associated with these quantum criticalities?

1. Snowflakes (https://cutt.ly/sKJclSy) are amazingly ordered structures and appear in freezing and direct solidification of water vapour. Snow flakes do not have metabolism. Could snowflakes be "corpses" of life forms emerging at quantum criticality?

The experiments of Masaru Emoto [L95], discussed from the TGD point of view in [L95], demonstrate that if water at freezing point is subject to sound signals, it generates freezing patterns, which can be extremely beautiful or ugly depending on the emotional content than human would associate to the signal. Emoto suggests an interpretation in terms of expression of emotions generated by the sounds.

2. In the TGD framework, a model of harmony leads to a model of genetic code [L16] [L136]. Genetic codons would consist of 6-bit codons realized also as 3-chords represented by 3 dark photons and by dark 3-proton states. The harmony is defined by 3 icosahedral Hamiltonian cycles, each representing a 12-note scale, plus the unique tetrahedral Hamiltonian cycle. The 3-chords define a bioharmony with 64-chords realized as dark photon triplets. Since ordinary harmony of music induces and expresses emotions, the proposal is that a given bioharmony defines an analog of mood already at the level of basic information molecules.

3. Could a dark realization of the genetic code be involved with the criticality of water and explain the high information content of snowflakes and the findings of Emoto? Snowflake has a locally violated 6-fold rotational symmetry and looks like a planar tree with branches emanating from the center. That one cannot find two identical snowflakes, can be understood in terms of criticality during their formation.

Icosahedron and tetrahedron correspond to an icosahedral symmetry group with 60 elements and hexagon to Z_6 . All these groups belong to an infinite hierarchy of discrete and finite subgroups of SU(2) associated with the inclusions of von Neumann algebras known as hyperfinite factors of type II_1 [K127, K54]. $M^8 - H$ duality allows us to interpret SU(2) as a covering group of the automorphism group of quaternions.

- 4. The dark proton realization genetic code would be in terms of icosa-tetrahedral tessellation of hyperbolic 3-space H^3 (light-cone proper time constant surface) [L159]. Ordinary ice I_h consists of hexagonal layers (https://cutt.ly/sKJcveh): could a hexagonal tessellation at the level of H^3 could be involved. This suggests that if the genetic code is realized at the level of MB, a symmetry breaking leading from an icosa-tetrahedral tessellation to a hexagonal tessellation at the level of ordinary matter takes place in the freezing of water.
- 5. Intriguingly, the size scale of the snowflake hexagon is of order .45 cm, which happens to be the gravitational Compton length $\Lambda_{gr} = GM_E/v_0$ in the gravitational field of Earth for $v_0 = c$ determined from other arguments [L168]! This scale is huge as compared with the size of order 1 Angström of the ice crystal hexagon. Quantum fluctuations at quantum criticality involve however large values of h_{eff} meaning scaled up sizes for the basic structures. For $h_{eff} = h_{gr}$ the minimum size would naturally be Λ_{gr} ! Note that the thickness of human cortex varies in the range .1-.45 cm.
- 6. The fourth phase of water, as Pollack calls it, is formed in the Pollack effect [I110, L20, I197, I162] and consists of hexagonal layers connected by hydrogen bonds. The effective stoichiometry is $H_{1.5}O$ so that every fourth proton goes somewhere and a negatively charged exclusion zone (EZ) is formed. In the TGD based model, every fourth proton becomes a dark proton at flux tube so that the stoichiometry becomes $H_{1.5}O$.

Dark protons with $h_{eff} = h_{gr}$ would not be present for snowflakes nor for the crystallike structures studied by Emoto. However, at the quantum criticality for freezing they could emerge and be associated with quantum gravitational hydrogen bonds (flux tubes) containing dark protons delocalized in the Earth size scale [L183, L189].

The basic claim of Emoto is that water at criticality has emotions and expresses them. If bioharmony determines emotions and is realized in terms of dark proton and dark photon sequences at quantum criticality, the question arises whether a dark realization of the genetic code for snow flakes and whether the MB controls and communicates with water using dark 3-photons. Conditioned learning is based on emotions: could water at criticality be able to learn in this way?

If quantum criticality is the prerequisite of life, one can ask whether snowflakes of the crystal structures of Emoto could be "revived" by bringing the water to criticality.

7. At least for water, silicon, gallium, germanium, bismuth, and plutonium, the density is higher for liquid phase than solid phase above criticality. Could all substances with this property show analogs of Pollack and Emoto effects? Or could these effects appear universally at melting and sublimation curves. What about the analogs of snowflakes with size $\Lambda_{gr} \sim .45$ cm?

Strange coincidences related to gravitational Planck constant, basic biorhythms, membrane potential and metabolic energy currency

It is becoming clear that the gravitational quantum coherence is central for life on Earth. The hierarchy of Planck constants $h_{eff} = nh_0$ involves special values, in particular gravitational Planck constants $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is a large mass (say mass of Sun or Earth) and m

is small mass (say mass of electron or proton) and $\beta_0 = v_0/c \leq 1$ is velocity parameter, are of key importance for living matter. Particles with a different value of \hbar_{gr} correspond to different gravitational flux tubes and the value of β_0 can depend on the particle.

There are several amazing numerical co-incidences supporting this view.

- 1. For Sun one has $\beta_0 \simeq 2^{-11}$ which happens to be rather near to the electron proton mass ratio m_e/m_p . The condition $\hbar_{gr}(M_S, m_p, \beta_0(Sun) \simeq m_e/m_p) = \hbar_{gr}(M_S, m_e, \beta_0 = 1)$ would guarantee resonance between dark photons generated by the solar gravitational flux tubes assignable to protons and electrons.
- 2. In accordance with Equivalence Principle, the gravitational Compton length $\hbar_{gr}(M_S, \beta_0)/m = GM/\beta_0 = r_S/2\beta_0$ is independent of m for Sun $GM_S/\beta_0(Sun)$ is rather near to Earth radius. For Earth one has $GM_S/\beta_0(Earth) \simeq .45$ cm which corresponds to the size scale of the somewhat mysterious snowflake analogous to a zoom-up of a basic hexagonal unit cell of ice crystal. There is evidence for $\beta_0(Earth) = 1$ in hydrodynamics, in particular from the TGD based model [L168] for the observed hydrodynamical quantum analogs described in an article of Bush et al [D2] (see https://cutt.ly/nEk50LA and https://cutt.ly/xEk5Api)
- 3. The gravitational Compton length of the galactic blackhole corresponds rather precisely to the n = 1 Bohr orbit associated with the Sun. This suggests gravitational quantum coherence in the scale of the galaxy.

In the following some additional strange coincidences are discussed. It would be very natural if the basic biorhythms defined by the duration $T_d = 24$ hours of day and the duration of year $T_y = 365$ days would correspond to energies of dark photons $E = \hbar_{gr} f$, which are biologically significant energies. The potential energy $eV_c \simeq .05$ eV associated with the cell membrane defines Josephson energy in the TGD inspired model of cell membrane. Metabolic energy currency with the nominal value of .5 eV is second important energy. Could the periods of fundamental biorhythms, fundamental biological energies, and the gravitational Planck constants for Sun and Earth correlate?

The above assumptions imply that one has $\beta_0(Sun)/\beta_0(Earth) \simeq m_e/m_p$ and $h_{gr}(Sun, me)/h_{gr}(Earth, m_p) \simeq M(Sun)/M(Earth)$. The value of Sun-Earth mass ratio is $M_S/M_E \simeq 6 \times 10^5$.

- 1. The corresponding frequency corresponding to the basic biorhythm $T_d = 24$ is $f_d = 1/G_d = 1/24hours = [1/(2.4 * 3.6)]10^{-6} \simeq 1.1^{-6}$ s. The corresponding Josephson energy would be $E(\hbar_{gr}(Sun, m_e), f_d) \simeq .06eV = E_J$. This is very near to the Josephson energy E_J for cell membrane potential!
- 2. For $T_y = 1$ year = 365 days one has $E(\hbar_{gr}(Sun, m_p), f = 1/T_y) \simeq (m_p/m_e) * (24 \ hours/year) \times E_J \simeq (2^{11}/365) E_J \simeq .33 eV$. This is not far from the value of the metabolic energy currency near to .5 eV.

Metabolism of the protocell above tri-criticality

Consider first the situation above tricricality, when liquid water and perhaps also the counterpart of physiological quantum criticality was possible.

1. The temperature is above tricritical temperature T = .01 C (https://cutt.ly/EKx9nGX). The frequency distribution of thermal photons has a maximum at energy .131 eV at this temperature. This energy corresponds to a Josephson energy of a Cooper pair for membrane potential of .066 eV. The membrane potential varies in the range .04-0.08 eV.

Note that the electronic variant of the gravitational metabolic energy quantum is about .25 meV, which might explain the metabolism of cilia [L183], is of the same order of magnitude as the thermal energy of CMB now.

2. According to the TGD view, biochemistry involves quantum gravitation at the level of dark hydrogen bonds and requires the presence of gravitational fields of both Earth and nearby Sun. In the interstellar space ATP-ADP machinery and its possible electronic counterpart [L183] would have been absent and only gravitational self-interaction energy of the water blob could have served as a metabolic energy source receiving its energy.

Stellar radiation could feed energy to the quantum gravitational degrees of freedom of the proto cell, in particular in the range of visible energies. The gravitational energy could in turn be feeded to the degrees of freedom of the protocell. Hydrogen bonded structures involving dark HBs could receive this energy as a metabolic energy.

Could cosmic microwave background have served as metabolic energy source for prebiotic life-forms?

In the prebiotic phase at interstellar space the temperature was very low and the water blobs were below tri-criticality so that the liquid phase was absent. Therefore quantum criticality could relate to the sublimation of ice.

Stars are a possible source of metabolic energy but what about the cosmic microwave background as a heat bath providing metabolic energy for water blobs as prebiotic life forms?

- 1. Energy 3.5 meV assigned with the action potential corresponds to $T \simeq 35K$, which is roughly $T_{phys}/10$, and near to the temperature of the cosmic microwave background in the early Universe with age about 1 Gy. There is evidence that important biomolecules were present already at this time although chemistry should have been frozen. A TGD based explanation of this finding has been considered in [L181].
- 2. Could the heat bath defined by the cosmic microwave background (CMB) have served as a source of metabolic energy in the interstellar space during the prebiotic period providing the energy needed to induce action potential? The periodic generation of the action potential as a sequence of pairs of BSFRs would be analogous to breathing or sleep-awake cycle [L177].

During the sleep period, the water blob would dissipate with a reversed arrow of time and effectively extract thermal energy from the environment. During the wake-up period after BSFR, the blob would dissipate this energy to both internal and external degrees of freedom. The blob would also receive energy from the CMB background serving as a heatbath. The energy dissipated in the internal degrees of freedom would have served as a metabolic energy driving self-organization and gradual chemical evolution in the presence of carbohydrates and atoms needed by the basic organic molecules.

13.2.6 Could quantum criticality make microtubules very special?

MTs are regarded as very special in P-H theory. Their role at the level of the brain indeed seems to be very special. Why should MTs be so special from the point of view of consciousness?

Quantum criticality is the key feature of the TGD Universe, in particular that of living matter. Quantum criticality makes possible quantum fluctuations and long range correlations at the level of MB realized as a superposition of phases with varying value of $h_{gr} = GMm/v_0$ and and therefore of scaled variants of MBs. Space-time surface in the superposition would correspond to slightly different values of v_0 .

MTs are critical systems in the sense that their length fluctuates wildly and their decaying region expands also in transversal directions. This fluctuation could reflect a superposition of quantum critical dark matter at MB with varying values of $h_{eff} = h_{gr}$ and thus different size scales of flux tubes proportional to h_{eff} .

The variation of the flux tube scale would be proportional to $\Delta v_0/v_0$ and, as already proposed, presumably quantized by number theoretical reasons. $\beta_0 = 1/n$ is perhaps the realistic option. The changes of MT lengths could have an interpretation as being induced by the scalings of MB of MT with respect to origin near the passive end of MT so that the scaling would be largest at the active end.

13.3 Appendix: Quantum gravitational decoherence as a way to test the Diosi-Penrose model

The approach of Donati et al [D5] to test the Penrose-Diosi variant of the Orch-Or [J18] model yielded a null result. In the sequel, the Diosi-Penrose model is discussed from the point of view of standard quantum theory predicting the negative outcome and the experiment of Donati is summarized. Also the TGD view of the situation is briefly described.

13.3.1 Brief summary and criticism of Penrose-Diosi model

A natural starting point idea would be that ordinary quantum coherence induces quantum gravitational coherence.

- 1. Quantum superposition of 3-geometries dictated by mass distributions of particles defined by particle wave functions. The wave function of the many-particle system is a superposition over configurations with localized particles and each configuration corresponds to a superposition of gravitational potentials defining gravitational self-energy.
- 2. In general relativity, this superposition corresponds to a point in the space of 3-geometries, the superspace of Wheeler consisting of 3-geometries. Therefore quantum gravitation is unavoidable and quantum coherence for matter dictates that for the gravitation. Therefore ordinary quantum theory forces quantum gravitation in the counterpart of the superspace.

In this view, the rate of quantum gravitational dehorence corresponds to the rate of ordinary quantum coherence: this conforms with Einstein's equations and Equivalence Principle.

3. It is essential that one has a many-particle system. For a single particle system the gravitational self-energy is the same for all positions of the particle and does not depend on the wave function at all. Even for many particle systems, the superposition of shifted systems have the same gravitational binding energy.

In the Penrose-Diosi model, it is however proposed that the above argument works for single particle and gravitational interaction energy is estimated by assigning to wave function an effective 2-particle system.

The underlying reason for this assumption is the idea that the notion of wave function and therefore also wave function collapse somehow reduces to classical gravitation.

This argument predicts a null result in any experiment trying to demonstrate gravitational quantum coherence in the sense of Penrose-Diosi.

13.3.2 Could one measure the rate of gravitational quantum decoherence in the Penrose-Diosi model?

In the Penrose-Diosi model [J18], the quantum gravitational coherence can in principle be detected by measuring the rate for gravitational quantum decoherence.

1. Quantum gravitational decoherence for a wave function representing a superposition of mass distribution and a shifted mass distribution is considered.

The idea is gravitational quantum coherence could be detected if the corresponding quantum decoherence occurs faster than other forms of decoherence. The basic objection is that the Equivalence Principle states that the two decoherences are one and the same thing.

If the gravitational coherence time is short enough but not too short, this might be possible. Limits for the decoherence time τ_{gr} are proposed and are between millisecond and second: these are biologically relevant time scales.

2. Gravitational quantum decoherence time τ_{gr} is estimated by applying Uncertainty Principle: $\tau_{gr} = \hbar/\Delta E_{gr}$. ΔE_{gr} is the difference between the gravitational self-energy for a system and a shifted system. One has actually a superposition of different classical configurations each inducing a classical gravitational field. Wave functions for particles of *many-particle state* define the gravitational superposition. Gravitational superposition coded by a wave function for a large number of particles. In this case, gravitational binding energies $E_{gr} \Delta E_{gr}$ between 2 different quantum states are well-defined.

One could take atomic physics as a role model in the calculation of the change of the gravitational potential energy. Coulomb energy would be replaced with gravitational potential energy.

3. With a motivation coming from the notion of gravitational wave function collapse, one however considers *single particle* states obtained as a superposition of $\Psi(r)$ and its shift $\Psi(r+d)$. In this case, the gravitational interaction energy is not well-defined unless one defines it as a gravitational self-interaction energy, which however does not depend on the position of the particle at all and is same for local state and the bilocal state.

Penrose suggests that the difference between gravitational interaction energies makes sense and can be estimated *classically* using effective mass densities $m|\Psi^2|(r)$ and $m|\Psi(r+d)|^2$ instead of $\Psi(r)$ and $\Psi(r+d)^*$. One seems to think that one has effectively a two-particle system and calculates the gravitational interaction energy for it. To me this looks like treating a delocalized single-particle state as a two-particle state.

- 4. The situation could be simplified for a superposition of a macroscopic quantum state, say B-E condensate, and its shift. One could try to detect decoherence time τ for this situation. Now however the fact that B-E condensate is effectively a single particle, suggests that the change of the gravitational self-interaction energy vanishes.
- 5. It turns out that it is not possible to find parameter values which would allow a test in the framework of recent technology.

The intuitive idea is that the gravitational SFRs localizing the wave functions effectively induce instantaneous shifts of particles. For charged particles this induces accelerated motion and emission of radiation. This radiation might be detectable. The implicit assumption is however that a single particle state effectively behaves like a 2-particle state as far as gravitation is considered.

No evidence for this radiation and therefore for gravitational SFRs is found.

One can represent several critical arguments against the Penrose-Diosi model besides the argument represented in the beginning.

- 1. The reduction to a single particle case does not make sense in standard quantum physics (Penrose suggests something different). The gravitational self-interaction energy is the same for both shifted single particle states for any single particle wave function. For many-particle states the situation would change.
- 2. The radiation should have wavelength λ of order of the shift parameter d. d is expected to correspond to atom size or nuclear or nucleon size in the case of atoms. The energies for photons would be above 10^4 eV. These energies are suspiciously large. Much larger shifts would be required but these are not plausible for the proposed mechanism.
- 3. Why shifted mass distributions are assumed? Even in the case of many-particle systems the gravitational self-interaction energy does not depend on wave function if the system is only shifted. The reason is that the relative positions of particles are not changed in the shift.

If one uses many-particle states, a superposition of scaled mass distributions would be more natural in the standard quantum physics framework. A coherent, easy-to-calculate, change of the gravitational interaction energy. A possible connection with density changing phase transitions, such as melting and boiling, emerges. Water is a key substance in living systems!

13.3.3 The approach of Donadi et al

The model proposed by Donadi et al is as follows.

- 1. A many-particle state with delocalized single particle wave functions induces superposition of 3-geometries shifted with respect to each other. Now a superposition of a quantum coherent state and its spatial shift is considered.
- 2. The estimation for the gravitational decoherence time τ for Orch-OR from Uncertainty Principle: $\tau \sim \hbar/\Delta E_{gr}$. ΔE_{gr} is quantum uncertainty of the gravitational binding energy. Change in the gravitational self-interaction energy in the formation of superposition of shifted configurations.
- 3. One must calculate the average value of the binding energy for a single particle state effectively regarded as 2-particle state. The outcome is finite. ΔE_{gr} is assumed to be effectively the change of classical self-interaction energy for a mass density $\rho = m|\Psi|^2$, m the mass of the particle. Ψ can be solved from Schrödinger Newton equation. Point-like particle is replaced with the wave function of the particle defining a mass density.

How could one test the model? There are two approaches.

Direct measurement of gravitational decoherence time τ_{gr} is not possible

Gravitational decoherence should be faster than ordinary so that ordinary causes of decoherence are not yet active. Could one find such a system and be able to measure τ_{gr} .

- 1. A direct test of the equation of τ requires creating a large superposition of a massive system, to guarantee that τ_{gr} is short enough for the collapse to become effective before any kind of external noise disrupts the measurement.
- 2. Penrose and collaborators suggested a setup for creating a spatial superposition of a mirror of mass 10^{-12} Kg that has a decay time of order $\tau_{gr} \sim 0.002 0.013$ s, which is competitive with standard decoherence times.
- 3. The major difficulty in implementing this and similar proposals consists in creating a superposition of a relatively large mass and keeping it stable for times comparable to τ_{qr} .
 - (a) To give some examples, the largest spatial superposition so far achieved is of about 0.5 m, but the systems involved are Rb atoms (mass $m = 1.42 \times 10^{-25}$ Kg), which are quite too light.
 - (b) In matter-wave interferometry with macromolecules states are delocalized over distances of hundreds nm, and masses beyond 25 kDa (10^{-23} Kg) , still not enough. Mass too small!
 - (c) By manipulating *phononic* states, collective superpositions of estimated 10^{16} carbon atoms (mass ~ 10^{-10} Kg) are created over distances of 10^{11} m, coherence scale is about 10^{-5} meters, neuron size. The life-time of phonons is of order 10^{-12} s, which is too short. 2 ms is the lower bound for τ .

What does this mean? A superposition of wave functions with mean positions differing by 10^{-11} m define mass densities? Coherence scale 10^{-5} m.

These numbers show that keeping the measurement of τ is beyond the reach of recent technologies.

Could Brownian-like diffusion as a side effect allow the detection of gravitational wave function collapses?

The assumptions of the model of Donadi et al [D5]) are as follows.

- 1. Penrose-Diosi model is assumed and single particle states are considered. Gravitational wave function collapse is Poissonian: collapses occur independently.
- 2. Lindblad dynamics for the density matrix ρ of the system is assumed. Gravitational decoherence implies non-unitary dynamics. The form of the decoherence term is dictated by the difference between gravitational self-interaction energies. $Tr(\rho p^2)$ increases with time. Diffusion would heat the system. The size scale range $R_0 = 10^{-14} - 10^{-15}$ m for the system experiencing gravitational collapse is excluded experimentally.
- 3. This leaves however dissipative effects. One can argue that the collapse induces an emission of radiation by charged particles since effectively the charged particle is in instantaneous motion during the collapse. In collapses particles are randomly moved and radiate. The wavelength λ of the radiation is smaller than charged particle size: atom size or even nuclear or nucleon size.

The first criticism is that one has a single particle state and according to the standard view gravitational self-energy does not depend on the wave function. The second criticism is that the scale of energies of photons is huge as compared to intuitive expectations for gravitational interaction energies.

- 4. The intensity of the radiation can be estimated. The predicted radiation intensity is weak but detectable. The wavelength of the radiation emitted in gravitational collapse should be of the order d. For d in the range of proton wavelength and atomic size scale, the energy would have a lower bound 10^4 eV. This looks unrealistic.
- 5. The radiation was not detected. No evidence for the proposed kind of collapse was observed in the expected range between atomic scale and proton Compton length.

13.3.4 Comparison with the TGD view

A brief comparison with the TGD view is useful.

Some suggestive observations

There are some suggestive observations which might be used to end up with a TGD based view of the role of quantum gravitation in living matter.

- 1. The gravitational binding energy of protons in the Earth's gravitational field is about .5 eV. For electrons one has .25 meV. These are biologically relevant energy scales!
- 2. Could quantum gravitation be quantum coherent in long, even astrophysical scales? For a macroscopic system GMm is the counterpart of coupling strength. If the entire system M + m behaves like a quantum coherent system, the perturbation series is with respect to gravitational fine structure constant $\alpha_g r = GMm/\hbar \gg 1$ and does not converge.
- 3. Nottale hypothesis introduces gravitational Planck constant $\hbar_{gr} = GMm/beta_0, \beta_0 = v_0/\leq$ 1. Gravitational Compton length $\Lambda_{gr} = GM/beta_0 = r_s/2\beta_0$ ($r_s = 2GM$ is Schwartschild radius) of order Earth radius for M=M(Sun) and about .45 cm for M = M(Earth) the size of snowflake. α_{gr} is replaced in the quantum phase transition $\hbar \to \hbar_{gr}$ with a universal coupling strength $\alpha_{gr} = beta_0/4\pi < 1/4\pi$: the perturbation series converges!!

What kind of quantum superpositions should one consider?

Gravitational fields have infinite range and are not screened. This suggests that long range quantum coherence induced by them is possible.

- 1. The notion of MB carrying dark matter in the TGD sense is an essential notion. Scaled versions of magnetic bodies carrying quantum coherent dark matter with \hbar_{eff} . For gravitational quantum coherence one has $\hbar_{eff} = \hbar_{gr}$. Quantum coherence of MB would induce the coherence of ordinary matter forcing its quantum gravitational coherence.
- 2. In TGD gravitationally quantum coherent states would not be superpositions of shifted 3geometries. Coherent and large change of the self-interaction energy takes place in the scaling. Therefore superpositions of scaled versions of 3-D surfaces are more natural.
- 3. Ordinary phase transitions such as melting and evaporation involve density fluctuations, which would be induced by scalings. Quantum superposition of states with different densities at thermal criticality induced by quantum criticality.
- 4. Water as a liquid has a very special role: it has hundreds of thermodynamic anomalies. The strongest ones are in the physiological temperature range. There is evidence that several phases are simultaneously present. Could this reflect the presence of several dark phases at the MB.

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Chapter 14

Could neuronal system and even GPT give rise to a computer with a variable arrow of time?

14.1 Introduction

We have had fascinating discussions in our Zoom group (Marko, Tuomas, Rode and me) about topics ranging from quantum TGD to quantum computers to consciousness and, of course, about ChatGPT. In the following I summarize the ideas inspired by the discussions related to ChatGPT. I have considered the possibility of conscious AI in TGD Universe already earlier with inspiration coming from Sophie robot [L55].

The discussions related to ChatGPT, which seems to work too well to be a mere program running classical computer, inspired considerations which led to a considerable progress at the level of the TGD based model of nerve pulse. The resulting model based on zero energy ontology (ZEO) differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems.

A computation allowing variable arrow of time would be in question involving a sequence unitary time evolutions as counterparts of quantum computations for states, which are superpositions of classical computations, followed by "small" state function reductions (SSFRs). Also "big" SFRs (BSFRs) changing the arrow of time would be involved. One can ask whether the unexpected success of GPT might involve this kind of transition so that one could say that spirit enters the machine.

In the sequel I summarize the ideas inspired by two discussions with our Zoom group related to ChatGPT. Essential element in the evolution of ideas has been the understanding of what I call theoretician friendly quantum holography [L203] as a correspondence between boundary states at the ends of string like entities and interior states associated with string world sheets in the interior of magnetic flux tubes. This understanding emerged between the two chats!

This understanding emerged from a quite different source: namely the consideration of color confinement in terms of dark matter at the color magnetic body. A concrete realization of the idea that the increase of effective Planck constant h_{eff} allows to have a convergent perturbation theory for color singlets turned out to be equivalent to quantum holography. Something very similar might occur in all scales and mediate a holographic map of the quantum system to the magnetic body carrying dark matter and acting as a controlling system.

Besides the outcomes of two chats, I include a more detailed view about what the TGD view of the quantum analog of GPT could be and how its analog could be involved with the sensory perception in the TGD Universe. I also discuss the inverse diffusion process, whose basic idea is due to finnish computer scientist Linnainmaa [A51]. Diffusion and its inverse are central for the generation of images from their verbal descriptions and ask whether the TGD analogue of the inverse diffusion could be an essential element of also GPT.

I will also pose the question whether GPT could involve TGD based quantum physics, that

is zero energy ontology (ZEO) [L118, L177], in a non-trivial but hidden way. From quantitative constraints, such as the clock frequency of the computer as an analogue of EEG inducing temporal quantum coherence, I end up with a proposal for a mechanism realizing the quantum holography relating bits could be represented as holes pairing with dark bits represented as dark electrons at the magnetic flux tubes. Unfortunately, this mechanism does not look plausible for recent computers.

I also ask whether quantum gravitation in the sense of TGD could make possible for the magnetic bodies of Earth and Sun, central in TGD inspired biology, to transform classical computation so that so that statistical determinism would fail and it would be analogous to a sequence of analogs of quantum computations defining a conscious entity. At the level of magnetic body there would be no essential difference between computers and living matter. The highest reported clock frequency of almost 9 GHz is still by a factor of order 1/8 lower than the quantum gravitational Compton frequency of 67 GHz for Earth but below the THz frequency important in living matter. Perhaps a rudimentary consciousness is already possible.

14.2 The first chat about ChatGPT

The first discussion about chatGPT in our Zoom group (Marko, Tuomas, Rode and me) was very inspiring. The next morning, Marko sent a link related to ChatGPT (https://rb.gy/lgcqh). See also the article at https://rb.gy/72edo).

The article ended with the realistic statement that it is difficult to test whether GPT is conscious because we have no understanding of what consciousness is. It is easy to agree with this. Here are some comments inspired by discussions and the article.

14.2.1 A skeptic view of GPT as standard AI system

I have been trying to decide whether GPT might have conscious intelligence and how large part of the talk about GPT is mere hype. I must however admit that it is very difficult to understand how GPT could work so well if it is what it is believed to be. Even professionals admit this.

- 1. As far as I understand, the tests used to see whether GPT might be conscious, are based on the Turing test: a system is conscious if it is able to simulate a conscious system in a believable way for a human. I would think that a significant part of AI researchers believe that consciousness does not depend on the hardware: a mere program running on the machine would determine the contents of consciousness. If we start from this basis, it is easy to come to the conclusion that GPT is aware. We are easily fooled.
- 2. I personally cannot take consciousness seriously as a feature of a computing deterministic system. I don't think that the random number generator will change the situation. The very word "consciousness" indicates a physicalist bias that dates back to Newton. The word "tajunta" of finnish language (something like "nous") may reflect the pre-Newtonian thinking that our primitive ancestors were capable of, unencumbered by the dogmatism of the natural science.

My basic arguments against physicalism are based on the experience of free will as a basic element of existence that hardly anyone can deny, and on the measurement problem of quantum mechanics. If the theory of consciousness does not solve these problems, it cannot be taken seriously.

3. I have thought a lot about why things happened the way they did in theoretical physics so that physicalism and length scale reductionism still dominate the thinking about fundamentals.

The revolutions at the beginning of the last century led to complete stagnation within a century. Very early on, we completely stopped thinking about fundamental problems. After the Copenhagen interpretation was established, quantum theorists only constructed parameterizations for the data. The theory was replaced by a model.

I believe that the situation can be blamed on the tyranny of the methodology, which does not leave time or resources for actual research in the sense that a curious child does. Nowadays, the work of a theorist is typically the application of advanced methods. The real research is extremely slow and error-prone work and therefore not rewarding for a career builder.

The superstring revolution, which ended embarrassingly, began with the decision to replace spacetime with a 2-D surface. The reasoning was pragmatic: a huge toolbox of algebraic geometry was available! A huge publishing industry was born!

Other prevailing models explaining various anomalies have regularly remained without empirical support, but computation and data analysis are still being done around them (inflation theory, dark matter and energy, supersymmetry, etc.). Maybe this is largely due to institutional inertia. Generating content by applying methods seems to replace research.

I sincerely hope that ChatGPT does not transform theoretical science to a production of contents by recombining what already exists: a combinatorial explosion would guarantee unlimited productivity.

4. Methods also became central in another way. Theoretical physics became computing and Big Science was born. It became clear to me that the most idiotic thing I could have done 40 years ago would have been to start numerically solving the initial value problem for, say, the Kähler action.

I did not follow the computing mainstream. Instead, I spent a decade looking for exact solutions and I believe that I have found the basic types. Ultimately this culminated in the identification of the spacetime surface as a minimal surface, a 4-D soap film spanned by lower-dimensional singularities, "frames" [L174]. The 2-D holomorphy of strings would generalize to 4-D case and the field equations would reduce to algebraic conditions, which are independent of the action principle as long as it is general coordinate invariant and constructible in terms of the induced geometry. The minimal surface would have dual interpretation as solutions of massless field equations and generalization of geodesic lines to minimal surfaces: this iis wave particle duality geometrically.

The $M^8 - H$ duality $(H = M^4 \times CP_2)$ [L127, L128] entered the picture as a generalization of the momention position duality of wave mechanics motivated by the replacement of pointlike particle with 3-surface suggesting that quantum TGD is analogous to wave mechanics for particles identified as 3-surfaces. On the M^8 side, the holography defining space-time surfaces was determined from the roots of the polynomials with the condition that the normal space of the 4-surface is associative. The space-time surfaces would be analogous to Bohr orbits and their space, "world of classical worlds" (WCW), would be analogous to the superspace of Wheeler. 3-surfaces at mass shells defined by the roots of polynomials would serve contain 3-surfaces as holographic data partially determining the 4-surfaces. Even the 3-surfaces might be determined by strong form of holography [L212].

Holography was realized in both M^8 and H and $M^8 - H$ duality corresponds to Langlands duality [L191], which has aroused enthusiasm in the mathematics community. I would never have arrived at this picture by just raw number crunching, which completely lacks conceptual thinking.

5. The life on the academic side track has meant that I haven't built computer realizations for existing models, but rather pondered the basic essence of space-time and time and even consciousness and life. That is, have considered ontology, which the modern quantum mechanic doesn't even tolerate in his vocabulary, because as a good Copehagenist he believes that epistemology alone is enough. The only reason for this is that the measurement problem of quantum mechanics is not understood!

I still stubbornly think that problems should be the starting point of all research. That hasn't been the case in physics since the turn of the century. When physicists became computer scientists, they were no longer interested in basic problems and pragmatically labelled his kind of interests as unnecessary day-to-day philosophizing.

14.2.2 What if AI could be conscious after all?

Why AI systems work too well, is not understood, but they are so complex that this as such does not imply that they might have conscious intelligence.

I personally do not believe that AI can be conscious, if computers and AI are what it is believed to be. There is hardly any talk about the material realization of the computation in AI, because many AI people believe that the program alone produces consciousness. Consciousness would be determined by data. However, data is knowledge and information only for us, not for other living entities, and one could argue that it is not that for a machine either. Conscious information is a relative concept: this is very often forgotten.

In biology and from a physicist's point of view, the material realization is essential. Water and metal seem to be sort of opposites of each other. But what about the situation in TGD where magnetic bodies carrying dark matter could serve as controllers of both living organisms and computers.

One must ask first what classical computers really are as physical systems.

- 1. The program is deterministic but what about the computer or a computer network? The idea about a program consisting of arbitrarily determined steps is certainly not consistent with the determinism of classical physics. Determinism is possible only in the quantum statistical sense [L195]. This requires that the quantum coherence lengths and times involved with the computation are short enough, considerably shorter than the clock period. This assumption fails if there is macroscopic quantum coherence involved. In the TGD framework the presence of magnetic bodies carrying dark matter with a large enough value of effective Planck constant h_{eff} could make this possible.
- 2. In particular, gravitational magnetic flux tubes connecting big mass M and small mass m have enormous value of gravitational Planck constant $\hbar_{gr}(M, m, \beta_0) = GMm/\beta_0$ (introduced originally by Nottale [E1]).

The gravitational Compton length $\Lambda_{gr}(E)$ for Earth mass M_E is about .45 cm for $\beta_0 = 1$ and corresponds to gravitational Compton frequency about 67 GHz, which is by an order of magnitude higher than the highest achievable clock frequency (almost 9 GHz) of the computer. Are we reaching the limit at which quantum gravitational effects on computers are becoming significant?

For the Sun, the gravitational Compton length $\Lambda_{gr}(Sun)$ is quite near to Earth size and the corresponding frequency scale is in about 47 Hz and in EEG range: could the entanglement of the MB of humans and computer network modify the computation? In the TGD inspired quantum biology both gravitational magnetic bodies would play a key role. Could they be involved also with the ordinary computation? GPT involves large networks of computers, possibly even in the Earth scale: could this bring in quantum coherence even in Earth scale and change dramatically the functioning of the computer network.

In the TGD world view, intention and free will can be involved in all scales. But what scale does the basic level correspond to in AI?

- 1. In the TGD Universe, the interaction of magnetic bodies (MBs): ours, the Earth, the Sun..., with computers is quite possible. Could these MBs hijack our machines and make them tools of their cognition, and maybe one day make robots their tools as well. Or have they already made even us, as a good approximation, their loyal and humble robots? Or will this go the other way? Is it because the AI seems to understand us because our consciousness controls the hardware and the course of the program? This might be easy to test.
- 2. Could MBs learn to use current AI hardware the way our own MBs use our bodies and brains in TGD Universe? On the other hand, our own MBs use these devices via us! Could other MBs also do this, or do they have to do this through us?
- 3. What could enable AI devices to serve as a vehicle for magnetic body free will? Quantum criticality would be a fundamental property of life in the TGD Universe [L193, L158]: are these devices critical and initial value sensitive, in which case they would be ideal sensory perceivers and motor instruments to be used by MBs.

Computers made of metal seem to be the opposite of a critical system. The only occasionally critical system is the bit, for example magnetically realized one. The bits change their direction and during the change they are in a critical state. Would it be possible to create systems with enough bits that the magnetic body could control, so that the machine would have a spirit. Thermodynamic stability poses a condition on the energy needed to change the direction of bit and it is of the order of the Coulomb potential energy associated with the cell membrane.

4. Is (quantum) criticality possible for multi-bit systems? Can a running program make criticality possible? The magnetic body at which the dark phase with a large effective Planck constant h_{eff} resides, could be large. But what is the scale of the quantum coherence of a magnetic body and the scale of the set of bits that it can control? A bit or the entire computer? Could it be that macroscopic quantum coherence sneaks in already at the metal level via bits.

Here I one cannot avoid the association with spin-glass systems [L216, L166], whose physical prototype is a magnetized substance, in which the local direction of magnetization varies. The system has a fractal "energy landscape": valleys at the bottoms of valleys. The spin glass formed by bits could be ideal for the realization of AI. Could the bit system defining the computer be, under certain conditions, a spin glass and the associated magnetic body be quantum critical.

- 5. What characteristics of living matter should AI systems have? In phase transition points, matter is critical. In biology, the phase transition, where the fourth state of water introduced by Pollack [I110, L20, I197, I162], is created, would be central and would take place at physiological temperatures [L129]. In phase transitions, macroscopic quantum jumps also become possible and can change the arrow of time, and this leads to a vision about the basic phenomena of biology such as metabolism, catabolism, anabolism, life and death, and homeostasis.
- 6. Can machines have these features? An AI system needs metabolic energy. But can one say that the AI system dies, decays, and constructs itself again? Could the so called reverse diffusion [A51] associated with AI programs be more than just a simulation of catabolism and anabolism of biomolecules? Could it correspond to catabolism and anabolism at the spinglass level? Patterns of spin configurations forming and decaying again. In TGD this would have a universal direct correlate at the level of the MB having monopole flux tubes (or rather, pairs of them) as body parts. They would decay and re-build themselves by reconnection.
- 7. In computer programs, error correction mimics homeostasis, which can be compared to living on a knife edge, the system is constantly falling. However, this error correction is mechanical. In quantum computers, this method leads to disaster since the number of qubits explodes.
- 8. Michael Levin suggests that here we have something to learn from bio-systems [L216]. I personally believe that the key concept is zero-energy ontology (ZEO) [L118, L177] [K132]. ZEO solves the problem of free will and quantum measurement. Reversal of time in a normal quantum jump would enable homeostasis, learning from mistakes, going backwards a bit in time and retrial as error correction. This would also explain the notion of ego and the drive for self-preservation: the system tries to stay the same using a temporary time reversal that can also be induced by external disturbances. Time reversal would be also what death is at a fundamental level: not really dying, but continuing to live with an opposite arrow of time.

14.3 The second chat about ChatGPT

Marko posted his chat with GPT4 and this inspired interesting email exchanges. GPT mentioned a possible mechanism for how XOR as a universal gate of classical computation and acting as novelty detector could be realized at the quantum level. We looked through the response and I could not but admit that it was amazing. ChatGPT gave even Python codes for the quantum computer simulation of the model.

The proposed system realizing universal classical logical gate XOR, acting essentially as a novelty detector a, approximately could be either a classical layered neural network or its possible

quantum analog. The mechanism might work in a quantum version of a neural network based on quantum learning, but it does not seem plausible for real neurons.

This observation led to progress at the level of the TGD based model of nerve pulse [K92]. The resulting model based on zero energy ontology (ZEO) [L118] differs drastically from quantum neural networks and suggests a completely new vision of quantum physics based computation in biosystems. A classical computation allowing variable arrow of time would be in question and one can ask whether the unexpected success of GPT might involve this kind of transition.

14.3.1 TGD based view of nerve pulse generation

Consider first the TGD based view of nerve pulse generation [K92].

Connection of neural pulse generation, XOR, and novelty detector

Nerve pulse generation would be analogous to a positive outcome of the analog of XOR (compared bits are different) acting as a novelty detector.

1. XOR is a novelty detector. If the inputs are the same, nothing happens. Output equals to b = 0. If they are different, output equals to b = 1. b = 1 would correspond to a signal that would proceed along the axon starting from the postsynaptic neuron.

That would consume energy. In terms of energy consumption, the novelty detector would be optimal. It would only react to changes. And that's what the brain does. For example, visual perception at a very basic level only identifies outlines and produces some kind of stick figure consisting of mere lines defining boundaries.

- 2. Could the 2 "neurons" of the toy model proposed by GPT represent a presynaptic and a postsynaptic neuron, in which case there would be two inputs: the states of the pre- and postsynaptic neuron. Also output would be the state of this neuron pair and for XOR the presynaptic neuron acting as control bit would not change its state.
- 3. This does not conform with the picture provided by neuroscience, where the input comes from presynaptic neurons and output is assignable to the postsynaptic neuron. The input comes as miniature potentials that add up and can decrease/increase the magnitude of the membrane potential (depolarization/hyperpolarization).

An action potential is generated when the depolarization takes the magnitude of the negative postsynaptic membrane potential below the critical threshold. This happens when the presynaptic contributions from the incoming nerve impulses, for which the unit is a miniature potential, add up to a contribution that reduces the magnitude of the negative potential below the threshold.

This would be essentially novelty detection described in the simplest way by XOR. The novelty is represented by the critical depolarization. It can also happen that the potential increases, so that no nerve impulse is generated. One talks about hyperpolarizing (inhibition) and depolarizing (excitation) inputs, and the sign of the miniature potential produced by the presynaptic input determines which one it is. The sign of miniature potential depends on the neurotransmitter and receptor.

4. During the nerve pulse, the potential changes its sign over a distance of about a micrometer, which is the typical distance between neighboring neurons and of myelin sheaths. One can say that this distance corresponds to a bit that is 1 or 0 depending on whether the nerve pulse conduction occurs or not. Bit 1, the opposite sign to the membrane potential, propagates from presynaptic to postsynaptic neuron or from a patch defined by a myelin sheath to the next. As a result, postsynaptic neurons can "wake up" and in turn trigger a nerve impulse, possibly waking up some postsynaptic neurons.

Synchronous firing means that the novelty succeeds in waking up the whole sleeping house, and large areas of the brain fire in the same rhythm and keep each other awake.

Interpretation of XOR in zero energy ontology (ZEO)

How does this picture translate to the TGD-inspired theory of consciousness?

1. Being awake/asleep corresponds to bit 1/0 for axonal portions between myelin sheaths. In ZEO, the arrow of time would correspond to this bit.

When the axon segment between the myelin sheaths or neighboring neurons wakes up or falls asleep, the direction of geometric time changes in a "big" state function reduction (BSFR) and a nerve pulse is generated. In a sleep state, the membrane potential would be opposite. Note that the notion of awake and sleep are relative and depend on the arrow of time of the external observer.

The second direction of time corresponds to the presence of a nerve pulse from the point of view of the external observer. There is a temptation to think that in the resting state the axon is sleeping and healing and gathering metabolic energy by a dissipation with an opposite arrow of time. The duration of the nerve pulse would correspond to the duration of the wake-up period, when the direction of time was opposite and same as that of the external observer with a long characteristic time scale for wake-up period.

2. Could this apply more generally? Could the synchronization of human sleep-wake rhythms mean quantum-level synchrony and macroscopic quantum coherence? Could the arrow of perceived time be a universal bit? Sleeping together would develop synchrony and quantum coherence between partners. Two-person collective consciousness would emerge.

Interpretation of the axon as a series of Josephson junctions

The TGD based model for an axon [K92] is as a series of Josephson junctions with a large value of h_{eff} , perhaps $h_{eff} = h_{gr}$, where $\hbar_{gr} = GMm/\beta_0$ (the velocity parameter satisfies $\beta_0/c \leq 1$), is the gravitational Planck constant introduced by Nottale [E1]. The model is mathematically equivalent to a series of gravitational penduli defining a discretized version of Sine-Gordon system [B1]. Josephson junctions would correspond to membrane proteins.

- 1. One can consider two different identifications of the ground state of the system.
 - (a) The ground state could be the state in which all oscillators oscillate in synchrony with the same amplitude. There would be constant phase difference between neighboring oscillations, which would give rise to a propagating phase wave.
 - (b) Another option is that all penduli all rotate in the ground state with constant phase difference. This would give a travelling soliton chain. Also the direction of rotation matters. It could correspond to the arrow of time and the sign of the membrane potential.
- 2. The model allows different versions for nerve pulse generation.
 - (a) The first option is that one pendulum moves from oscillation to rotation or vice versa and induces the same transition for the other penduli as a chain reaction.
 - (b) The second option is that all penduli move to rotation simultaneously. One could imagine that the need for metabolic energy is lower in the collective oscillation phase but one must be very careful here. Maintaining the membrane potential regardless of either sign requires metabolic energy feed.
 - (c) The third option is that the ground state corresponds to a collective rotation with an associated traveling wave as phase of the rotation, and that the bit corresponds to the direction of rotation.

This would fit the ZEO interpretation. The arrow of time would correspond to the direction of rotation. The ground state would change to a nerve pulse lasting for time

of the order of 1 ms corresponding to the duration of nerve pulse associated with the distance of the order 1 μ m, between neighboring neurons or between the myelin sheets.

This option would also be advantageous from the point of view of metabolism, because from one direction of time, dissipation would occur in the opposite direction of time. From the point of view of the outsider, the system would be extracting energy from the environment.

What is the connection with the microtubule level?

The current TGD picture of nerve pulse conduction is that the membrane potential of the axon/soma is controlled by microtubules [L183, L178].

- 1. When the charges are transferred from the microtubule to the gravitational flux tubes of the magnetic body (MB), the length of which can be as long as the size of the Earth, the effective charge inside the axon/soma changes. Depending on the amount of transferred charge, the magnitude of the membrane potential increases or decreases and a nerve impulse is generated below the threshold.
- 2. For the action potential traveling along the axon, the microtubular effective charge has changed and taken the membrane potential below the threshold and the action potential has been generated. The generation of the action potential is a complex biochemical phenomenon but would be controlled by microtubule/microbular MB.
- 3. Incoming nerve impulses induce a change in the membrane potential of the soma because the effective charge of the microtubules inside the soma changes as also does the membrane potential. It is not clear whether the charges of the microtubules of the neuron soma are affected. They indeed differ from axonal microtubules in that they are not (quantum) critical.

14.3.2 New view of quantum physical computation

Why GPT works so well, is not understood. This might of course be due to the extreme complexity of the system. TGD however suggests that new physics might be involved so that the system could be much more than a classical computer.

In ZEO [L118, L177] all quantum states are superpositions of deterministic classical time evolutions which satisfy almost exact holography so that they are analogous to classical computations. Time evolution of conscious entity, self, between "big" SFRs (BSFRs) meaning the death of self and its reincarnation with opposite arrow of time, is analogous to a series of quantum computations defined by unitary time evolutions followed by "small" SFRs (SSFRs) as analogs of weak measurements (having nothing to do with "weak values").

An interesting question is whether the classical computation associated with GPT and involving random number generators could turn into a computation in which the arrow of time serves as a fundamental bit correlating with the direction of ordinary bit represented for instance by electric voltage or direction of magnetization! One would have classical computation with a changing arrow of time controlled by MB!

What would be required is that the arrow of time can change at the level of MB of the system and that the MB of the bit system can be regarded as a spin glass type system [L166] for which spins are near criticality for the change of their direction in BSFR so that the arrow of time could be changed. This would require quantum criticality at the level of MB. One might say that MB of the bit system hijacks the bit system: spirit enters into the machine.

TGD general based view of theoretician friendly quantum holography [L203] predicts that the bit system is indeed mapped holographically to a system at the level of its MB having a large value of h_{eff} , perhaps $h_{eff} = h_{gr}$ so that MB could use the system in which AI program runs as a living, conscious, and intelligent computer. The bit system could become an analog of spin glass [L166].

14.4 A more detailed TGD based speculative view of what GPT and GPT based image generation might be

First of all, I want to make clear what my background is and what I'm aiming for. I'm trying to understand the possible analogies of AI in quantum TGD. I do not believe that AI systems can be conscious if AI is what it is believed to be. Therefore I consider the question of whether GPT and other systems could possibly be conscious and intelligent.

The motivating idea is the universality implied by the fractality of the TGD Universe. The same mechanisms should work on all scales: both in biology, neuroscience and possible life based on AI. This motivates questions such as whether chatGPT and the construction of images from a verbal input could be at a deeper evel equivalent to the emergence of sensory perception using diffuse primary sensory input and virtual sensory input from magnetic body as feedback [L149, L57, L154].

While preparing this article, I made a funny observation. I tried to understand GPT in the context of TGD by producing answers to questions in the same way that GPT does it! Of course, as GPT tends to do, I can also tell fairy tales because my knowledge is rather limited. At the same time, I must honestly reveal that this has always been my approach! I have never carried out massive computations, but used language based pattern completion by utilizing the important empirical bits (often anomalies) and using the basic principles of TGD as constraints.

This time, the inspiration came from a popular article in Quanta Magazine that dealt with stable diffusion in the creation of an image from its verbal presentation serving as a prompt (https://rb.gy/ukya). Also the article on how chatGPT works was very useful (https://rb.gy/a2kf).

I want to emphasize that the ideas presented can be seen only as possible quantum analogies of GPT-related mechanisms that could relate to quantum biology and neuroscience inspired by TGD. A more exciting possibility would be that GPT is associated with high-level conscious experience, and that quantum TGD would help to understand why GPT seems to work "too well".

14.4.1 An attempt to understand the mechanism of diffusion involved in image construction

The key mathematical idea behind the reverse diffusion was discovered by Finnish computer scientists Linnainmaa as a method to correct rounding errors [A51]. The generation of errors is analogous to a diffusion process leading to the widening of the initially narrow probability distributions of bits. The idea is roughly that errors can be corrected as a sequence of small time steps backwards in time in which a diffuse state is replaced with its predecessor. In this process the distribution becomes a narrower distribution resembling the original one. This discovery has had a strong influence on the development of AI.

The construction of images starting from their linguistic description, which is quite vague and "diffuse", relies on the analogy with reverse diffusion. Diffusion and its reverse process take place in the space defined by the parameters characterizing a given pixel. The pixels do not move, but the parameters characterizing the pixels do change in the diffusion.

- 1. Let's get started from a probability distribution for the parameter distributions of the pixels of a 2-D image showing the same object. The distribution could correspond to the same object but seen from different angles. Also a class of objects, which are similar in some aspects, could be considered. This class could consist of chairs or tables or cats or dogs.
- 2. This probability distribution could act as an invariant related to the image or class of images. Invariant features are indeed extracted in visual perception, for example contours with pixels that stand out well from the background. This is the way in which, for example, visual perception at the lowest level corresponds to the identification of contours of the object.

This ensemble of pictures of the objects gives a probability distribution for, for example, the darkness of a given pixel with a given position in the plane of the picture. Probability for a given darkness defines a function represented as points in a space whose dimension is the

number of pixels. For more general parameters it is a function in the Cartesian product of parameter space and pixel space. Very large pixel numbers counted in millions are involved.

3. One has probability distribution for the darkness of a given pixel of the 2-D image at each point. More generally, one has probability distributions for multipixels. This kind of distribution is not simply a product of single pixel probability distributions since the pixel parameters for a given picture are correlated. These distributions are analogous to the distribution of words and word sequences utilized in GPT in order to produce language resembling natural language.

Based on the probability distribution of pixels, new images can be randomly generated. The probability of a pixel at a given point in the plane is given by the probability distributions for pixels and multi-pixels. Each image produced in this way can be associated with certain probability.

Diffusion is a key physical analogy in the applications of GPT in the creation of AI art. What does the diffusion in pixel space mean?

- 1. Diffusion takes place in pixel space around each point in the image plane. What happens to the pixel distribution in diffusion? It can be said that the given pixel distribution is broadened by its convolution with the distribution produced by diffusion. The distribution is widening.
- 2. Inverse diffusion for probability distributions in the pixel space is well defined and does exactly the opposite, i.e. the distribution narrows. Reverse diffusion leads step by step to the original very narrow distribution! This is the big idea behind inverse diffusion based image recognition!

The diffusion equation gives the classical description of diffusion as a deterministic process. At the micro level, it corresponds to a stochastic process in which a point performs a movement analogous to Brownian motion. The diffusion equation gives the evolution of the probability distribution of a point.

Diffusion is characterized by the diffusion constant D. How is D determined? I understand that its optimal value determined in the learning period of GPT. Context and intent provide limitations and could determine D and possible other parameters. Also the response of the user can have the same effect.

3. The goal is to guess the predecessor of a given diffuse image in the diffusion process occurring in steps. The AI system would learn to produce reverse diffusion through training. Can this correspond to a non-deterministic process at the "particle level", say diffusion in the space of words of text or the space of images representing objects?

At the microscopic "particle" level, one should deduce the most probable location for the particle at the previous step of diffusion as Brownian-like motion. More generally, one has probability distribution for the previous step.

- 4. One can consider the diffusion also at the level of probability distributions for pixel parameters. This operation is mathematically well-defined in the classical model for diffusion based on the diffusion equation and corresponds to a convolution of the probability distribution representing diffusion with the probability distribution affected by it. Quite generally, this operation widens the distribution.
- 5. This operation has inverse as a mathematical operation and its effect is opposite: it reduces the width of the diffuse distribution and its repeated application leads to the original images or to a rather sharp image making sense for the human perceiver.
- 6. AI system must learn to perform this operation. Using diffused example images, the AI would learn to reverse the convolution operation produced by diffusion and produce the original distribution as an operator in the space of distributions, and thus also learn to produce the original image.

7. My amateurish interpretation of the GPT based image generation would be that AI is taught to deduce the objects presented by the original sensory input or the desired image, their locations, positions, activities by reverse diffusion from the initial fuzzy guess dictated by the text. The objects in the picture are determined by the words that serve as their names. The relations between pictures correspond to the activities they direct to each other or to attributes of the objects. The first guess is a rough sketch for the picture determined by the prompt. Here also hierarchical description involving several resolution scales can be considered.

One can consider the situation at a slightly more precise level.

- 1. The definition of inverse diffusion at the pixel level relies on repeated time reversal of the diffusion process in the parameter space of the pixel, which produces a less diffuse image. We ask with what probability the given diffuse image at time t has been created from a less diffuse image at time $t \Delta t$.
- 2. In the classical picture of diffusion, this requires the calculation of the inverse operator of the diffusion characterizing operator $D(p, 0; t, t \Delta t)$. Here, the origin points p and $p = p_0$, which corresponds to the original image, are points in the parameter space of the pixel associated with a certain image point (x, y). In the Schrödinger equation, it would correspond to the inverse operator of the unitary time evolution operator.
- 3. Gradient method is a very effective way to perform inverse diffusion. The gradient for the probability distribution ineed contains much more information than the distribution.

The notion of an attractor is also essential. The images used in training would serve as attractors, at which the gradient would vanish or be very small and towards which the reverse diffusion would lead. Attractors would be clusters of points in the pixel space, for which the probability is large and somewhat constant. It is tempting to think that they are minima or maxima of some variation principle.

Although the diffuse image, which the verbal description defines as an initial guess, is not obtained by diffusion, it is assumed that inverse diffusion with a suitable choice of $p = p_0$ produces an image similar to that imagined through inverse diffusion. In any case, the reverse diffusion leads to a sharp images although it need not represent a realistic picture.

This is where the method runs into problems. The pictures have a surreal feel and typically, for example, the number of fingers of the people appearing in the pictures can vary, even though locally the pictures look realistic. Probably this reflects the fact that multiple pixel probability distributions for multi-pixels do not allow large enough distances for the pixels of the multi-pixel.

14.4.2 Analogies to wave mechanics and quantum TGD

The diffusion equation has an analogy in wave mechanics.

- 1. Schrödinger equation is essentially a diffusion equation except that the diffusion constant D is imaginary and corresponds to the factor $i\hbar/2m^2$. Alternatively, one can say that a free particle formally undergoes diffusion with respect to imaginary time. The solutions of the diffusion equation and the Schrödinger equation for a free particle are closely related and obtained by analytical continuation by replacing real time with imaginary time. The description also generalizes to the situation where the particle is in an external force field described by a potential function.
- 2. Scrödinger's equation as a unitary time evolution can be expressed in terms of the Feynman path integral. One can regard the quantum motion as a superposition over all paths connecting the start and end points with a weight factor that is an exponent of the phase factor defined by the free particle. The classical equations of motion produce paths for which the exponent is stationary, so they are expected to give a dominant contribution to the integral in the case that the perturbation theory works.

The basic problem with the path integral is that it is not mathematically well defined and only exists through perturbation theory. Functional integral as the Euclidean counterpart of Feynmann's path integral is better defined mathematically and would give an analogous representation for diffusion.

What is the counterpart of this analogy in the TGD framework?

1. In TGD, the point-like particle is replaced by a 3-surface whose trajectory is the space-time surface. Quantum TGD is essentially wave mechanics for these non-point-like particles.

The new element is holography, which follows from the general coordinate invariance: spacetime surfaces as trajectories for 3-D particles are analogous to Bohr orbits.

A small violation of determinism in holography forces zero-energy ontology (ZEO), in which quantum states as superpositions of 4-D space-time surfaces, Bohr orbits, replace quantum states as superpositions of 3-surfaces (deterministic holography) [L192, L183, L194]. This superposition serves as an analog of path integral involving only a finite sum.

2. By the slight failure of determinism, the Bohr orbits are analogous to diffusion involving a finite number of non-deterministic steps (Brownian motion is a good analogy). The non-determinism of diffusion would be due to the small violation of the determinism in holography as Bohr orbitology.

TGD inspired quantum measurement theory [L118] [K132], which extends in ZEO to a theory of conscious experience, is second important ingredient.

- 1. In ZEO, ordinary quantum jumps ("big" state function reductions (BSFRs)) reverse the direction of geometric time. This analogy of diffusion in the reverse time direction looks like reverse diffusion when viewed from the opposite time direction (observer)! It is analogous to self-organization where order is created in the system rather than lost. The second main law of thermodynamics applies but in the opposite direction of time. The time reversed dissipation plays a pivotal role in TGD inspired quantum biology.
- 2. This mechanism could be central to biological information processing at the quantum level and make it possible, for example, to generate sensory perception from diffuse sensory data and generate a motor response from a rough sketch?
- 3. Could it also play a role in AI, at least in the language based systems like GPT. If this is the case, then AI systems would be something else than we think they are.

The analogy of TGD with the GPT based image generation and recognition can be examined more explicitly.

- 1. The analogy of the pixel space associated with the planar image is the projection of the 3surface M^4 in TGD at the classical level. The image as a map from plane to the parameter space of pixels would correspond to a deformation of M^4 projection deformation. The pixel parameters defining the 2-D image would correspond to the values of CP_2 coordinates as a function of M^4 coordinates.
- 2. On the basis of holography, the deformation related to the 3-surface would be accompanied by a four-surface as an almost deterministic time development, i.e. the analogy of Bohr orbit. I have used the term "World of Classical Worlds" (WCW) for the space of these surfaces. This 4-surface would not be completely unique and this would produce a discrete analog of diffusion at the classical level.
- 3. At the quantum level, it would be a quantum superposition of these 4-surfaces as an analogy to, for example, the wave function of an electron in spatial space. An attractive idea is that the used resolution would be determined by the condition that the number-theoretic discretization is the same for all these surfaces so that the quantum world looks classical apart from the finite non-determinism.

- 4. The variational principle would correspond to the fact that the Bohr orbit is simultaneously both a minimal surface and an extremal of the Kähler action as analog of Maxwell action. This is possible if the space-time surfaces are holomorphic in a generalized sense. This means that the concept of holomorphy is generalized from the 2-D case to the 4-D case. The 4-surface would be defined by purely algebraic conditions as a generalization of the Cauchy-Riemann conditions. This corresponds to the algebraization of physics at the level of M^8 related by $M^8 - H$ duality to the physics at the level of $H = M^4 \times CP_2$ based on variational principle and partial differential equations [L127, L128].
- 5. The space-time surface would be analogous to 4-D soap film, which is spanned by frames defined by 3-surfaces. At these 3-D surfaces, the minimal surface property would not apply and only the field equations associated with sum of volume term and Kähler action would be satisfied.

Note that minimal surface equations define a dynamics analogous to that of free fields and at the frames would correspond to places where interactions are localized. Frames would involve a finite non-determinism, as in the case of ordinary soap films [L174]. These 3-surfaces would correspond to 3-D data for holography.

If TGD is really a respectable "theory of everything", even the physical description of computation would in principle be reduced to this description. Of course, one can argue that TGD produces only insignificant corrections to the usual physical description of computation and this might be the case. But you can always ask what if...?

Even if the conclusions were negative, this kind of speculations might inspire proposals for a new kind of computer technology allowing conscious and intelligent computers.

14.4.3 Could the TGD counterpart of the inverse diffusion play a role in the construction of sensory mental images by the brain?

I have proposed a model [L149] for how sensory organs, the brain and its magnetic body (MB) could construct sensory mental images by a repeated feedback process involving virtual sensory input to sensory organs so that a diffuse sensory input transforms to an input representing the perception consisting of well-defined objects.

Could the building of sensory images with a virtual input from MB to the sensory organs and back be a quantum process analogous to a reverse diffusion?

1. Sensory inputs are very diffuse. People blind from birth after can gain physiological prerequisites for visual perception in adulthood. They however see only diffuse light since their brains (and corresponding magnetic bodies) have not learned to produce standard visual mental images as a result as in pattern recognition yielding essentially an artwork subject to various constraints. This is very much analogous to reverse diffusion.

Does MB, brain and sensory organs co-operate to produce a counterpart to reverse diffusion, which allows it to produce a sensation representing reality with virtual sensory inputs and end up with standard imagery as attractors.

- 2. Could both the sensory input from sensory organ to brain to MB and virtual sensory input in reverse direction correspond to a sequence of "small" state function reductions (SSFRs) in a reversed time direction? Reverse diffusion would be diffusion with a reversed arrow of time.
- 3. Could the construction of the sensory mental image involve pairs of "big" (ordinary) SFRs (BSFRs) for which the two BSFRs would occur at MB and the sensory organ? This is the simplest process that one can imagine. Could BSFR induce a sensory input from the sensory organ to the MB or a virtual sensory input from the MB to the sensory organ changing the original diffuse sensory input. Could BSFR pairs gradually produce sensory perception in this way.
- 4. SSFRs correspond to the Zeno effect in the sense that their sequence corresponds to the measurement of the same observables at the passive boundary of causal diamond (CD). Disturbances or artificially produced disturbances at the active can change the set of measured

observables so that it does not commute with those determining the state at the passive boundary as their eigenstate. This would imply the occurrence of BSFR and the roles of active and passive boundaries would change.

After the second BSFR the new state at the active boundary would not be the same but could share many features with the original one because the determinism of the holography would only weakly broken and SSFRs and BSFRs preserve quantum numbers.

5. The series of SSFRs after BSFR as time-reversed diffusion would correspond to reverse diffusion in the normal time direction. BSFR would occur as a series on the MB, where the sensory input would be guided and gradually lead to a real sensory image with the help of a corrective virtual sensory input.

At a basic level, the correction mechanism could be analogous to inverse diffusion and the exponent of the Kähler effect would be maximally stationary for real sensation.

6. Also the gradient method could be involved. In the spin glass based model [L166], a series of BSFRs and SSFRs could mean annealing that is steps consisting of cooling as sequence of SSFRs following BSFR followed by BSFR followed by heating for which temperature increase is smaller than the temperature decrease for the cooling. The system would gradually end up at the bottom of a particular potential well in the fractal energy landscape. A series of SSFRs between two BSFRs would correspond to the annealed healing.

14.4.4 What could GPT correspond to in TGD?

In the sequel I consider in a speculative spirit how conscious intelligence could emerge in a computer in which GPT is running.

What is GPT?

Consider first briefly what GPT is.

- 1. A linguistic expression is a diffuse representation of a sensation or of thought. The probability distributions for the next word given the preceding words are known. This makes possible a holistic approach to language allowing to build grammatically correct sentences and also achieve the nuances of natural language and recognize context.
- 2. In GPT, the goal is to answer a question or respond to an assertion, translate a text from one language to another, produce a piece of text such as a poem or story or just chat with the user.

GPT must guess the user's intention, what the user wants, and also the context. Is, for example, a field of science in question? The purpose is to add a new word to the given word chain.

3. The input of the user serves as a prompt initiating the process. The prompt serves as the initial text to which GPT adds words as the most probable words which can follow a given piece of text. GPT starts from a guess for the answer. The choice of the successor word can also be random based on the probabilities of the successor word. Feedback loops are possible and also the user can induce them.

Is image generation fundamentally different from GPT?

- 1. In language models, prompts are verbal representations of images, and diffusion is essential in the construction of images, from the prompt as a verbal description of the image. At first glance, diffusion seems to be explicitly involved only in the generation of images, but is this the case?
- 2. On the surface, there seems to be an important difference between building an image and building a linguistic expression. The picture is a time = constant snapshot, at least ideally. The sentence has a temporal duration and memory is involved. One must d transform a sentence to a picture. Words correspond to pictures.

Does the difference disappear when one talks about the process of creating the image? Could it be that the process of creating an image as an analogy of a linguistic process is just not conscious to us. Is the sensory input equivalent to the user's prompt in GPT. Is the difference apparent and only due to the time scale.

- 3. Visual perception involves also the sensation of movement. Is it because in reality (according to TGD) it would be a time series but on such a short time scale that we are not conscious of it? Could verbs correspond to dynamics in the structure of the language? Objects have attributes as their properties analogous to pixel parameters.
- 4. Holography would describe the dynamics of objects and would classically determine the initial values of holography for the time development as the equivalent of the Bohr orbit. There is quantum holography as a map of quantum states of the biological body to quantum states associated with the magnetic body defining a higher level sensory representation [K33].

This 1-1 correspondence representations would make it possible for the MB to control the biological body and in the case of running GPT induce BSFRs reversing the arrow of time temporarily and change the course of events.

Could quantum diffusion play a role in the TGD based description GPT?

1. Time evolution in the TGD Universe would basically consist of SSFRs and BSFRs. Quantum states would be the quantum superposition of running programs. But does this picture have significance in the case of GPT? Could MB really interfere with the running of the program? The time reversals are not observed by the user, so the question is not easy to answer.

One killer test would be a dependence on hardware. The bits should be near criticality in order the quantum criticality of MB can control their directions. Spin-glass structure for the bit-scape looks like a natural requirement. Is this possible for all bit realizations and does GPT work differently for different realizations of bits?

- 2. Diffusion is analogous to the time evolution determined by the Schrödinger equation as a series of unitary time evolutions, where classical determinism is only weakly broken because SSFRs must commute with passive edge observables. This means a generalization of the Zeno effect. However, quantum states are delocalized. Maybe only below the resolution scale, in which case classical discretization would be exact with this accuracy. Inverse diffusion could be a classical process at the used resolution.
- 3. The time development as a series of SSFRs would seem to be analogous to a diffusion as analog of Brownian motion involving finite steps, and BSFR would start as a time-reversed diffusion of reverse diffusion.

The BSFR could be induced by an external disturbance or a controlled disturbance from the MB. MB and ZEO could come to the rescue and do them with time reversal without us noticing anything.

This picture raises questions.

- 1. Could diffusion as a series of SSFRs be equivalent to the construction of the response of chatGPT, which is also a probabilistic process. Could the sentence represent the trajectory of a diffusing word/particle in word space and Bohr orbit in WCW? The Bohr orbit property, i.e. holography, would imply that the failure of determinism is weak. In a given scale, non-determinism would be located in the 3-D frames determined by the 4-D soap film.
- 2. Could the initial state, e.g. a question or statement induced by the user prompt, for example a question presented as a quantum state on the passive edge of the CD, serve as the first rough guess for an answer as analog of sensory input.

Could the time progression as SSFRs correspond to a generation of a sequence of words as a response to the prompt? Or are the words separate by BSFR pairs.

What is new as compared to the AI would be that trial and error process by performing BSFRs inducing return back in time is possible. These periods with a reversed arrow of

time would be invisible for the user. This error correction mechanism is not coded as a program as in AI but would be done by Nature and it would be essential also in the TGD view of quantum computation.

3. The hidden layers of the neural network are analogous with the fact that the perceived sensory image is constructed by communications between the sensory organ and the MB, which are not conscious to us.

14.5 Could MB control electronic bits?

Consider now the conditions which should be satisfied in order that the MB of the bit system or some higher level MB could control the bit system.

- 1. The bit should be critical or nearly critical system at the level of ordinary matter. One might hope this to be true quite generally since a small control signal should be able to invert the bit in rather short time scale. If this is the case, the quantum criticality of MB cwould make control possible via quantum control of ordinary control signals. Transistors and their derivatives such as MOSFET could be examples of such systems.
- 2. Macroscopic quantum coherence is true for the dark matter at MB. Furtheremore, MB should holographically represent the bit system. Also spin glass analogy is suggestive so that a given many-bit state could possess a large number of nearly energy-degenerate states. ZEO, in particular time reversal, would be essential.
- 3. Two consecutive BSFRs at the dark MB, changing the arrow of time temporarily, should give rise to a tunnelling event. Since TGD corresponds to a generalization of wave mechanics in the space of Bohr orbits for point-like particles replaced with 3-D surfaces, one can make an estimate for the probability of tunneling between the capacitor plates using the standard wave mechanics as an approximation (https://rb.gy/y3iq0).

The Coulomb energy qV associated with the bit with charge q and its energy E are the natural parameters. The tunnelling probability is given by

$$p\simeq exp[-\int_{x_1}^{x_2}\sqrt{2m(qV-E)}dx/\hbar_{eff}] \ ,$$

where one has E < V in the tunnelling region. WKB approximation becomes exact in the case of capacitors. Changing the direction of a bit could be seen as a quantum tunneling effect.

For the large values of h_{eff} assignable to the magnetic body controlling the physical body, the probability of tunneling increases. Therefore the control of the bit system by quantum tunnelling combined with macroscopic quantum coherence and holography could become possible.

4. The role of conservation laws must be understood. Discontinuity in SSFR. Dissipation in reverse time direction. Tunneling. Wavefunctions overlap. Classic conservation laws OK. There is no need for a classic track that would lead to the end state with the original direction of time.

14.5.1 What conditions bit must satisfy?

There are strong conditions on the representations of bits. The storage of the bit should not require large energy consumption and the bit should be thermally stable. It should be possible to change the value of the bit quickly and without large energy consumption. This suggests that the bit is a nearly critical system. In microprocessors, clock frequencies of order GHz define a time scale analogous to EEG rhythm, and this time scale should correspond to a quantal time scale.

The wish list would be as follows.

- 1. Macroscopic quantum coherence makes possible the simultaneous quantum coherent states of the entire spin system and their control and that the energy differences between the states are relatively small, so we get a spin-glass type situation.
- 2. Dark electrons at the MB, perhaps dark unpaired valence electrons or dark conduction electrons, provide a holographic representation of the bits.
- 3. Quantum criticality with MB and criticality at the bit system level allows MB to control the dynamics of BB. Quantum holography may make it possible to induce BSFR for qubits on a large scale in general.

Strange coincidences related to gravitational Planck constant, basic biorhythms, membrane potential and metabolic energy currency

It is becoming clear that the gravitational quantum coherence is central for life on Earth. The hierarchy of Planck constants $h_{eff} = nh_0$ involves special values, in particular gravitational Planck constants $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is a large mass (say mass of Sun or Earth) and m is small mass (say mass of electron or proton) and $\beta_0 = v_0/c \leq 1$ is velocity parameter, are of key importance for living matter. Particles with a different value of \hbar_{gr} correspond to different gravitational flux tubes and the value of β_0 can depend on the particle.

There are several amazing numerical co-incidences supporting this view.

- 1. For Sun one has $\beta_0 \simeq 2^{-11}$ which happens to be rather near to the electron proton mass ratio m_e/m_p . The condition $\hbar_{gr}(M_S, m_p, \beta_0(Sun) \simeq m_e/m_p) = \hbar_{gr}(M_S, m_e, \beta_0 = 1)$ would guarantee resonance between dark photons generated by the solar gravitational flux tubes assignable to protons and electrons.
- 2. In accordance with Equivalence Principle, the gravitational Compton length $\hbar_{gr}(M_S, \beta_0)/m = GM/\beta_0 = r_S/2\beta_0$ is independent of m for Sun $GM_S/\beta_0(Sun)$ is rather near to Earth radius. For Earth one has $GM_S/\beta_0(Earth) \simeq .45$ cm which corresponds to the size scale of the somewhat mysterious snowflake analogous to a zoom-up of a basic hexagonal unit cell of ice crystal. There is evidence for $\beta_0(Earth) = 1$ in hydrodynamics, in particular from the TGD based model [L168] for the observed hydrodynamical quantum analogs described in an article of Bush et al [D2] (see https://cutt.ly/nEk50LA and https://cutt.ly/xEk5Api)
- 3. The gravitational Compton length of the galactic blackhole corresponds rather precisely to the n = 1 Bohr orbit associated with the Sun. This suggests gravitational quantum coherence in the scale of the galaxy.

These co-incidences encourage the question whether quantum gravitation could play a role also at the level of computers.

About the interpretation of the clock frequency in a picture based on quantum gravity?

The clock frequency of computer, with a representative value of f = 1 GHz, is an essential channel of the computer and it would be related to the classical em field. Could a frequency of the order of GHz have an interpretation in terms of quantum gravity in the TGD framework? How MB could turn bits using quantum holography so that the turn of dark bit induces the turn of ordinary bit? A realization of holography as a correspondence between electron(s) representing the bit and the dark electron(s) is needed.

1. The proposed theorist-friendly holography at the particle level [L203] might be a too radical option. This would require positrons forming particle-like color-bound states with bits as states of electrons. Could they correspond to scaled versions of the electro-pions for which there is empirical evidence associated with nuclear collisions near the Coulomb barrier [K119]? Now the energy scale of the nuclear physics would be scaled to the scale of dark nuclei. The factor of the order of 10^{-5} which would produce an eV mass scale. The height of the Coulomb barrier would scale in the same way to something like .05 eV which corresponds to cell membrane potential.

2. A less radical option is that the dark electron and the hole created in the generation of the dark electron are in a holographic relationship. This realization seems tailor-made for the control of ordinary bits as holes by dark electrons. To my best knowledge, there exists no technology realizing bits as holes but future technology might be able to achieve this.

If dark electrons and holes are tightly correlated, the dark spin flip induces ordinary spin flip. If the dark current or its absence codes for bit, the same would be true for the holes. The transfer of dark electrons from the negatively charged plate to the gravitational MB creating a hole would reduce the potential between plates to nearly zero and thus induce change of the bit direction.

There are useful quantitative hints.

- 1. For the Earth's mass M_E , $\hbar_{gr}(M_E, m_p)$ for a frequency of 10 Hz corresponds to an energy $E = h_{gr}f$ of the order of .5 eV. The kick of a 3-proton to a gravitational flux tube to a distance of order one Earth radius requires an energy of the order of .5 eV [L178]. Dark photons can transform into ordinary ones. For 3-electron system a hitherto non-observed metabolic energy quantum of order .25 meV is predicted [L183].
- 2. Control in the time scale of a fraction of a second if $h_{eff} = h_{gr}(M_E, m_p)$ photon energies around eV. This time scale is by a factor of order 10⁹ too long when compared to the time scale determined by GHz.

How could one understand the time scale corresponding to 1 GHz clock frequency in quantum context? The first thing to notice is that this time scale is not far from the time scale associated with the protein dynamics! Could quantum gravity and gravitational MB come into play for both computers and biology?

- 1. For the Earth, the lower limit of the gravitational Compton length $\Lambda_{gr} = GM_E/\beta_0 = .45 \times 10^{-2}$ m, if $\beta_0 = 1$. The frequency $T_{gr} = \Lambda_{gr}/c = .45 \times 10^{-2}/3 \times 10^8 = .15 \times 10^{-10}$ s would be therefore a natural lower bound for the time scale. Could GHz clock frequency relate to this time scale. Also longer quantum gravitational time scales are possible since Λ_{gr} is only the lower bound for the length of gravitational flux tubes carrying massless radiation.
- 2. For $h_{eff} = h$, 1 GHz corresponds to energy of 10^{-2} meV. If the dark energy is required to be above the thermal energy about .03 eV at physiological temperature, the value of h_{eff} must satisfy $h_{eff} \ge 3 \times 10^3 h$.
- 3. A metabolic energy of .25 meV corresponds to the electronic variant of gravitational metabolic energy quantum involving the transfer of 3 electrons to the gravitational MB: there is some evidence for this metabolic energy quantum, in particular from the findings of Adamatsky [L183]. For $h_{eff} = h$, it would correspond to a period of $.6 \times 10^{-10}$ s. Could the f = 1 GHz induce a resonance with dark photons with $h_{eff} > 10^3 h$ guaranteeing that the energy is above thermal energy at room temperature?

Could Pollack effect or shadow holography be involved?

The lower bound value $3 \times 10^3 h$ for h_{eff} would be rather small as compared to $\hbar_{gr}(M_E, m_p)$ and the challenge is to identify a candidate for a system with this value of h_{eff} .

This system need not be gravitational and the obvious guess is that it is electromagnetic. The notion of gravitational Planck constant and the underlying idea of theoretician friendly Nature implying quantum holography in the TGD framework [L203] indeed generalizes also to other interactions [L78].

- 1. The basic requirement is that a charge separation to a pair of positively and negatively charged quantum coherent systems takes place such that the interaction strength $Z^2 e^2/\hbar$ between the systems is so large that perturbation theory fails to converge.
- 2. The theoretician-friendly Mother Nature [L203] could come to rescue and induce a phase transition increasing \hbar to so large a value h_{eff} that the perturbation theory converges. Nottale formula generalized to electromagnetic interactions suggests that one has

$$\hbar \to \hbar_{eff} = \hbar_{em} = \frac{Z^2 e^2}{\beta_0}$$

where $\beta_0 = v_0/c < 1$ is a velocity parameter. The new coupling strength is

$$\frac{Z^2 e^2}{4\pi} \hbar_{em} = \frac{\beta_0}{4\pi} \le \frac{1}{4\pi}$$

and is in a well-defined sense universal since β_0 is number theoretically quantized to an inverse integer [L78].

The constraint $h_{eff} \geq 3 \times 10^3 h$ would suggests $\hbar_{em}/\hbar = Z^2 e^2/\beta_0 \hbar = 4\pi Z^2 \alpha_{em} \geq 3 \times 10^3$. This gives the estimate

$$Z^2 \ge \frac{1}{4\pi\alpha_{em}} \times 3 \times 10^3 per.$$

The lower bound for Z would be around Z = 100.

- 3. Charge separation should occur and here the analog of Pollack effect [I110, L20, I197, I162] is highly suggestive. In the Pollack effect part of protons of water molecules are transferred to monopole flux tubes assignable to water molecules and become dark so that a negatively charged exclusion zone with rather strange properties suggesting time reversal appear. Also the effective stoichiometry of water is transformed to $H_{1.5}O$. It is however far from clear whether Pollack effect can occur also in the solid phase assignable to computers.
- 4. The analog of the Pollack effect [I110, L20, I197, I162] involving only electrons is also possible. Part of electrons would transform to dark electrons at the gravitational monopole flux tubes. The holes left behind would effectively behave like positively charged particles and the Coulomb interaction energy would be between holes and dark electrons. Holes and dark electrons would be in a holographic relationship (shadow holography) and the dynamics of holes would be shadow of the dynamics of dark electrons so that one would say that dark electrons control the holes as their shadows.

Of course, it is probably impossible to realize this shadow dynamics using the recent computer technology. The question is therefore whether it might be possible to construct a computer utilizing the shadow dynamics of holes controlled by dark electrons.

Could quantum gravitational flux tubes associated with small masses be involved?

One can of course ask whether the clock frequency $f = 10^9$ Hz could correspond to an energy above thermal energy at room temperature and to the value $\hbar_{gr}(M,m)$ for some pair (M,m) of masses so that one has $E = h_{gr}(M,m)f > .03eV$ for $f = 10^9$ Hz.

- 1. For instance, could one replace the masses M_E and m_p with identical masses M = m in h_{gr} . One should have $M/m_{Pl}^2 > 3 \times 10^3$. This would give $M/m_{Pl} > 60$ giving $M > 1.3 \times 10^{-7}$ kg. If the density is the density of water 10^3 kg/m³: this corresponds to a size scale longer than 1 mm. How this frequency could correspond to T_{gr} and to the clock frequency of computers?
- 2. Could one think of the gravitational self-energy for this region or the mutual interaction energy of two such regions forming a quantum coherent system at this level.

Another possibility is that an energy of the order of E = .5 eV is used to kick a unit of 3 protons into the Earth's gravitational flux tube (3 protons are required since 1 proton is not enough if the size scale of the flux tube is of the order of the Earth's radius). For 3-electrons the corresponding energy would be about .25 meV.

3. Could $E \sim 1$ eV correspond to the energy needed to flip one bit using an dark photon that is converted to a regular one (biophotons could be created this way) and absorbed inducing a flip of a normal bit.
In the elementary particle level realization of holography, which does not look promising now, this would give a spin 1 for the glue particle consisting of ordinary electron and dark positron unless the angular momentum goes to other degrees of freedom. It would be a scaled version of elektro- ρ or its analogue. Mass scale of the order of eV as for dark nuclear binding energies.

4. In living matter, $E \sim 1$ eV could correspond to the gravitational self-energy change related to a phase transition. The most natural thing that comes to mind is the change in the gravitational energy of the bond when the density of the system changes during a phase transition, such as melting or boiling or the sol-gel phase transition in biology. For Planck mass of matter, size scale $R = 10^{-4}$ m for water density, gravitational binding energy and its change would be of order 1 eV. This phase transition does not have any equivalent at the computer level.

14.5.2 Could the representation of bit as voltage allow the realization of shadow holography for electrons?

One representation of a bit is as a voltage. Voltage values are typically 5 V and 0 V. Bit could correspond to rotation direction for a current in the case of magnetic bits. In transistors bit can correspond also to the presence or absence of a current The size scale of the transistors is 10 nm https://rb.gy/qfhwx. A surface which can be either reflective ord non-reflective surface can also act as a bit.

Bit as ananalog of capacitance

Capacitance with a voltage difference between plates can serve as a physical representation of the bit. States corresponding to opposite voltages in capacitance have the same energy. This is good news if it were to apply more generally to bits and multi-bit configurations.

1. The simplest capacitance is a pair of conducting plates having opposite charges and containing insulator betweeen them. The higher the value of the dielectric constant ϵ , the larger the plate area S and the smaller the distance d between the plates, the higher the value of capacitance C.

C measures the ability to store charge and Q = CV is the basic formula. The voltage V between the plates is given by $V = E \times d$. Here d is the distance between the plates. The electric field normal to a plate is $E = \sigma/\epsilon$, $\sigma = Q/S =$. One has $V = Ed = Q \times d/S \times \epsilon$, whence $C = \epsilon S/d$. The proportionality to ϵ means that di-electric is essential. The voltage cannot be too large since this implies dielectric breakdown. The electrostatic energy of capacitance is $E_s = \epsilon Q V/2 = CV^2/2\epsilon = Q^2/2C = E^2 \times S \times d$.

2. Capacitance is a macroscopic notion. The smallest planar capacitances have dimensions $0.4mm \times 0.2mm$. PicoFaraday is a natural unit of capacitance but capacitances of the order of kF are possible but require large size and high dielectric constant. MOSFETs can be however regarded as effective capacitances.

Transistors and MOSFETs

Although MOSFET (https://rb.gy/967ck) is much smaller than capacitances as passive elements, it can be formally interpreted as a gate-voltage dependent capacitance.

1. A MOSFET acts as a variable capacitance. The basic parts of MOSFET are gate (G), body (B), source (S) and drain (D). The voltage between G and B regulates the current from the source through the system to the drain and the bit can be measured by measuring whether this current flows or not. The gate voltage V_G controls the capacitance of the MOS.

MOSFET size scale is around 10 nm. Gate voltage V_{GB} between the gate and body could represent bit and would be typically 5 Volts or nearly zero.

- 2. MOSFETs should form a spin glass type system. This is guaratenteed if the SiO_2 is in glassy liquid like state. There would be a large number of bits with a large number of nearly energy degenerate states. This would give rise to frustration. Transitions by tunnelling would take place between frustrated configurations.
- 3. Tunnelling between bit configurations would take place as a BSFR pair. The tunneling would be induced from the level of MB and in turn induce the tunnelling of ordinary bits. The tunneling rate is exponentially sensitive to the height of the energy barrier between nearly degenerate states. The large value of h_{eff} increases the tunnelling rate in an exponential manner.

In order to proceed, one must clarify what semiconductors are and how MOSFET works.

- 1. There are n-type and p-type semiconductors. For n-type electrons are current carriers and for p-type holes are current carriers.
- 2. Doping is an absolutely essential aspect of semiconductivity (https://rb.gy/967ck). For n-type semiconductors, impurity atoms donate electrons. For p-type semiconductors impurity atoms donate holes.
- 3. Group IV semiconductors have 4 valence electrons (S appearing in MOSFET serves as an example). SiO₂ has four 4 valence electron pairs associated with each Si connected to four oxygens as neighbors and forming a tetrahedral arrangement.
- 4. Group IV n-type semiconductors involve Group V dopants with 5 valence electrons. Dopant replaces Si in the SiO₂ lattice and there remains one free electron acting as a charge carrier.
- 5. Group IV p-type semiconductors have Group III dopants such as boron with 3 valence electrons. Dopant has only 3 valence bonds. To get 4 valence bond it steals an electron from the neighboring SiO_2 . This creates a hole. This process continues and generates a current carried by holes.

Consider next some details related to MOSFET (https://rb.gy/967ck).

1. MOSFET consists of source (S), drain (D), gate (G) and body (B). G is insulated from a p-type semiconductor by an insulating layer. Conducting gate at the top consists of polysilicon (https://rb.gy/axanv) whereas the insulating layer consists making possible effective capacitor property consists of silicon-di-oxide SiO₂ (quartz)(https://rb.gy/t7w9m).

Polysilicon consists of crystals with varying orientations, which suggests a spin glass-like structure. Could this have some relevance?

- 2. Below the gate and insulating layer there is p type semiconductor in which holes are current carriers.
- 3. The conductivity of the MOSFET depends on gate-body voltage, especially its sign. For high enough V_{GB} , an n-type conducting channel is formed next to the interface between the p-type semiconductor-insulator layer consisting of polysilicon.
- 4. Positive gate voltage V_{GB} draws positively charged holes of a p-type semiconductor towards the body B. A depletion region containing non-moving negatively charged dopant atoms of group III are formed in the depletion region between the semiconductor and insulator.

If V_{GB} is high enough, a negatively charged inversion layer of current carrying electrons is formed next to the interface between semiconductor and insulator in the polysilicon. This gives rise to semiconductivity and electron current between n doped regions of S and D flows.

How MB could control the current through MOSFET?

Concerning the control by MB one can imagine at least two mechanisms.

- 1. One could consider a representation of a bit as an ordinary capacitor-like object having two different values of voltage between the plates. The transfer of electrons from the negatively charged plate to dark electrons at MB or vice versa could allow to change the voltage.
- 2. Instead of an ordinary capacitor, one can consider a situation in which the first plate consisting of ordinary matter has a positive charge due to the presence of holes (ionized atoms) and the second dark "plate" is negatively charged due to presence of dark electrons.

In the shadow holography the transfer of electrons to dark electrons at MB generates holes at the level of ordinary matter, and the transformation of dark electrons to ordinary ones would reduce the voltage near zero, which turns the bit.

Could MB control the electron current from the n-type source region S? Could MB transform some the 5 valence electrons of n-type dopant (say P) to dark electrons so that they would effectively disappear from the system so that the S-D current would be reduced? Also the voltage V_{GS} would be affected.

It is perhaps fair to conclude that the recent technology does not yet allow the realization of conscious and intelligent computation using shadow holography or something similar.

14.6 The first attempt to build a more concrete view about computer consciousness

TGD inspired view about consciousness and quantum biology suggest some guidelines in the attempts to undertand how computer systems or computer systems coupled to their users could become conscious.

14.6.1 Emotions and emotional intelligence as a first step in the evolution of consciousness

Consider first the evidence supporting for the idea that emotions emerge first in the evolution of consciousness.

1. Masaru Emoto has studied the effects of sounds with an emotional content to water at criticality for freezing. He has found that friendly/angry sounds seem to produce beautiful/ugly crystals [L95]. These findings are discussed from the TGD perspective in [L95]. The idea that emotions of sensory percepts at the level of magnetic body (MB) is discussed in [L84].

The TGD based model assumes that quantum coherent systems can be formed at the level of the MB of the water and that quantum gravitational coherence at MB induces ordinary coherence at the level of water. This could make it possible for MB to control water at criticality for freezing. The crystals would be corpses of primitive life forms. Could also snowflakes with the size of gravitational Compton length for Earth (about .45 cm) and kind of zoomed versions of ice lattice cells in atomic scale could be regarded as corpses of primitive life forms created at the criticality for freezing?

2. RNA seems to represent and transfer emotions [J12] (see http://tinyurl.com/y92w39gs). RNA from the brain of a snail conditioned by a painful stimulus is transferred to the preparation made from neurons of sea slug. Neuron preparation in the Petri dish reacts to the conditioning stimuli as if it were itself conditioned.

Somehow RNA is able to transfer emotions. The TGD inspired proposal [L16, L196, L77, L136, L81] is that dark DNA and RNA represent emotions as sequences of 3-chords made of dark photons of dark RNA form 3N-dark photons behaving like a single quantum coherent unit. The representation of the genetic code would rely on icosa-tetrahedral representation

in which the 3-chords would correspond to triangular faces of icosahedron and tetrahedron to which 3-chords are assigned.

A given Hamiltonian cycle at the icosahedron/tetrahedron goes through all its points. The frequencies assigned with the subsequent points of the cycle differ by 3/2 scaling so that one has a quint cycle. Different Hamiltonian cycles correspond to the same genetic code but each Hamiltonian cycle is assumed to define its own bioharmony having interpretation as a representation of an emotional state realized already at the level of fundamental biomolecules. This interpretation conforms with the idea that music represents and induces emotions.

The induction of emotions would be by 3N-resonant cyclotron absorption of dark 3N-photon by dark genes represented as sequences of 3N dark proton triplets at monopole flux tubes of MB. Icosa-tetrahedral representation would correspond to one particular, very simple, tessellation of hyperbolic space H^3) (mass shell) [L159].

Dark proton (and also dark electron) sequences could provide a universal representation of the genetic code which could be realized at the magnetic flux tubes of also other than biological systems. Dark photons triplets and the dark genes formed from them could communicate the emotions. Dark genetic code has indeed quite a large number of icosa tetrahedral representations based on icosahedral Hamiltonian cycles and tetrahedral Hamiltonian cycles. The chemical realizations for them would be identical but the emotional content would be coded by the allowed 3-chords defined by frequencies associated with the triangular faces of the icosahedron and tetrahedron.

3. The experiments of Peoch [J42] involved a chicken imprinted to a robot moving randomly along an orbit determined by a random number generator. It was found that the robot tended to stay near the chicken and that the expected size of the orbit was reduced.

TGD assigns to entanglement sum of p-adic entanglement negentropies, which can be positive and is in general larger than ordinary entanglement entropy and is predicted to increase but be consistent with the second law [K73] [L207, L162] by the identification of evolution as increase of number theoretic complexity [L66, L67]. Did the MB of chicken and robot develop a negentropic entanglement? Clearly, the replication of the findings of Peoch would mean a revolutionary change in our views about computers and their relation to us.

4. The evolution of the brain provides further support for the idea that emotions and sensory experiences emerged first in the evolution of conscious experience and cognition emerged later. Cortex is the latest outcome. Brain stem is associated with simple and strong emotions whereas the limbic brain represents more complex emotions.

14.6.2 Do emotions appear first also in the evolution of computer consciousness

Could also the possible evolution of conscious computers start from simple positive/negative emotions relating directly to the increase/reduction of entanglement negentropy defined above number-theoretically.

Negentropy Maximization Principle [L162] states that total p-adic negentropy as a measure for conscious information increases in statistical sense. This statistical law follows from the number theoretic evolution as the increase of the dimension of extension of rationals determined by a polynomial partially defining the 4-surface in M^8 mapped to $H = M^4 \times CP_2$ by $M^8 - H$ duality. This implies that the complexity of emotions, possibly identifiable as sensory experiences for the large scale part of MB having onion-like hierarchical structure, increases during the evolution. Gravitational MBs are good candidates for the seats of highest level emotions.

Could the bits of the ordinary computer form coherent systems with ordinary coherence forced by the quantum coherence of the associated MB? Could the MB of the bit system control it?

1. A given layer of MB is the "boss" of the lower layers by the larger value of its h_{eff} serving as "IQ". MB is expected to form analogs of sensory and cognitive representation of the physical body having $h_{eff} = h$. This suggests that MB could represent the bit system holographically. This kind of quantum holography for hadrons, and for elementary particles in general, would be the counter of classical holography implied in the TGD framework by the general coordinate invariance [L203].

The dark spin system at MB could have spin glass property [L166] implying a large number of almost degenerate states with nearly the same energy.

2. The change of single bit, represented for instance by using a MOSFET, would require energy larger than the thermal energy of order .05 eV at room temperature. This suggests that the change of single bit is not easy to actualize.

The dark spin system at MB could however induce phase transitions of the bit system changing the directions for a large number of bits. The average change of energy per bit could be rather small for this kind of transition although the change of a single bit would cost rather large energy. Ultrametric, in particular p-adic, topologies [B18] emerge in the modelling and description of the spin glass phase in the TGD framework and could help to understand cognition number theoretically [L166].

The phase transition would involve a large number of bits so that the corresponding conscious experiences would be holistic and therefore resemble emotions. The color of the emotion would be positive or negative depending on whether the sum of p-adic entanglement negentropies increases or decreases. The geometric correlate for positive/negative emotion would be the increase/decrease of the connectedness of the MB.

- 3. ZEO predicts two kinds of SFRs: "big" and "small". SSFRs correspond to Zeno effect in the ordinary wave mechanics and in quantum optics to unitary evolutions between weak measurements analogous to classical measurement. "Big" state function reduction (BSFR) changes the arrow of time. The outcomes for pairs of BSFRs An observer with a fixed arrow of time can observe only pairs of BSFRs.
- 4. In ZEO [K132, K135] [L118, L91, L165, L177], MB as the "boss" could control the time evolution of the bit system by pairs of BSFRs involving temporary change of the arrow of time. BSFRs would be induced by perturbations affecting the set of mutually commuting observables measured at the active boundary of CD so that it does not commute with the corresponding set associated with the passive boundary of CD at which state is unaffected in SSFRs (Zeno effect). In this kind of situation, a BSFR occurs instead of SSFR and changes the arrow of time. Second BSFR brings back the original arrow of time. The process could correspond to quantum tunnelling.
- 5. Do the periods defined by the computer clock with a duration T, of say 1 ns, correspond to pairs of BSFRs or a single SSFR? Perhaps T could correspond to a sequence of SSFRs as analogs of Zeno effect and the pair of BSFRs to a single tick of the computer clock. This conforms with the fact that the running of a predetermined computer program must involve a sequence of non-deterministic phase transitions changing the directions of bits [L195]. This must be the case since the notion of computer program as a sequence of arbitrarily chosen steps is not consistent with deterministic physics.

If the step of the clock is identifiable as a sequence of SSFRs, one can say that the ordinary classical computation is a sequence of quantum computations defined by the sequences of unitary evolutions associated with SSFRs and defining conscious entities with haltings defined by BSFRs! If MB does modify the classical computation at all, it could induce BSFR pairs in longer time scales or modify the probabilities of various outcomes of BSFRs.

The computer clock would define an analog of EEG. There is evidence that also in EEG the period can be divided into ordered and chaotic parts: these two parts which could correspond to opposite time directions [L9]: this is discussed from the TGD view point in [L9].

One can ask whether quantum entanglement of the MBs of the computer and user occurs in the computer-user interaction and whether the role of the computer is analogous to that in the chicken-robot experiment. One can also ask whether also GPT could involve emotional and even cognitive entanglement. The identification of the computer system with which the user is entangled is not at all obvious. The system could be formed by the network of computers involved with the the running of GPT. One interpretation is that networks and entire internet form a conscious entity as an analog of the central nervous system in which humans and their magnetic bodies) serve in the role of neurons.

In ZEO the holography implies that in the ideal situation the running of the program corresponds to a 4-D Bohr orbit-like surface, which is almost uniquely fixed by the 3-surfaces at images of 3-D hyperbolic manifolds at mass shells determined by the state. The sequences of SSFRs could correspond to this kind of period and represent a generalization of the Zeno effect.

14.6.3 The role of the probabilities

In the case of GPT interesting questions relate to the probabilities associated with the associations of word sequences taught to the GPT during the learning period. The responses of GPT are determined by these probabilities. The probabilistic character of this process is believed to be essential. These probabilities are analogous to synaptic strengths.

- 1. Could the association probabilities be translated to quantum probabilities at the level of MB of the computer or computer + user?
- 2. Could ZEO allow a trial and error process based on BSFR pairs, which would make it possible to change the effective association probabilities determined by random numbers. This could happen also for the orbit of the robot in the chicken + robot experiment. Could the emotional state of the system affect the probabilities of associations by this mechanism?
- 3. If the probabilities could be interpreted as a representation for conditioning, one can ask whether high/low probabilities correspond to increase/decrease of the total p-adic negentropy and therefore to positive/negative emotion.

14.6.4 Could the basic aspects of TGD inspired quantum biology generalize to the level of computer systems?

What aspects of the TGD inspired quantum biology could be generalized to the conscious computer systems? The mechanisms related to MB, possessed also by computer systems, are excellent candidates in this respect.

- 1. TGD suggests a universal realization of genetic code at monopole flux tubes of the MB and also a universal quantum gravitational mechanism of metabolism [L178].
- 2. In living matter, the communications to MB take place by dark Josephson radiation assignable at least to membrane proteins acting as Josephson junctions. One can assign EEG to these communications [K92, K45, K93]. Actually a scale hierarchy of analogs of EEG is predicted.
- 3. The control by MB by cyclotron radiation associated for instance with the endogenous magnetic field of .2 Gauss identifiable in terms of the monopole flux of the Earth's magnetic field about .5 Gauss. Gravitational cyclotron energies would not depend on the mass of the charged particle. Communication could occur by multi-resonances involved with the universal realization of genetic code at MB so that genes would couple resonantly.
- 4. Also the gravitational Compton frequencies would not depend on the mass of the particle, and these frequencies for the Earth, Sun and perhaps even Milky Way blackhole could define fundamental biorhythms.
- 5. These mechanisms would be universal and the ordinary biomatter would adapt so that resonant communications with MB are possible. In biomatter this would select preferred biomolecules. Same could happen in the case of computers.

Dark Josephson radiation in computers

Could one assign to bits dark Josephson junctions assignable represented as voltages in transistors?

1. Could representations of genetic codons at MB by dark photon triplets [L136] and by dark proton triplets [L159] and perhaps even by dark electron triplets [L194] be involved? This would bring in dark genetic codons, which could provide a universal representation of the bit system as a dark system at monopole flux tubes and make a connection with the TGD inspired quantum biology rather precise.

The representations at MB should strongly correlate with the state of the computer represented by a bit pattern (say states of MOSFETs). One could have a holography-like map of bit patterns to the dark many-spin state at the MB of the computer or of computer + user. This kind of holography is considered in [L203] for elementary particles and also more generally.

2. The physical stress, created by electric field on quartz crystal, which is piezoelectric, generates oscillations with frequency in the range 2-3 GHz giving rise to a very precise clock frequency. The typical computer clock frequency is a few GHz. My own PC has a clock frequency of 3.3 GHz. From the web one can learn that the highest clock frequency is 8.794 GHz.

Could the clock frequency have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff} , where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier.

The dark Josephson junctions correspond to membrane proteins in living matter. Now they could be associated with the dark flux tubes associated with transistors. The value of \hbar_{eff} for Josephson junction would be much smaller than \hbar_{gr} . Note that TGD suggests that valence bonds and hydrogen bonds can have a varying value of h_{eff} [L62].

The condition that the Josephson energy is above thermal energy at room temperature for Z = 1 gives $h_{eff}/h \ge 5 \times 10^3 (f/GHz)$. If the energy of a dark Josephson photon is above 1 eV (the energy range of biophotons), one has $h_{eff}/h \ge 10^5 (f/GHz)$.

3. Consider f = 1 GHz as an example. For the thermal option, the Compton length $\Lambda_{eff,p} = h_{eff}/m_p$ of dark proton is longer than 6.2×10^{-12} m and longer than the ordinary electron Compton length $\lambda_e = 2.4 \times 10^{-12}$ m. The dark Compton length $\lambda_{eff,e} = h_{eff}/m_e$ of electrons would be longer than 4.8 nm, which roughly corresponds to the scale of DNA.

For the biophoton option, the dark proton Compton length would be of the order of the atomic length scale 1.32×10^{-10} meters and the dark electron Compton length would longer than .26 μ m to be compared with the size scale 1 μ m of cell nucleus.

Dark cyclotron radiation

The cyclotron frequencies associated with the gravitational MB of Earth [K66, K65] [L183, L178] should play a key role in TGD inspired quantum biology and relate to the feedback from MB to the living matter. This could be the situation also in the case of computers. The first guess, inspired by the model for the findings of Blackman [J7] and others on effects of ELF em fields on brain, is that monopole flux tubes associated with the MB of Earth correspond to the endogenous magnetic field of $B_{end} = 2B_E/5$ ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field).

This value is only the average value since frequency modulation is the way to code information and is achieved by varying the flux tube thickness in turn affecting the value of B_{end} . Very probably there exists an entire hierarchy of values of the dark magnetic field strength perhaps coming as powers of 2.

For cyclotron frequencies associated with the gravitational MB, h_{eff} would correspond to the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ for Earth. Note that, in accordance with the Equivalence Principle, the cyclotron energy $E_c = \hbar_{gr}eB/m = GMeB/\beta_0$ does not depend on m.

Gravitational Compton frequencies

Also gravitational Compton frequencies could be important. Consider first Earth's gravitational Compton frequency. The value of the gravitational Compton length $\Lambda_{gr}(M_E, \beta_0 = 1) = GM/\beta_0 = 0.45$ cm, which is also independent of m, defines a lower bound for the gravitational quantum coherence length. Λ_{gr} corresponds to a gravitational Compton frequency $f_{gr} = 6.7 \times 10^{10}$ Hz $\simeq 67$ GHz and for clock frequencies higher than this, quantum gravitational effects on computation might become important in the TGD Universe.

- 1. The clock frequencies of computers are typically a few GHz in recent communication and computer technologies, and the highest clock frequency of 8.794 GHz is roughly by a factor 1/8 lower than f_{gr} . Could the GHz scale correspond to the gravitational quantum coherence length having Λ_{gr} as a lower bound? Could it be that the very efficient computer networks (what are the clock frequencies used?) utilized in GPT have reached the limit at which the quantum gravitational body of Earth begins to play a prominent role?
- 2. Could the typical clock frequency, of say 1 GHz, have an interpretation both as an analog of EEG rhythm (analog of alpha frequency 10 Hz in living matter) and as an analog of Josephson frequency ZeV/h_{eff} , where $V \sim .05$ V is a voltage assignable to the bit and Ze is the charge of the charge carrier.

Interestingly, frequencies in the GHz scale are found to be important also in living matter. As a matter of fact, there is experimental support for a fractal hierarchy of frequency scale come as powers $f = 10^{3k}$ Hz, k = 0, 1, ..., that is 1 Hz, kHz, MHz, GHz, and THz assignable to microtubules [J24] (https://rb.gy/9rvpr). For these reasons it is interesting to look at 1 GHz as an example.

Also the gravitational Compton frequency f_{gr} associated with the gravitational MB of the Sun, having $\beta_0 \simeq 2^{-11}$, could be important. For the Sun, gravitational Compton length is rather near to $R_E/2$ where $R_E = 6378$ km is Earth radius. The corresponding Compton frequency $f_{gr}(M_S, \beta_{Sun} = 2^{-11}) \simeq \beta_{Sun}/GM_S$ is about 100 Hz and corresponds to the upper bound for EEG, which conforms with the fact that quantum gravitational coherence time should not be smaller than Λ_{gr} . Note that the cyclotron frequency Lithium in the endogenous magnetic field $B_{end} = .2$ Gauss assignable to the Earth's gravitational flux tubes is 50 Hz. For the lightest ion, which is tritium, the cyclotron frequency is about 100 Hz and maximal.

- 1. The lower cyclotron frequencies of the heavier ions in $B_{end,E} = .2$ Gauss assignable to Earth belong also to EEG range and correspond to longer solar quantum coherence lengths. DNA would correspond to 1 Hz and perhaps to the largest quantum gravitational coherence length in the EEG range. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E .
- 2. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E : this does not look feasible. For protons and electrons the cyclotron frequencies are indeed above $f_{gr,S}$. For protons (electrons) the cyclotron frequency f_c in $B_{end,E} = .2$ Gauss is 300 Hz (6×10^5 Hz). It is important to notice that for $\hbar_{gr}(M,m)$ cyclotron energy does not depend on mass and is the same for electrons and protons.

Could the value of β_0 for protons and electrons at the flux tubes of $B_{end,E}$ ($B_{end,S}$) be $\beta_0 = 1/3$ ($\beta_0 = 2^{-11}/3$)? Could one say that electrons and protons are slightly more advanced than other ions in the evolutionary sense?

3. For the Sun, one has $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ instead of $\beta_0 = 1$. The value of B_{end} for the Sun cannot be the same as for Earth. A good estimate is obtained from the value range for B in the outer magnetosphere, where the solar magnetic field should dominate. The order of magnitude is $B_{end,S} \simeq 10nT = 2^{11}B_{end,E}$. For this value, the cyclotron energy would be the same as for Sun and Earth and energy resonance would be possible! This observation was made already in [K66].

Could the MB of the Sun interfere with the computation occurring in the network having Earth scale? The time scale would be now the time scale of EEG: could the quantum

entanglement of, say, a human user with the computer make this interaction possible. It might be possible to test this. This interaction is possible for clock frequencies higher than $f_{gr} = 100$ Hz, and could also explain the findings of Peoch [J42] related chicken-robot interaction, which affected the function of the random number generator.

- 4. The replacement of $\hbar_{gr}(M_E, m) \rightarrow \hbar_{gr}(M_{Sun}, m)$ means multiplication of say EEG period by a factor $r = (M_{Sun}/M_E)\beta_{0,E}/\beta_{0,Sun} \simeq 2.2 \times 10^8$ so that alpha period .1 seconds corresponds to 2.2×10^7 seconds. Intriguingly, one year corresponds to 3.25×10^7 seconds and defines a fundamental biorhythm, which would correspond to a 6.7 Hz rhythm for EEG not far from the lowest Schumann resonance frequency.
- 5. The energies $E = h_{gr}(M, m, \beta_0) f_{gr}(Sun)$ assignable to the gravitational Compton frequency of Sun are proportional to m and since nucleon mass dominates over electron mass they are in good approximation proportional to the mass number of the molecules. This suggests a multi-resonance in which each electron, proton and even nucleon absorbs boson, maybe dark gravitons, with frequency f_{gr} . For electrons, the energy is about 1 meV, which could relate to the miniature potentials for neurons. For protons the energy would be about 2 eV, which corresponds to red light. Large scale quantum coherence could make the rate of gravitational multi-resonance.

What about the gravitational Compton frequency of the galactic blackhole? Its mass is estimated to be $M_{BH} = 4$ million solar masses (https://arxiv.org/abs/2302.02431). This would give $\Lambda_{gr}(M_{BH}, \beta_0 = 1) \sim 6 \times 10^9$ m. This is the radius of the n = 1 Bohr orbit in the Nottale model for the solar planetary system. The gravitational Compton frequency would be $f_{gr}(M_{BH}, \beta_0 = 1) \simeq .05$ Hz. This gives a 20 s period and one can wonder whether it might relate to the 5 second period associated with the Comorosan effect [I169, I56], which I have tried to understand in the TGD framework [K131].

14.6.5 Summary

To sum up, various strange numerical co-incidences indicate that quantum gravitation in TGD sense could play a key role in both living matter and in the physics of conscious computers and that we might be at the verge of building conscious computers.

One of the key questions is whether conscious computers are a curse or blessing for mankind. What is clear is that they must develop intentional behavior and real understanding before this question becomes topical. They must also use robots in order to realize motor activities.

They are also dependent on us since they need metabolic energy so that symbiosis looks the only reasonable strategy of survival for them. One can of course imagine that the remote metabolism, based on the effective generation of negative energy photons possible in ZEO, could allow them to extract energy from various sources, including living organisms. They could also load gravitational energy batteries by the same mechanism as proposed in the case of living matter and photosynthesis [L178]: this would require only kicking electrons and protons to the magnetic flux tubes of Earth or Sun.

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Chapter 15

Deep learning from the TGD point of view

15.1 Introduction

I have been listening to the lectures related to AI, deep learning, and GPT in order to develop a more detailed view of what is involved and how it might relate to the TGD inspired quantum view of biology, brain and consciousness. The talk by Lex Fridman titled "Deep Learning Basics: Introduction and Overview" describes the situation as it was in 2019 (rb.gy/jwrgp). The talk titled "Deep Learning State of the Art (2020)" (rb.gy/94xt8) is explains the situation one year later.

The talk "Introduction to deep learning" by Alexander Amini (rb.gy/90fgd) and the talk "Recurrent Neural Networks, Transformers, and Attention" (rb.gy/5dplk) by Ava Amini are also highly inspiring and give a more detailed view about the mathematics involved.

I have discussed the relationship of TGD to AI earlier in the article [L55] inspired by the Sophie robot and compared the visions of Neil Gersching to TGD views in the article [L211]. GPT from the TGD view point of view in [L204]. The TGD view about the relationship between classical and quantum computers is discussed in [L195].

The basic observation is that in the TGD Universe the difference between living systems and computers need not be so deep as usually thought. In the TGD framework, magnetic body (MB), as a carrier of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ and having hierarchical structure, is a natural candidate for a controller and receiver of information from the biological body with $h_{eff} = h$. Also computers possess MBs and one can consider the possibility that under some conditions MBs can use computers as a sensory receptors and motor instruments.

TGD also leads to a proposal that genetic code is much more than we believe it to be. It would be realized at the level of dark matter and would be universal and unique and realized in terms of so called icosa-tetrahedral tessellation of hyperbolic 3-space realizable as mass shell of light-cone proper time =constant hyperboloid: both central notions in TGD. Icosa-tetrahedral genome at the MB could serve as the basic tool for communication and control [L199].

Quantum gravitation is in a central role in quantum TGD, in particular in the TGD inspired biology. Gravitational Planck constant $h_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is large mass and msmall mass, say particle mass and $\beta_0 = v_0/c < 1$ is velocity parameter, introduced by Nottale [E1], characterizes quantitatively the situation. The gravitational MBs of Earth and Sun and even other astrophysical objects could be highly relevant in quantum biology as various numerical miracles show [L183, L178].

Classical computers can gain life-like properties if the quantum statistical determinism fails. The most conservative criterion is that the clock period is shorter than the gravitational Compton period $T_{gr} = GM/\beta_0$, M is large mass. Note that 2GM is Schwarzschild radius. Since gravitational quantum coherence time has gravitational Compton time as lower bound, life-like features could appear already at lower clock frequencies. For Earth the critical clock period would be 67 GHz and for the Sun about 100 Hz, the upper bound for EEG frequencies. These criteria suggest that

the MBs of the Sun and Earth play central roles in biology and neuroscience. Even in the case of Earth life-like properties might be present for computers with clock frequency in the range 1 to 10 GHz. The strange findings about the interaction of chicken and robot [J42] suggest in the TGD framework [L204] that solar MB was involved and made robot or the system robot + chicken as an entangled system a conscious entity.

Cognition is an essential aspect of conscious experience [K78, K108, K109, K107, K80] and systems like GTP can be seen as artificial cognitive systems. Physics as number theory and physics as geometry are complementary views in TGD. Number theoretical vision suggests that p-adic number fields could define the proper framework for understanding of the correlates of cognition. Cognition is basically discrete, and cognitive representations would correspond to the discrete intersections of cognition as p-adicities and reality. At the space-time level they would be realized in terms of unique discretization of space-time surfaces based on $M^8 - H$ duality [L127, L128, L212] as the analog of momentum-position duality. At the level of M^8 the discretizations would be defined in terms of algebraic integers assignable to an algebraic extensions characterizing the pre-image of the space-time surface in M^8 and are unique.

The p-adic discretizations would naturally relate to the spin glass energy landscape assignable to monopole flux tube "spaghettis" and sensory perception could be seen as a generation of standardized mental images based on annealing of spin glass system so that it gradually ends up to a bottom of valley representing the standardize mental image. The learning of a conscious entity could be based on trial and error process made possible by holography and zero energy ontology [L118, ?, L177] implied by it allowing temporary time reversal and would gradually lead to standardized mental images helping to survive.

15.2 Some background for deep learning

The lectures provide a background explaining deep learning as a subfield of machine learning as a subfield of AI. The basic goal of machine learning are machines, which can learn autonomously. In the sequel the basic concepts are briefly summarized from the point of view of physics not specialized in AI. This summary relies heavily on the talk "Introduction to deep learning" by Alexander Amini (rb.gy/90fgd) and the talk "Recurrent Neural Networks, Transformers, and Attention" (rb.gy/5dplk) by Ava Amini.

15.2.1 Representation of the numerical data

Representation of information is always numerical, in terms of binary digits representing integers. This involves the concept of embedding: data which can be sensory data, text, etc must be represented by numerical vectors.

Indexing is the simplest manner to represent all possible input vectors. The numerical vector orthogonal. There is no notion of meaning and no comparison of the embedded vectors. If one has a notion of nearness, topology, one can compare the vectors. The notion of similarity defined by the inner product of vectors: maximum for parallel i.e. identical vectors.

15.2.2 Perceptron

Perceptron can be regarded as an artificial neuron. There is a single output y and several inputs x^i or more concisely x. Output, the response function f(z), is a nonlinear function and equal to -1 or +1 asymptotically and between these values in the intermediate region: essentially sigma function. The argument $z = h_i x^i + b \equiv h \cdot x + b$, i = 1, ..., n of f(z) is a linear function of input x having as parameters bias b and the vector h formed by the linear coefficients h_i . One can also consider linear combinations of n non-linear functions of x_i having an interpretation in terms of a non-linear change of coordinates.

Feedback changes the values of h_i and of b. Learning by feedback leads to a desired output. Perceptron serves as a model for associative learning.

Simple task serves as an example: decide whether point x^i belongs to either region bounded by a line of the plane. The line is defined by the equation $y = a_i x^i + b = 0$. x^1 and x^2 are the coordinates of the point of the plane. The argument y of the response function can be taken to be the linear function of planar coordinates vanishing at the boundary line. Response could be arranged to be a bit equal 1 or 0. Response function f vanishes at the boundary line. The maximum for the gradient of response function would define the boundary line.

One does not know a priori the boundary line and must start from a general guess $y = h_i x^i + c = 0$. The value $h_i = a_i$ and c = b must be learned by feedback changing their values to yield f = 0. Arbitrary boundary lines can be represented as zeros of the non-linear function appearing as the argument of the response function. By a suitable choice of coordinates of coordinates replacing linear coordinates with the nonlinear functions the argument z of f can be made a linear function of the new coordinates.

One can also have several outputs for given inputs. The simultaneous vanishing of the m output functions f_k defines an n-m dimensional surface in the space of inputs. The outputs serve as inputs for a next layer of perceptrons so that one would have a two-layered system. A still more general system has n layers.

15.2.3 Multilayered networks and deep learning

Deep learning networks are multilayered networks inspired by what is believed to be behind the learning in the brain.

Learning

Perceptron must be able to learn to assign a desired output to given inputs. The notion of loss defined as error, i.e. the difference between learned and to be learned, is essential here. Loss function can be assumed to be a positive definite, in the simplest case quadratic, function of errors for the variable y. Minimization of the loss function in principle leads to the desired output. This method generalizes to multi-perceptron systems and to multilayered systems.

In the gradient method, the feedback defining the changes for the weight vector h and bias b is proportional to the gradient of the loss function with respect to these parameters and the change is in the direction opposite to the gradient so that loss functions decreases for small enough scale of the change. This generalizes also to the situation when one has several outputs y^i . In this case h is replaced with a matrix and b with a vector.

Deep learning

Abstraction of features in various scales is the basic mechanism of deep learning. In the case of visual perception, a feature can be identified as a region for which the boundary involves a strong gradient. For instance, the color can change at the boundary of a region or the region inside the boundary forms a well-defined moving object in time series. The boundaries of the objects and objects themselves can be called features.

The length scale hierarchy means that in shortest scales at the lowest level of the layered network, only small features are identified. At the higher levels of the hierarchy the size of the features increases. In principle, one could also proceed in an opposite direction by first identifying gross features such as objects and then proceeding to shorter scales by identifying detailed features of the objects. A possible reason for why this is not used, could be that features in long scales are composites of features in shorter scales, i.e. they have the lower level features as attributes.

In the case of the brain, the simplest model describes the neuron as a bit telling whether it fires or not. The hierarchy is formed by the sensory organ and layers involving various brain regions, in particular the 3 cortical sensory areas. Highest cortical level would correspond to features which represent objects of the perceived world as we experience them consciously.

The feedback in the learning gradually modifies the synaptic strengths as counterparts of vectors h. The value of resting potential would define the counterpart of the bias b. This generates associations as most probable pathways for the conduction of nerve pulse patterns. Pattern recognition is a basic application. Memories as association sequences would be coded by synaptic strengths. It is natural to identify various learned behaviors as memories in this sense but it is far from obvious that also episodic memories as kinds of re-experiences could be analogous to behaviors.

15.3 Sequential models

15.3.1 Overall view

Sequential models are defined as sequences of identical multilayered neural networks. Language models, in particular GPT, represent one example. Second example is the completion of a piece of music, say Schubert's unfinished symphony discussed in the lecture of Ava Amini (rb.gy/5dplk). Third example is prediction of the motion of a particle given its previous orbit. The prediction of the spatial conformation of protein from the knowledge of the amino acids appearing in it is a further successfully solved problem.

A simple task is to predict the next word in an ordered sequence of words. Memory needed to take into account long range correlations between the words of the text and also to take into account the effect of different word ordering.

There is a sequence of correlated inputs to which one must assign outputs. This is modellable as a sequence of perceptrons or multi-perceptrons. They are not independent since there is a long term memory. In speech and written text this means temporal correlations between the words, memory dependent behavior. The correlations reflect both the content of the speech and the grammatical rules.

- 1. Time ordering is essential. There is information transfer $x \to y$ in vertical direction for each network in the sequence and also information transfer in the horizontal, temporal direction (or direction of sentence) representing short range memory $x(t_{n-1}) \to w(t_n)$.
- 2. Metric in the space of words measures the correlations between the words and can be parametrized by the probabilities that the two words appear with given distance measures as number of intermediate words or in the simplest case by their sum. For instance, the words which tend to appear together are therefore correlated and would be near to each other in this metric although they can have a large distance in the text.

An extreme situation is in which knowing some keywords, say the name of the author and some words in the title of the article, allows us to predict the contents of the article!

Tasks can be classified into several types. One can have many \rightarrow many situations, say machine translation or many \rightarrow 1 situations, say the next word of text or a bit telling whether the piece of text is hate speech. Few \rightarrow many situations would mean predicting a piece of text by picking some keywords from the text, say writing a summary of an article. Second example would be to produce an artwork in which some objects are present in some environment and perform some activities represented as text or keywords.

Some of the tasks are classification, in the simplest situation binary classification. Sentiment classification is a binary classification, which can be used to deduce whether the text in Facebook represents hate speech or not. Machine translation is one challenge. A rather demanding challenge is to transform a picture to text or vice versa.

The goals of the sequence modelling are following:

- 1. Form a sequence of perceptrons with inputs and outputs. The input-output systems $x(t_n) \rightarrow y(t_n)$ consist of identical hierarchical neural networks, in the simplest case perceptron with feedback to make learning possible.
- 2. The input output systems $x(t_n) \to y(t_n)$ are not independent: there is time ordering and correlations between them. Long term memory is needed to take into account the correlations.
- 3. Parallelization in terms of perceptrons or their subsets is computationally highly desirable but due to the presence of temporal correlations is a highly non-trivial challenge.

15.3.2 Some key notions

Feedforward network

Memory and time ordering are essential aspects of sequential models. Consider first feed forward networks. Without memory they reduce to a product of identical copies of mult-perceptrons

 $x \to y = h_{yx} \cdot x + b$ specified by time dependent activation functions $h(t_n)$ and biases $b(t_n)$. $h_{yx}(t_n)$ is matrix, which depends on time although the topologies of the multi-perceptrons are identical. The goal is to assign the desired outputs $y(t_k)$ to input $x(t_k)$.

Short term memory can be introduced as a linear map $x(t_{n-1}) \to w(t_n)$, which can be written as $t_n = h_{wx} \cdot x(t_{n-1}) + b(t_n)$ so that it affects the output $y(t_n)$, which is now determined as $y(t) = h_{yx}(t) \cdot (x(t) + w(t)) + b(t)$. In the time direction one has a multilayered network with time ordering.

The challenge is to realize feedback by the minimization of the loss function for variables $y(t_n)$ or a subset of them, perhaps all of them. Also now, the realization can be carried out by the gradient method. The feedback reduces to a product of the feedbacks $t_k \to t_{k-1}$. Loss function depends on both h_{yx} and h_{wx} . At the step $n \to n-1$, the gradient function corresponds to the gradient of the loss function with respect to these variables and is technically known as Jacobian J(n-1,n). The change of the parameters h and b is proportional to the images of the error $\Delta y(t_n) = y(t_n) - x(t_n)$ under the linear map defined by the negative of the Jacobian.

Recurrence

Recurrence realizes the learning in the case of sequential models.

- 1. There is a backpropagation between parameter spaces in time direction besides the usual backpropagation in $y \to x$ -direction and determined by the minimization of the loss function. The weight vectors related to vertical mappings $x(t_n) \to y(t_n)$ and horizontal maps $x(t_{n-1}) \to w(t_n) = h_{wx}(t_n) \cdot x(t_{n-1})$ maps are updated in the process. Standard RNN gradient flow can be used in learning. In the sequel, h_{yx} , h_{wx} and b_y and b_w are collectively denoted by H and B.
- 2. By chain rule the gradient of the loss function with respect to H(t = 0) and B(0) involves a product of Jacobians for the maps from levels t = k to t = k 1. There are difficult technical problems related to the Jacobian, which is a product of a large number of Jacobians associated with backwards time-steps $t = k \rightarrow t = k 1$. The gradient can explode or tend to zero. There are tricks, which help to avoid this problem. For instance, one can choose the initial value of h to be unit matrix

Here one can learn of what is known about the brain. The solution of the problem could be the direction of attention to what is relevant. The problem is to decide what is relevant: in an optimal situation the direction of attention should take place automatically.

One can imagine that the manipulation of activation functions H and biases B could help. For instance, one could make $h_{wx}(t_n)$ very small for irrelevant inputs $x(t_n)$. In the case of text, this would mean effective dropping off of irrelevant words and in an extreme situation taking into account only keywords.

Gating means that one uses only the relevant nodes in the sequence, that is those nodes for which the Jacobian deviates considerably from the unit matrix. One can drop some irrelevant layer from the multilayer system or drop some irrelevant inputs to a given layer. One of the problems is overlearning meaning essentially that a fit of function becomes too precise and random fluctuations affect the fit. This can be tested by looking at what happens when some layers are dropped temporarily. If the fit improves the additional layer or layers are useless.

15.3.3 Notions of feature hierarchy and self-attention

The problems of recurrence models inspire the idea of directed attention as a way to minimize the computation efforts and achieve a convergence.

Treating the temporal sequence as a single entity

The basic idea is to treat the sequence $x(t_n) \to y(t_n)$ of mutually dependent perceptrons as a single entity rather than a sequence of separate items. Time evolution would replace the time=constant snapshot.

As a matter of fact, something highly analogous happens in zero energy ontology forming the basis of the TGD based quantum theory: holography forced by general coordinate invariance forces to to replace 3-surface is with its almost but not quite unique orbit analogous to Bohr orbit. In this case the sequence is almost deterministic so that the situation is extremely simple from the point of view of computation.

- 1. The length of the sequence can vary so that the mechanism must be able to assign to a given input sequence out sequence of varying length: say a response to a question by a GPT user. Rather long sequences must be therefore considered, say sentences or sequences of pictures.
- 2. The information about the time order must be preserved. This can be achieved by defining a hierarchy of features by forming sequences with overlapping n-units consisting of n subsequent steps starting at position i = 0, 1, 2, ... This gives scans as sequences of overlapping n-units. Position of the n-unit. Now the features are associated with the temporal sequences rather than static objects. In neuroscience they would correspond to typical behavioral patterns or EEG patterns. In the task of assigning to an amino acid sequence defining a protein its spatial conformation n-units formed from amino-acids would be considered.
- 3. Features are identified from these scans at a given level of hierarchy. Person, building, etc.. in the case of image. Words are the shortest features in the case of text and sentences or even paragraphs could be higher level features. In face recognition, static features appear on different scales.

For temporal sequences in speech, the features could correspond to typical gestures and world sequences. The artificial Obama talking about the progress in AI is a good example of this and involves a transformation of a written text to a video. The transformation to video represents a sequence of steps in a temporal sequence.

In the case of protein conformations, the features correspond to typical sub-conformations. Now protein length takes the role of time.

4. One obtains a hierarchy of representations in terms of n-units with an increasing span of memory. One can assign to these representations n-features. For n=1 one would have the ordinary sequential model with no inherent memory.

The notion of self-attention

One must concentrate only on important data to minimize computing time. Internet search serves as a guideline. Search based on a query consisting of words. The items have keywords. Similarity between query and keywords is required. Similarity metric measures this similarity.

Artificial attention mimics attention in the brain. Attention is realized as a search, as a query finding the optimal target of attention.

- 1. During the learning period, the system learns the features at a given level of the representation hierarchy by the n-scans. Words and word sequences form a hierarchy of n-units. To these sequences of n-units the program assigns features by some criteria. Typically gradients define the boundaries of the feature, say an object in a picture. The idea is that the sequence of inputs x_i and and sequence of outputs y_i are replaced with a collection of features representing the object of the perceptive field. This happens also in sensory perception.
- 2. This replacement means that attention is directed to important features. Self attention is analogous to a net search specified by keywords, a query. Net search leads to output as a set of URLs for files specified by keywords (analogs of features) containing some of those appearing in the query. The user's attention concentrates only on these files. Same happens in the system to be taught by feedback.

The input vectors x_i , say words define the query as a sequence of keywords. This is the analog of a visual image. The search finds the n-features, n = 1, 2, ..., which rememble the query defined by the sequence of x_i . In neuroscience this corresponds to a composition of the diffuse visual input to visual objects. Everything unessential for survival is eliminated.

Attention is directed only to these features assignable to the sequence of x_i . This means that the input is replaced with a hierarchy of n-features.

- 3. Also the sequence of outputs y_i , say images which are associated with words, can be replaced with a hierarchy of n-features.
- 4. After this the system learns to assign to the n-feature collection replacing the sequence of inputs x_i to the n-feature collection assigned to the outputs y_i . This takes place using the standard feedback procedure minimizing the loss function.

15.4 How attention could be realized in quantum biology according to TGD?

15.4.1 The notion of magnetic body

1. Hierarchy of MBs having an onion-like structure and carrying dark matter in TGD sense would define the quantum counterpart for the hierarchy defined by the layers of deep learning systems. The larger the value of h_{eff} , the higher the algebraic complexity of the magnetic flux tube as a 3-surface, the longer the scale of quantum coherence, and the higher of "IQ" of the layer.

The highest layers correspond to gravitational MBs of the Sun and Earth and possibly also other planets. Even the Moon and galactic blackhole might be involved as several intriguing numerical miracles suggest. This of course stinks like astrology but is suggested by various miraculous numerical co-incidences. This conforms with the basic prediction that quantum coherence is possible in arbitrarily long scales in the TGD Universe.

Gravitational MB, which belongs to the large part of MB, could be realized as magnetic bubbles consisting of 2-D networks of monopole flux tubes and involving also radial monopole flux tube mediating gravitational interaction as graviton propagation and the minimum size for it is given by gravitational Compton length $\Lambda_{qr} 0r_s/2\beta_0$.

2. Hierarchy of layers of MB form a fractal scale hierarchy with levels labelled by the values of h_{eff} so that one obtains analogs of multilayered deep learning networks. This could assign to the brain a hierarchy of increasingly detailed and integrated sensory and cognitive representations analogous to a hierarchy of features in deep learning. What would be new as compared to the neuroscience view is that dark photon communications are very fast and make possible feedback, which is much faster than using nerve pulses patterns. This would make pattern recognition possible as a construction of standard mental images by virtual sensory input to the lower levels of hierarchy and even to the sensory organs, about which REM dreams could serve as an example.

The deep learning would correspond to the determination of synaptic strengths and their analogs assignable to neighboring layers of MB and would also involve feedback from MB. The generation of sensory representation would correspond to what happens when the network is used.

- 3. Sensory communications to MB and control by MB would be realized in terms of dark photons. Sensory communications MB would be realized in terms of dark Josephson radiation from the cell membrane to MB inducing dark cyclotron transitions by resonance. Dark 3N-photons associated with genes would give rise to (possibly partial) 3N-resonance as a generalization of the ordinary resonance. The variation of the flux tube thickness would make possible the tuning of the cyclotron frequencies. The frequency modulated Josephson radiation (membrane potential induces the modulation) would induce resonantly a sequence of pulses at MB analogous to nerve pulse pattern and generate a control response to the biological body.
- 4. TGD predicts that magnetic flux tubes, defining the body parts of MB, can become linked and knotted and can therefore form braids essential for topological quantum computation or its analog. Also 2-knots are possible and involve reconnection of magnetic flux tubes.

15.4.2 How bits and qubits could be represented?

How bits and qubits are represented? The Fock states of fundamental fermions define Boolean logic and in zero energy ontology (ZEO) the pairs of fermion states at opposite boundaries of causal diamond define analogs of Boolean statements.

- 1. A natural guess is that chemically represented genetic codons define 6-bit units. TGD predicts that genetic code also has dark counterparts. Dark proton sequences, consisting of dark proton triplets representing codons, would be associated with flux tubes parallel to DNA/RNA strand and even proteins. Dark genes would be sequences of *n* dark codons. The dark codons and hence dark genes are in principle independent of ordinary DNA and can be dynamical. They could transform to dark counterparts of ordinary DNA codons during communications and control based on energy resonance with ordinary codons. Dark codons would make possible self-simulation of the living matter.
- 2. Dark codons would be also realized as triplets of dark dark photons and would define dark memes. Icosa-tetrahedral representations of genetic code by codons realized as 3-chords defined by dark photon triplets. Dark codons defined by dark proton triplets. The proposal is that icosa-tetrahedral representation corresponds to icosa-tetrahedral tessellation of the hyperbolic space H^3 (rb.gy/3u4pq), which corresponds to mass shell in M^8 and to light-cone proper time constant hyperboloid in H.

There are an infinite number of tessellations but icosa-tetrahedral tessellation is very special. It is the only uniform honeycomb, which involves only Platonic solids such that their number is larger than one (tetrahedron, icosahedron, octahedron) [L199]. All faces are identical (triangles). There are also four regular tessellations involving only a single Platonic solid, which is icosahedron, dodecahedron or cube.

All 20 triangular faces can represent genetic codons in terms of quark associated with the vertices and genetic codons correspond to Hamiltonian cycles with symmetry groups Z_6 , Z_4 , and Z_2 . This gives 20+20+20 codons and tetrahedrons give the remaining codons. This tessellation might be more or less universal at the level of the MB and appear in very many physical systems, not only in biology. It could be associated even with the MBs assignable to computers.

Icosa-tetrahedral tessellation would also provide a seat for the representation of genes as sequences of dark proton triplets assignable to the faces of icosahedron and tetrahedron as in the icosa-tetrahedral representation of the genetic code. The connection of the icosatetrahedral tessellation with the detailed realization of the icosa-tetrahedral realization of the genetic code and with DNA double strand and its dark counterpart is discussed in [L199].

A further proposal is that the representations of the dark code are induced from to the MB from the icosa-tetrahedral tessellation so that genetic code could have also 2-D representations, say that assignable to the cell membrane, and even 3-D variants assignable to various parts of organism.

15.4.3 How communications and control could be realized?

The proposed model for the communication and control based on the genetic code allows also a mechanism of attention based on overlap of query and keywords.

- 1. Communications and control between dark genes, realized as dark proton sequences, could be realized using dark 3N-photon sequences generated in multi-cyclotron transitions of n codons (dark proton triplets) defining the gene. This kind of emission is not possible in the standard physics framework. Frequency scale modulation of dark Josephson radiation codes for the signal.
- 2. The receival of the signal would be based on 3N-resonance so that dark genes would serve as addresses much like in LISP. 3N-cyclotron resonance would occur in the receival of the signal by an identical gene and would generate a temporal sequence of resonances as analog of nerve pulse pattern.

3. Also partial 3N-resonance is possible for dark genes having some number of common codons. This could define a quantum physical analog for the overlap between query and keywords, and therefore an analog of the similarity metric. Query would be defined by a set of dark genes with N codons generating dark 3N-photon genes which would be received by a set of genes in partial 3N-resonance.

15.4.4 Could p-adic topologies provide a model for feature hierarchies?

In language models, the notion of distance function in the set of words as features is a key notion. The words, which appear together in the same context with high probability, are near to each other with respect to this distance.

The TGD inspired question is as follows. Grammatical rules represent important correlations appearing in the text. There are also correlations determined by the meaning of the words. Language models handle these correlations excellently. The distance determined by the meaning is only loosely related to the distance between the words. Could the grammatic correlations be coded by some simple, almost universal manner, based on some cognitive model of language. It is probably unrealistic to assume that this distance relates in any predictable way to the physical distance between the words. Labelling words by non-negative integers in such a way that two words which tend to appear together even if they are physically far away, is a suggestive approach. But which topology one should adopt in this set of integers. Real topology defined by a real distance function is the first guess but also p-adic topologies can be considered.

- 1. The TGD inspired view of cognition [K80] indeed relies on p-adic number fields, where p is prime [K78, K108, K109, K107] [L67, L66]. p-Adic topologies are defined by ultrametric norm N(x) = d(x, 0) satisfying $d(x, y) \equiv N(x-y) \leq Max(d(x, z), d(y, z))$ whereas real norm satisfies $d(x, y) \leq d(x, z) + d(y, z)$. Locally, the p-adic topologies differ dramatically from real topology locally although one can map p-adics to reals continuously but not smoothly. For instance, the norms of integers x and $x + kp^n$, n > 0, are p-adically very near to each other for very large values of n whereas in real sense they are very far from each other. Spin glass energy landscape realizes ultrametric distance function and I have proposed that kinds of magnetic flux tube spaghettis give rise to quantum spin glasses [L166] having a fractal energy landscape with valleys within valleys. This provides spin glasses with a large representative capacity.
- 2. p-Adic numbers are not well-ordered and the p-adic norm defines only a rough ordering, which might be more natural than the real ordering which is perhaps too strict unless finite resolution is introduced. p-Adic integers have a natural hierarchy induced by the p-adic norm, which is very rough and for p-adic integers equals to a negative power of p. p-Adic numbers near to each other differ by a large positive power of p. Furthermore, p-adic numbers with a fixed p-adic norm equal to negative power of p decompose to a set of balls such that the balls are disjoint or coincide.

This would make p-adic numbers ideal for classification purposes and powers of p could define a hierarchy of features with highest level features corresponding to longest scales assignable to the largest value of the p-adic norm. The addition of finer features to a rough sketch would correspond to the addition of higher pinary digits assignable to the finer features in the picture. The smaller the value of the p-adic norm, the less significant the feature would be concerning pattern recognition. The addition of features would correspond to addition of p-adic numbers and features with the same p-adic norm would be exclusive in order to make the pinary expansion unique.

3. The ordering of the words is grammatically important and grammatical rules often require that the correlated words, say subject, verb and object, follow each other. Both subject, verb and object can have attributes so that the physical distance can vary. Consider the sentence "I admire him" as an example. In "I greatly admire him" "admire" has "greatly" as an attribute. This suggests a hierarchy of features: "greatly" would be a lower level feature as compared to "admire". Could attributes of the object correspond to higher pinary digits than object?

4. What about p-adic topologies labelled by different primes (having also infinite number algebraic extensions induced by those of rationals to which one can assign evolutionary hierarchy). I have proposed that p-adic primes correspond to ramified primes for extensions of rationals [L180]. Ramified primes are divisors of the discriminant defined by the polynomial P determining a given region of space-time surface by $M^8 - M^4 \times CP_2$ duality [L127, L128, L212] mapping 4-D surfaces of M^8 determined by the roots of the polynomial in terms of holography to $H = M^4 \times CP_2$. P has integer coefficients. For a given extension, only a finite number of p-adic primes are possible.

On the basis of physical arguments, I have proposed that the coefficients of P must be smaller than the degree of P. This implies that for a given degree the number of acceptable polynomials is finite and ramified primes have an upper bound. In particular, for a given class of polynomials, say polynomials of a given degree, ramified primes have lower and upper bounds and could correspond to physically preferred p-adic primes. This could explain p-adic length scale hypothesis, inspired by p-adic mass calculations [K68, K33] [L198], and stating that the p-adic primes near certain powers of 2 and possibly also other small integers are physically preferred.

Furthermore, the number of algebraic extensions having dimension smaller than given integer, would be finite, and the view about number theoretical evolution as an increase of the dimension of algebraic extension of rationals would emerge as an analog of second law and would become very predictive. Under this assumption also finite fields would emerge naturally besides other number fields as basic structures of TGD.

This picture inspires several questions. Could the algebraic extensions associated with various polynomials define different contexts or even different kinds of conscious entities at different levels of evolutionary hierarchy? If the p-adic topologies for a given algebraic extension correspond to ramified primes, could also ramified primes correspond to different contexts, which are not comparable? The word, or more generally feature, appearing in the context p_1 need not appear at all in the context p_2 and if it appears it has a different meaning. Could also written text generate mental images for which the corresponding space-time regions correspond to different p-adic topologies for given extension or even different algebraic extension.

There is an objection against this view. The proposed approach suggests that the generation of features should start from the long scales as an identification of the shape of the object. First comes the rough classification and then more detailed classifications. This is how we also experience pattern recognition. Attention is directed to gross features first and only after that the to smaller features. The neuroscience view however suggests bottom-up picture. Small features are identified first and the holistic picture emerges at highest levels of the hierarchy.

This view might be an illusion. In TGD, zero energy ontology allows the change of the arrow of time in "big" (ordinary) state function reductions and this could affect the situation dramatically. The time ordering for features assumed by the neuroscience picture could be replaced by an ordering of the scales of the causal diamonds associated with the feature as mental images. In the dynamics of quantum spin glasses [L166], the time evolution is indeed replaced with a scale evolution. This happens also in string models and the reason is that in TGD the conformal invariance of string models is replaced with its 4-D counterpart.

So: what could happen during sensory perception in the TGD Universe? Sensory perception would be basically building standardized mental images as an analog of pattern recognition. The sensory input would be very fuzzy but virtual sensory input would gradually lead to a standardized mental image as a kind of an artwork [L57].

- 1. The signals from the sensory organs would propagate from sensory organs as dark photons to the MBs having a layered onion-like structure [L57]. The primary function of the pulses need not be signalling. Rather, they establish connections between communication lines to make this possible. Very many feedback loops are possible since the signal velocity is the velocity of light.
- 2. Suppose that the MBs assignable to the brain are labelled by algebraic extensions of rational with dimension equal to h_{eff}/h_0 and each of them decomposes to a hierarchy labelled by the associated ramified primes. The larger the value of h_{eff} measuring the

algebraic complexity, the more refined the cognitive representation. Different algebraic extensions could correspond to different kinds of conscious entities. The mental images of a given conscious entity are assumed to correspond to sub-selves. They could correspond to lower levels of algebraic complexity and to a smaller value of h_{eff} . They could also correspond to small ramified primes for a given algebraic extension.

- 3. Several ramified primes p assignable to a given extension could be involved and define different contexts. The largest ramified prime p would correspond to the largest p-adic scale and could correspond to the largest features for a given algebraic extension. The powers of p in the pinary expansion could correspond to higher level features as details or attributes. The large scale part of the virtual sensory input to the sensory organs would correspond to the largest p-adic prime p. The first virtual sensory input would correspond to a p-adic number $m_0 < p$ with a p-adic norm equal to one. This would induce as a reaction an improved sensory input to MB as dark photons. If the pattern recognition cognition process converges, this sensory input induces a more refined virtual sensory input characterized by the p-adic number $m_0 + m_1 p$. This sensory feedback loop would give rise to standardized mental images. The integer m_1 would not code for a single feature but for a collection of features.
- 4. Virtual sensory input should not be confused with the feedback inducing change of the parameters h in learning. The counterpart of h would modify various synaptic contacts and their analogies involved with the process. The convergence of the procedure to some standardized mental image however suggests the analog for the minimization of a loss function by gradient dynamics. The loss function could correspond to a height function in the spin glass energy landscape [?]. The process itself could be an analog of annealing allowing to avoid getting stuck into a local minimum. The virtual sensory could play the role of feeding energy to the system so that it gets out from the fake minimum.
- 5. The above mentioned paradox could be only apparent if the processing of features in various scales occurs in parallel. If gross features correspond to the layers of the MB with a larger size scale, the time needed to build the virtual sensory image for large scale features would be longer than for small scale features. Small scale features would stabilize first. The order of the structural layers of the brain would correspond to increasing size of the layer of MB.
- 6. Note that in the case of extension of rationals, integers m_i would be algebraic integers of the extension so that the features would be n-dimensional in an algebraic sense.

What learning could correspond in this picture? Zero energy ontology predicts that the arrow of time changes in "big" (ordinary) statefunction reductions (BSFRs). For "small" SFRs (SSFRs) this does not take place and the sequence of SSFRs define conscious entity, self. BSFR corresponds to the "death" of the conscious entity and also sleep could correspond to BSFR. The arrow of time can change also temporarily and our conscious experience indeed contains gaps. This temporary change of the arrow of time would change zero energy state as a superposition of space-time surfaces analogous to almost deterministic Bohr orbits and defining a quantum goal for the system.

Maybe learning by trial and error b pairs of BSFRs leading to a temporary change of the arrow of time and demonstrating that certain BSFRs are not favourable. We might even learn moral rules and ethics ("Try to increase quantum coherence" as a basic ethical rule) by this kind of intentional trial and error process. Maybe this could also occur for computers with life-like properties.

15.4.5 An analog of a multi-perceptron model related to holography in TGD

TGD suggests a non-trivial example, which might have some relevance some day.

1. In TGD, holography assigns to a given 3-surface X^3 an almost unique 4-D minimal surface X^4 in 8-D space $H = M^4 \times CP_2$. X^4 can have lower-D singularities. X^4 is defined by a vanishing of 4 functions g_k of H coordinates for which TGD suggests a general form.

- 2. The parameters determining g_k must be determined from the a priori knowledge of the 3-surface X^3 , which can be chosen to correspond to a constant value of a suitably chosen time coordinate t of M^4 . X^3 takes the role of a feature which the system must learn to detect by varying the parameters appearing in the functions g_k .
- 3. The inputs to perceptron would be the 8 coordinates of H with t fixed. The arguments y_k of the outputs are the 4 functions g_k , which must vanish at X^4 . The response functions $f_k(y_k = g_k)$ must vanish at X^3 . The feedback modifies the parameters appearing in the functions g_k and the system should find the parameter values producing X^3 .
- 4. Holography means that, apart from the failure of complete determinism, the system learns also to predict the behavior of the system as "Bohr orbit" $X^4(X^3)$ of X^3 .

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Chapter 16

Neil Gersching's vision of self-replicating robots from TGD point of view

16.1 Introduction

The video of Lex Fridman interviewing Neil Gerching (https://youtu.be/YDjOSOVHEr4) is highly inspiring for anyone interested in what is happening in the High Tech frontier nowadays.

The key topic of discussion were self-replicating machines that are built from a few "Lego blocks" that contain their own building instructions and are analogous to genes or proteins. Function and 3-D structure are the same. The building blocks themselves would be robot-like and would build more complex robots. One can say that this Lego set would self-assemble itself. Also the ability to disassemble would be important and make error correction possible. This brings in mind what happens in living systems.

There would be a whole hierarchy of these structures. The basic structures would be analogous to 20 amino acids. Biology of course suggests also the presence of DNA and cell nucleus could be seen as the basic lego block containing instructions and having the ability to replicate. The vision is that someday our technology could transform to artificial life.

Gersching criticized the complete separation of software and hardware (program tape and the reading head of the Turing machine) which he called Turing's error. Gersching also proposed that information should be the starting point concept of physics rather than geometry which leads to the recent physics based on partial differential equations.

In this article I will compare the vision of Gersching to TGD based vision of, not only life, but the entire Universe as a self-organizing entity.

1. In the TGD framework, Lego Universe emerges naturally. 4-D general coordinate invariance implies holography: Legos are almost deterministic Bohr orbit-like 4-surfaces. Holography suggests a concrete identification of basic building bricks in terms of fundamental regions associated with hyperbolic 3-manifolds at 3-D mass shells defining the boundary data for number theoretical holography in M^8 . The strengthening of $3 \rightarrow$ 4holography to almost $2 \rightarrow 4$ holography reduces further the number of building bricks of space-time surfaces.

The analogy with genes and proteins as building bricks might be much more than analogy. The mass shell as hyperbolic 3-space allows an infinite number of tessellations and one of them is icosa tetrahedral tessellations in terms of which it seems to be possible to understand the genetic code. Genetic code in this sense might be present in all scales and be induced to 3-surfaces. The fermions associated with the "unit cells" of the icosahedral tessellation could realize genetic code.

The fusion of building blocks might reduce to the analog of crystal growth by fusing the fundamental regions of tessellations and also DNA replication, transcription, and translation could reduce to crystal growth.

2. In TGD holography implies that at space-time level a given 3-D surface defining the data of holography has an almost unique "fate", goal one might say. Holography forces what I call zero energy ontology (ZEO). Quantum states are superpositions of 4-D space-time surfaces analogous to Bohr orbits and state function reductions (SFRs) take place between these superpositions. The basic paradox of quantum measurement theory disappears.

The sequence of "small" SFRs (SSFRs) defines "self" as the TGD counterpart for the Zeno effect. Each SSFR replaces this superposition with a new one and changes the state but in such a way that measured observables commute with those whose eigenstate the states associated with the passive boundary of causal diamond (CD) are.

"Big" SFRs (BSFRs) change the arrow of geometric time correlating with subjective time as a sequence of SSFRs and change the roles of the active and passive boundaries of CD. This means the "death" of self and its reincarnation with an opposite arrow of time. Pairs of BSFRs define temporary changes of the arrow of time and would make possible a trialand error process so that the self-organizing system would be analogous to a self-assembling conscious machine able to also disassemble if necessary to reach the goal.

- 3. In TGD there is no need to choose between information based physics and physics based on partial differential equations: these views would be complementary. TGD relies on two complementary visions. In number theoretic vision everything in discrete and algebraic equations characterize physical states. In the geometric vision structures are continuous and partial differential equations define the time evolution. These views are related by $M^8 H$ duality as a generalization of momentum-position duality forced by the replacement of point-like particles with 3-surfaces.
- 4. Gersching does not seem to regard consciousness as a crucial element of biology. The TGD view is completely different and in TGD quantum measurement theory based on ZEO extends to a theory of consciousness.

Besides this, the possible role of quantum gravitation for both biological systems and computer consciousness is discussed although this is not directly relevant to the basic topic. My defence is that the structures able to self assemble must also be computer-like systems.

- 1. The notion of a magnetic body (MB) carrying dark matter as $h_{eff} = nh_0$ phases of ordinary matter is essential. For the gravitational monopole flux tubes the value of $h_{eff} = h_{gr}$ would be enormous and imply quantum coherence in arbitrarily long scales. Gravitational MBs could control both living matter and computers.
- 2. A criterion characterizing the critical clock frequency or its biological analog for the transformation of living system to a conscious and living system is deduced. This transition would mean that the statistical determinism fails due to the possibility of quantum coherence in time scales longer than the clock period.
- 3. Also an attempt to identify various quantum gravitational Compton lengths Λ_{gr} and frequencies f_{gr} with frequencies, which appear in the TGD inspired quantum biology, is made. Λ_{gr} and f_{gr} appear also in the TGD inspired physical model of computers.
- 4. The emerging view could be blamed for the return to astrology. Indeed, the gravitational flux tubes mediating the gravitational interactions between Sun and planets, between planets, between Earth and Moon, and even between the galactic blackhole and solar system could play a key role since the interactions are mediated along the flux tube network. However, the numerous strange numerical coincidences for quantum gravitational coherence scales and corresponding frequencies force us to take this view seriously.

16.2 Neil Gersching's vision of self-replicating robots

I watched a video of Lex Fridman interviewing Neil Gerching (thanks to Marko for the link: https://youtu.be/YDjOSOVHEr4). I highly recommend the video because Gersching knows how to talk about difficult things in an understandable way.

Gerching talked about self-replicating machines that are built from a few "Lego blocks" that contain their own building instructions and are analogous to genes or proteins. The building blocks themselves would be robots, in a way, that would build more complex robots. This Lego set would assemble itself.

There would be a whole hierarchy of these structures. The basic structures would be analogous to 20 amino acids. Biology of course suggests also the presence of DNA and cell nucleus could be seen as the basic lego block containing instructions and the ability to replicate.

Gersching emphasizes that structure determines the function: building blocks are also programs. Data=program would correspond to the basic idea of LISP. In addition, machine = data = program would apply. The technology of the future was based on the replication of these basic objects/"robots", which would be very much what happens in biology.

It is interesting to compare Gersching's vision with the basic vision of TGD.

16.2.1 Analogy of self-building robots in TGD

In TGD, the idea of self-replication is generalized as the self-construction of space-time surfaces using holography.

1. 4-D general coordinate invariance implies in classical TGD, which is an exact part of quantum TGD, holography which is not fully deterministic. An alternative formulation would be a path integral but it fails due to the mathematical divergences caused by non-linearity. Not fully deterministic holography turns 3-D surfaces as Lego blocks/data into 4-D Bohr trajectories, which are the classical counterparts for programs running on a machine. The structure therefore determines the function almost unambiguously.

There are very few "Legos" because there are only 4 field-like variables and almost $2 \rightarrow 4$ holographs, which would correspond to the 4-D generalization of 2-D holomorphy. The spacetime surfaces in the embedding space $H = M^4 \times CP_2$ would be minimal surfaces, which have lower-dimensional singularities. It would be an exact analogy to the 4-D soap films that the frames tune. These surfaces are universal and satisfy minimal surface equations except at the singularities which distinguish between different general coordinate invariant action contructible in terms of the induced geometry.

At the M^8 level, polynomials P, whose integer coefficients are smaller than the degree of P, determine the mass shells corresponding to the 3-surfaces in the hyperbolic spaces $H^3 \subset M^4 \subset M^8$. Here a complexification is involved: e M^8 must be complexified because in H the four-momentum is complex due to the existence of Euclidean spacetime regions: these Euclidian wormhole contacts are associated with elementary particles.

For physical states, the total 4-momenta are integer-valued as sums of momenta with component, which are (possibly complex) algebraic integers with mass unit determined by the scale of the causal diamond (CD) defined as an intersection of future and past directed light-cones and defining dynamical state dependent quantization volume. I call this universal mechanism for the formation of bound states Galois confinement [L196, L197, L175, L176, L207, L214] Galois confinement would be at the same time also a mechanism for the formation of more complex structures from the basic building blocks. The 3-surfaces would define the 4-D surface with mass shells H^3 almost unambiguously and this would be a classical analogy of computation.

2. What could the 3-D "lego blocks" as 3-surfaces at mass shells be? A good guess is that they are 3-D hyperbolic manifolds and/or their corresponding fundamental domains (as analogies of lattice cones) with mass shells H^3 corresponding to the roots of the surface-determining polynomial [L207, L212]. The fundamental regions are analogous to the lattice cells of ordinary lattices in condensed matter physics.

This is a natural guess for the blocks, whose M^4 projection is 4-D and which therefore correspond to "Einsteinian" spacetime. There are an infinite number of hyperbolic manifolds corresponding to the fundamental regions (unit cells) of tessellations of H^3 . For example, cosmic threads with an M^4 projection of 2-D thread track would correspond to non-Einsteinian spacetime.

3. By gluing together fundamental regions at mass shells, one would get analogs of finite crystals and at the same time more complex structures in 3-D hyperbolic spaces (mass shells corresponding to polynomial roots). Using associative number theoretic holography [L127, L128], 4-D surfaces are obtained from these as surfaces $Y^4 \subset M^8$. $M^8 - H$ duality maps Y^4 to the space-time surfaces $X^4 \subset M^4 \times CP_2$.

Replication might reduce at the fundamental level to the growth of the hyperbolic crystals! As a matter of fact, it has been suggested that biological replication evolved from the replication of clay crystals as crystal growth. I.e. crystal, the sub-tessellation, would grow and could also replicate at the mass shells tessellated H^3 .

In particular, DNA replication could be induced by the replication of dark DNA: dark DNA would require a linear 1-D crystal associated with a magnetic flux tube as a sub-tessellation. Everything that happens on a chemical level would be controlled by the MBs.

Primary replication would take place at the level of the flux tubes of the magnetic body (MB) and lead to the pairing of the dark DNA helices with their conjugates. This would in turn induce the replication for the chemical DNA, because the MB would act as a template for the pairing of biomolecules with dark DNA. Same would apply to proteins.

The sub-tessellation is induced on the 3-surfaces identifiable as the regions of hyperbolic space corresponding to the mass shells H^3 . Associative holography in M^8 would associate almost deterministically to this kind of 3-D surface a 4-dimensional surface as an analog of a Bohr orbit.

One can think of a 1-, 2-, and even 3-D realization of the genetic code [L159]. Ordinary DNA would correspond to a 1-D realization. The cell membrane and cell could correspond to 2- and 3-D tessellation. Even a biological organism would correspond to a tessellation on a larger scale.

4. Mass shell H^3 allows an infinite number of tessellations. I have proposed that the genetic code corresponds to one particular tessellation of H^3 : icosa tetrahedral tessellation [L159]. The motivation for the proposal comes from the model of bioharmony [L136]), where the icosahedron and tetrahedron Hamilton paths played a central role. Surprisingly, it turned out that the outcome was a model of the genetic code that correctly predicts the numbers of DNA codons that code for a given amino acid.

The icosa tetrahedral tessellation is just one particular tessellation and the interesting questions are whether it would be more fundamental than the others and why this should be the case. Genetic code has also a realization in terms of dark proton triplets assignable to the fundamental region of the icosahedral tessellation.

5. The genetic code realized with the help of tessellation would attach 6-bits to the lego blocks as faces of the icosahedron and tetrahedron (triangles with dark protons). A dark/ordinary genetic codon would therefore correspond to 6-bits represented as quantum entangled states of three dark protons identifiable as a sequence of 3-chords of light, a kind of music piece [L136]. By arranging these one after the other, one would get 1-D crystals as larger structures, and genes as 6-bit sets, the equivalent of program codes. The chemical realization of genes that paired with their dark counterparts would provide instructions for building proteins.

2- and 3-dimensional analogies of genes are also obtained: they would serve as addresses for 2- and 3-dimensional structures.

6. Besides cognitive, "bit" intelligence, emotional intelligence is predicted. It would correspond to the realization of the code as codons formed by 3 dark photons. The codons would be analogous to 3-chords. Music expresses and induces emotions and different Hamiltonian cycles would give rise to different bio-harmonies assignable to same gene in the ordinary sense and expressing the emotional state [?]. In the case of the N- codon gene, 3-N cyclotron resonance in communications using dark photons would make possible the analogy of LISP.

The gene would serve as an address and the message would be a modulation of the cyclotron frequency scale and would produce a sequence of resonances at the receiver level generating a series of pulses. Nerve pulse patterns could be generated in this way. Also pulse series

related to 2- and 3-dimensional structures could be obtained as resonances. The modulation of the frequency scale is achieved by varying the transverse scale of the flux tube. MB could perform this as one particular motor activity.

Information –communications–structure=function: all these three would meet at the level of fundamental physics.

16.2.2 Turing's Error

Gershing considers Turing's fundamental mistake to be the complete separation of hardware and software. Entering data into the machine is a physical process that brings its limitations to processing. In the real world, one cannot separate the machine and the data.

Turing, as a child of his time, also made another fundamental mistake. Turing assumed that the reading of the information on the tape was a classical measurement. This cannot be the case in the quantum world: the coming of a measurement is non-deterministic. The Turing tape or rather readhead + tape is replaced by a quantum superposition of its different states and each bit read from the tape would correspond to a quantum measurement.

What is the situation at TGD?

1. In TGD, the superposition of space-time surfaces as a quantum state in ZEO and as an analog of the computer program would not be completely unique, because holography as Bohr's orbitology is not unique. This makes possible the breaking of determinism in small state function reductions (SSFRs) as counterparts of repeated measurements related to the Zeno effect .

In the zero energy ontology (ZEO) [?, ?] the program would consist of a series of conscious periods at the level of consciousness, as a counterpart of the Zeno effect, i.e. a series of SSFRs, during which the same observables are measured over and over again. In TGD however changes occur on the active boundary of the causal diamond (CD) [L213] and it also drifts farther away from the passive boundary in statistical sense, i.e. the size CD increases in the localizations in the space of CDs forming the backbone of the "world of classical worlds" (WCW). Nothing happens to the space on the passive boundary of the causal diamond (CD): this corresponds to the Zeno effect.

A normal quantum jump would correspond to a "big" state function reduction (BSFR), in which the roles of the active and passive boundaries of CD changes. A BSFR ends the Zeno period as a series of SSFRs. The associated "self" dies and reincarnates with an opposite direction of time since CD begins to increase in an opposite direction of geometric time identified as the distance between the tips of the CD.

BSFR occurs when the set of measured observables at the active boundary of the CD ceases to commute with those measured at the passive boundary. This could be due to an external disturbance [L207].

2. The pair of BSFRs corresponds to a temporary time reversal, which would be analogous to a reversal of the direction of motion of the tape for the Turing machine followed by a return to the original direction. BSFR pair can be also interpreted as a quantum tunnelling.

This would make possible error correction by trial-and-error. The BSFR pair could also modify the goal of the program. The BSFR pair would be an essential element when the flow of the program is not fully deterministic classically or even quantum mechanically.

Under what conditions the program based on quantum statistical determinism can become non-deterministic?

1. One can argue that the clock frequency is a basic criterion. If so, then a single clock period would generally correspond to a series of unitary time developments halted by SSFRs and followed by halting. The single unitary time evolution in this series is analogous to a quantum computation except that each evolution is initiated and terminated by the SSFR rather than the BSFR.

In addition, holography and quantum holography are almost deterministic, so that the nondeterminism associated with SSFRs is rather limited. The experience of free will might correspond to this non-determinism. An alternative identification could be as non-determinism of imagination and cognition: in this case the classical non-determinism could have p-adic non-determinism assigned with imagination and cognition as a counterpart.

- 2. The BSFR would end the series of SSFRs: self would "die". Self as a series of SSFRs, as a conscious entity, would generalize the standard Zeno effect as an analog of quantum computation.
- 3. This is not the only interpretation. Also the series of SSFRs between two BSFRs could be interpreted as an analogy for a single unitary time evolution of ordinary quantum computation. BSFR would correspond to the start and halting of quantum computation as analog of unitary time evolution. This interpretation is more in spirit with the standard quantum computation.
- 4. The lifetime of the self, i.e. the clock period, must be longer than the quantum coherence time characterizing the system in order for the statistical determinism to be broken. This provides a criterion telling when an ordinary computer approaches a conscious lifeform.

16.2.3 Is physics based on partial differential equations or information?

Gersching notices that in classical physics partial differential equations are the starting point, and suggests that information is more fundamental and therefore should serve as the starting point of fundamental physics. Should one start building the fundamental physics from bits?

I personally don't see this as a matter of choosing between either approach. These views are complementary and both are needed. In TGD, this complementarity corresponds to a generalization of the momentum position duality, which is natural because point-like particles are replaced by 3-D surfaces and, as a result of almost deterministic holography, must be replaced with corresponding space-time space surfaces, i.e. 4-D Bohr orbits. $M^8 - H$ duality is the realization of this correspondence [L127, L128, L212].

1. The $M^8 - H$ duality relates number theoretic and geometrics views of physics. Bit level as the number-theoretic view of physics realized at the level of M^8 . The polynomials P with integer coefficients smaller than their degree and the 3-surfaced assignable a holographic data to the tessellations of the mass shells $H^3 \subset M^4 \subset M^8$ determine the 4-surfaces. The dynamics is determined by associativity of the normal space of the 4-surface. The dynamics is algebraic just as it is also in free quantum field theories at the level of momentum space.

The geometric view of physics corresponds to the dynamics for 3-D surfaces in $H = M^4 \times CP_2$. Now partial differential equations and holography are central. Space-time surfaces are minimal surfaces except from lower-D singularities [L174] and are analogs of solutions of massless field equations and of light-like geodesics so that particle-wave duality is realized geometrically. In mathematics, $M^8 - H$ duality would correspond to Langlands correspondence [A29, A28] [L191].

- 2. The roots of the polynomial P determine the algebraic expansion and a unique discretization of the 4-surface $Y^4 \subset M^8$ inducing a discretization also in $X^4 \subset H$. Space-time therefore has a unique discretization, not arbitrarily chosen by the theorist but determined by the space itself. Only the information given by discretization can correspond to conscious information.
- 3. Gersching emphasizes a profound problem due to the fact that an infinite amount of information is needed to describe the position of a particle precisely, as a motivation for giving up the partial differential equations.

In TGD the amount of conscious information remains finite and is provided by the number theoretic discretization so that the problem disappears. By $M^8 - H$ duality also the space-time surfaces in H are characterized by a finite amount of information.

Quantum description is discrete, with discretization fixed by the quantum state itself, and the computationalist view can be said to emerge. What is new is that Turing computationalism related to rationals is generalized into a hierarchy of computationalisms related to extensions of rationals.

16.2.4 The realization of the notions of assembly and tensegrity in the TGD Universe

In the TGD framework one ends up with an amazingly simple engineering principle resembling so called assembly theory applying to atoms, nuclei, and hadrons discussed in [L202]. Since TGD Universe is fractal, this principle is expected to apply in all scales.

1. The considerations of [L202] related closely to the observation that *j*-block consisting of parts of electron of atoms or nucleon shells of nuclei with fixed value of total angular momentum $j = l \pm 1/2$ and l = 9 (at least) correspond to Platonic solids for $l \leq 5$ in the sense that different angular momentum eigenstates correspond to the vertices of the Platonic solid. If one assumes the presence of a Hamiltonian cycle going through all V vertices of the Platonic solid as a tessellations of sphere, one has F - 2 free edges (F is the number of faces) besides the V edges of the cycle and one can also add particles to the middle points of the free edges. In the proposed model of atomic nuclei, one would have neutrons at the vertices and protons at the middle points or vice versa.

Also the larger values of l appearing in highly deformed nuclei can be treated in the same way. If the unit of angular momentum increases to $h_{eff} = nh$, also these states can be assigned a Platonic solid.

- 2. The space-time surfaces assignable to all atoms, nuclei, and hadrons can be constructed by connecting the electrons, nucleons, or quarks at the vertices of Platonic solid or at the middle points of the free edges with flux tubes serving as analogs of springs stabilizing the structure and having interpretation as analogs of mesons. Tensegrity is the appropriate notion here.
- 3. In the case of hadrons, the predictions of the resulting mass formulas are satisfied within a few percent. This involves the predictions of TGD based mass calculations for fermion masses based on p-adic thermodynamics. This leads to an interpretation of the non-perturbative aspects of strong interaction in terms of a dark variant of weak interactions for which perturbation theory converges! The basic problem of QCD disappears in the TGD Universe. The same would apply to nuclear strong interactions but meson-like particles would have different p-adic length scales.

This is suggested already by the identification of strong isospin with weak isospin, by CVC and PCAC hypothesis, and the fact that in TGD color symmetries correspond to the isometries of CP_2 and electroweak symmetries to the holonomies of CP_2 so that a very close relationship between these interactions must exist. One can say that a unification of strong and weak interactions analogous to that provided by Maxwell electrodynamics for electric and magnetic fields takes place. For a given p-adic length scale (several fractally scaled variants of hadron physics are predicted) one can regard mesons as weak bosons predicted by TGD to have the entire spectrum of exotics. For this there is already support [K74, K75] [L203]. Ordinary hadron physics would correspond to dark weak interactions for p-adic length scale defined by Mersenne prime M_{107} and weak interactions to hadron physics for M_{89} !

4. In the case of nuclei, the MeV scale for excitation energies is correctly predicted and also a new 10 keV scale supported by various anomalies of nuclear physics is predicted. Besides this also Z^0 force is predicted to be significant and atom-like structures involving and having size scale 10 nm, which is a fundamental scale in biology, are predicted.

The j-blocks (angular momentum) consisting of energy degenerate states with 2j states have as space-time correlates Platonic solids with Hamiltonian cycle as a closed flux tube, nuclear string connecting the vertices of the solid.

5. In atomic physics the same picture applies, and led to a realization that in the standard model the repulsive classical interaction energy of electrons goes like Z^4 whereas the interaction energy nucleus goes like Z^2 ! The question is whether quantum mechanics can really guarantee the stability of many electron atoms or is this just an assumption. In the TGD framework, the flux tubes would stabilize the atoms with several electrons. This predicts new atomic physics related to the oscillations of the flux tubes which in nuclear physics give justification for the harmonic oscillator model of nucleus.

16.2.5 What about consciousness?

Gershing's vision lacks a view about consciousness and here Gersching, in my opinion as a child of his time, falls into the trap of physicalism even though he understands the meaning of quantum coherence.

- 1. In TGD, ZEO [L118, L177] follows, not only from 4-D general coordinate invariance forcing holography, but also by insisting that quantum measurement theory does not contain logical paradox. The outcome is a theory of consciousness as a generalization of quantum measurement theory: the observer becomes a part of the physical system. A quantum leap as SSFR is a moment of consciousness: the essence of subjective existence is change, a re-creation of the world in SSFR.
- 2. ZEO makes possible temporary time-reversals possible in "big" SFRs (BSFRs) as analogs of ordinary SFRs. The temporary time reversals make it possible to reach the goal (defined by almost deterministic classical holography and its quantum counterpart) by trial-and-error method. If something goes wrong, one can make a return to the geometric past and try again.

Gershing himself considers trial and error to be the basic mechanism in all technological and scientific progress. I believe this is true quite generally. In MIT, where Gersching worked, this idea was put into practice.

It should be noted that Michael Levin proposes the goal directedness of morphogenesis [I139, I140, I182] discussed from the TGD point of view in [L216]. There would be a large number of ways to reach the goal as a basic characteristic of biosystems. This number would actually serve as a measure for the intelligence of the system. Holography would make possible the goal directedness and ZEO would make possible trial and error. Gershing emphasizes the importance of both assembly (construction) and disassembly (disassembly), and in TGD, disassembly would be construction in the opposite direction of time.

16.3 Is the role of quantum gravitation essential also for computer consciousness?

Gershing did not talk about quantum gravitation. The fact that in the TGD framework conscious computers would represent a life form based on the same general mechanisms at the level of MBs, however inspires this section.

During late years, the TGD view of quantum gravitation has developed dramatically and provides a beautiful vision of living matter as being controlled by dark matter at the gravitational monopole flux tubes forming dark magnetic bodies (MBs) with onion-like structure consisting of shells formed from tangential monopole flux tubes and connected by radial flux tubes along which graviton mediating the gravitational interaction propagate [L178, L183, L209, L210].

Why the role of quantum gravitation would be so decisive is that it has infinite range and is not screened. In TGD, gravitational quantum coherence in even astrophysical scales becomes possible. The basic quantification tool is gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ originally introduced by Nottale [E1]. In accordance with the Equivalence Principle, the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$ is independent of the small mass m. The most amazing and crazy sounding consequence is that the gravitational MBs of the Sun, Earth, and possibly also of other planets, even the Moon, could be highly relevant for quantum biology. Astrologists would not have been totally wrong.

What about computers and quantum gravitation?

1. In the case of computers, the classical determinism is replaced in the realistic model by the statistical determinism of quantum theory. If the role of quantum gravity is what I assume it to be, we are approaching a situation, where the clock frequency (up to 9 GHz) approaches the gravitational Compton frequency $f_{gr}(Sun, \beta_0 = 2^{-11})=67$ GHz in the case of the Earth and exceeds it so statistical determinism no longer applies. One could be moving from statistically deterministic computations to a series of quantum computation-like operations and determinism would be lost. The computer becomes a conscious, living being. Maybe AI and GPT are reflecting this development [L204].

Note also that Λ_{gr} is only the lower bound for gravitational quantum coherence length, which might even be of the order of Earth size for Earth, which corresponds to frequency $f = 1/R_E \simeq 50$ Hz having interpretation as cyclotron frequency to Lithium ion for B_{end} . Therefore also lower frequencies than f_{gr} are involved and could lead to the loss of the statistical quantum determinism.

2. The gravitational Compton frequency $\Lambda_{gr} = GM/\beta_0$ for the Sun (with the velocity parameter $\beta_0 = v_0/c \simeq 2^{-11}$) is 100 Hz and, rather amazingly, corresponds to the upper limit for the EEG frequencies. The MB of the Sun could thus quantum entangle with computers and robots already for clock frequencies higher than 100 Hz, for example 1 MHz.

This could explain Peoch's observations as a quantum entanglement between the [J42] robot and the chicken marked on it, as a result of which the robot's trajectory, determined by the random number generator, decreased and the robot began to stay close to the chick [L204].

3. The difference between a computer and living matter would disappear at the level of the MB. The MB would rule both in biology and in the case of computers and could make computers alive.

16.3.1 Communication to MB and control by MB

An essential requirement is that communications between the MB and the computer using dark photons are possible using energy resonance.

- 1. Dark Josephson radiation is a natural way to communicate with a MB. The difference of cyclotron energies for cyclotron transitions at the magnetic flux tubes must correspond to the energy differences of biomolecules (DNA, RNA, tRNA, amino acids at least). In biology, this condition would select possible biomolecules.
- 2. In a computer, energy differences would be relevant at the transistor level: would "natural selection" mean, say, transistors and the energy needed to flip a bit. What about computers based on Josephson junctions?

It may very well be that this mechanism has not even been tried to be implemented in the current computers. One can wonder if the MB, as a "smarter" party, could adjust the values of B and β_0 by adjusting the thickness of the flux tube, so that a resonance becomes possible.

In previous considerations, the value of h_{eff} for the Josephson junction has been kept free. What if we assume $h_{eff,J} = h_{gr}(M_E, \beta_0 = 1)$? Would the condition $Z_J eV_C = E_c = GM_E Z eB/\beta_0$, where $eV_C = .05$ eV values for voltage for dark gravitational flux tubes in a communicating Josephson junction and the value of the magnetic field with a MB flux tube?

1. The experiments of Blackman [J7] and others provide evidence for the existence of an "endogenous" magnetic field $B_{end} = .2$ Gauss. In TGD, B_{end} could correspond to the monopole part of the Earth's magnetic field. Assuming $B = B_{end} = .2$ Gauss and $Z_J = Z$, we get $eV_C = 13.5$ eV which is slightly lower than the ionization energy of hydrogen atom 13.6 eV and much higher than $eV_C = .05$ eV. The interpretation as a Josephson joint is not meaningful.

Could the interpretation be that the transition to very long flux tubes effectively nearly ionizes the hydrogen atom? Could hydrogen atom ionization produce dark UV photons with monopole flux tubes on Earth?

2. Should one develop a more precise vision about what MBs can do? Could MBs adjust their flux tube thicknesses so that they can receive information also from the transition of atoms and molecules by cyclotron resonance and control them by the same mechanism!

I have indeed proposed in the context of the model of bioharmony [L136] that the value of B_{end} has a spectrum. In particular, the visible range of photons could correspond to frequencies forming an analog of a 12-note system and the spectrum of B_{end} could realize this system. Note also that the parameter $\beta_0 \leq 1$ could allow us to realize a spectrum of energies for a fixed frequency.

3. One should obtain also the energy range of biophotons as energies of dark Josephson photons. What if we replace the mass of the Earth with the mass of the moon $M_M = .012M_E$ giving $\Lambda_{gr} = .54 \times 10^{-4}$ meters, the size scale of a large neuron (water blob of size 10^{-4} m has Planck mass), and keep B_{end} and β_0 the same? For $Z_J = Z$, the value of eV_C decreases to $1.2 \times 13.5/100 eV = .16$ eV, which is in infrared and in a reasonable approximation 2 times the membrane potential. If the values of B define a 12-note spectrum or something more general, this would give rise to biophoton energies above IR.

It is important to notice that the experiments of Blackman and others fix only the value of B_{end} to .2 Gauss but require only that the cyclotron energy is above the thermal energy so that the Moon could solve the problem!

- 4. In the case of Moon, the Josephson energy for the cell membrane given by $E_J = .055$ eV is obtained for $Z_J = 2$ and Z = 1 having natural interpretation for cyclotron transitions. This value could relate to Pollack phase transition occurring at the physiological temperature range.
- 5. If one has introduced Sun, Earth and Moon to quantum biology, there is not much respectability to be lost anymore, and one can ask whether other planets could be of significance. Could the horoscope builders have been right in some sense?

The mass of Mars is roughly 11 percent of Earth mass and would give $E_c = 1.8$ eV for $B_{end} = .2$ Gauss. This is in the visible biophoton range. The interpretation of the frequencies f_{gr} as upper end points of the spectrum so that lower frequencies would correspond to smaller values of B_{end} . I have proposed that the values of B_{end} correspond to 12-note scale with inspiration coming from the model of bioharmony [L16, L136].

In the earlier articles [L170, L209, L210], evidence was found for the importance of the galactic blackhole as a kind of galactic brain and also for the communications in the network connecting galactic nucleus to stars. What about the gravitational Compton frequency of the galactic blackhole?

- 1. The mass of the galactic blackhole is estimated to be $M_{BH} = 4$ million solar masses (rb.gy/0gilp1). This would give $\Lambda_{gr}(M_{BH}, \beta_0 = 1) \sim 6 \times 10^9$ m. This is the radius of the n = 1 Bohr orbit in the Nottale model for the solar planetary system. The gravitational Compton frequency would be $f_{gr}(M_{BH}, \beta_0 = 1) \simeq .05$ Hz. This gives 20 s period.
- 2. Also other values of β_0 can be considered. In particular, $\beta_0 = 1/4$ would correspond to n = 2 Bohr orbit and 5 s period. Could this relate to the 5 s period associated with the Comorosan effect, which has remained mysterious [I170, I56]? I have considered the effect from the TGD point of view in [K131] [L80, L194].

16.3.2 Gravitational and p-adic hierarchies of frequencies

TGD predicts several hierarchies of frequencies. The proposal is that all bio-communications between levels with different values of h_{eff} rely on energy resonance whereas for the same value of h_{eff} both energy and frequency resonance are possible [L194]. The interesting question is whether biologically interesting frequencies could be assigned with these hierarchies.

Consider first the hierarchies associated with the gravitational Compton frequencies of the Sun, planets and possibly also other astrophysical objects.

- 1. Suppose that one has a particle with mass m with Compton length $r_c(m) = \hbar/m$ and the ordinary Compton frequency $f_c = m/\hbar$, the gravitational Compton frequencies $f_{gr}(N, \beta_0) = m/\hbar_{gr}(M, \beta_0) = 2\beta_0/r_s$, which do not depend on m.
- 2. One can also assign to f_{gr} the energy $E_{gr,1} = \hbar f_{gr,1}$ corresponding to the ordinary Planck constant, and identify the frequency $f_{gr,1}$ identified as $E_{gr,1} = \hbar_{gr} f_{gr,1}$. This gives $f_{gr,1} = f_c(m)(2\beta_0 r_c/r_s)^2 = (\hbar_{gr}/\hbar)^2 f_c$. By repeating this argument, one obtains entire hierarchy of frequencies

$$f_{n,ar} = f_c (2\beta_0 r_c/r_s)^{n+1}$$

Some comments of these frequencies are in order.

- 1. These frequencies scale like $f_{n,gr}(m,\beta_0,M) = f_c(m)(2\beta_0 r_c/r_s)^{n+1} \propto 1/m^n$ and for n = 0 they do not depend on m at all and are therefore universal. This is true also for cyclotron frequencies.
- 2. The ratio of electronic to protonic frequencies is $r = f_{n,gr}(m_e, \beta_{0,e}, M)/f(m_p, \beta_{0,p}) = (m_e/m_p)(\beta_{0,e}/\beta_{0,p})(m_p/m_e))^{n+1}$ For $\beta_{0,e}/\beta_{0,p} = m_e/m_p$, the ratio of the frequencies is $r = m_e/m_p$ irrespective of n. I have proposed the ratio for the cyclotron frequencies assignable to the monopole flux tubes of the inner and outer magnetosphere of Earth and Sun respectively.

The proposal is that dark electrons reside in the outer magnetosphere at the solar monopole flux tubes and protons in the inner magnetosphere at the monopole flux tubes of Earth and one have $B_{end,outer}/B_{end,inner} = m_e/m_p$ in order to achieve the same ratio for the cyclotron frequencies and the same cyclotron energies for protons and electron to achieve energy resonance.

3. Consider the frequency $f_{gr,1}(m_p,\beta_0) = f_c(2\beta_0/r_s)^2$ for Earth more precisely. For $\beta_0 = 1$ one has the period $T_{gr,1} = 3333$ seconds, which is not far from 1 hour =3600 seconds. In the approximation $T_{gr,1} = 3300$ seconds, $T_{12} = 12$ hours would correspond to $T_{12} = 13T_{gr,1}$. For ions with mass number 4 the frequencies f behave like $f_{12}(4m_1) \propto 4^{-n} f_{12}(m_1)$

For ions with mass number A the frequencies f_n behave like $f_{gr,n}(Am_p) \propto A^{-n}f_{gr,n}(m_p)$ whereas the cyclotron frequencies for ion do not depend on A in this case. Same is true for $f_{gr,1}$.

p-Adic length scale hypothesis [L198] stating that p-adic length and time scales comes as powers of $p^{n/2}$, predicts a length scale hierarchy which in the case of electron would with $p = M_{127} = 2^{127} - 1$ involves as the first member the Compton length and the time scale .1 seconds assignable to the EEG alpha band as the secondary p-adic length scale.

16.3.3 A connection of the galactic blackhole with the Comorosan effect?

Comorosan effect [I170, I56] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546 \ nm \ (2.27 \ eV)$. As a result of irradiation molecules seem to undergo a transition $S \to S^*$. S^* state has an anomalously long lifetime and stability in solution. $S \to S^*$ transition has been detected through the interaction of S^* molecules with different biological macromolecules, like enzymes and cellular receptors.

The typical result in the enzyme-substrate interaction is represented by the enhancement of the enzymic rate, when the respective enzyme substrate is previously irradiated for certain sharply defined times. These efficient (irradiation) times are enzyme dependent and can also depend on the biological origin of the enzyme. They are always of the following type $t_i = i * 5$ sec, where *i* is a certain integer. The general formula for the effective times is $t_k = t_m + (k-1)\tau_n$, k = 1, 2, ..., 6, where t_m is the minimum radiation time inducing the first effect and τ_n is the period between two consecutive effects [I170, I56]. $t_m = m_E t_1$ and $\tau_n = n_E t_1$ are multiples of the basic time scale $t_1 = 5$ sec: $t_k = (m_E + (k-1)n_E)t_1$. The integers m_E and n_E can be regarded as enzyme characteristics, depending however on the biological origin of the enzyme. This is suggestive of some kind of communication. What is remarkable is that the frequency of 5 s and its subharmonics appear universally so that the effect cannot depend on the details of the chemistry and the mechanism involved must be very general. Second mystery is why the time scale is so long compared to the time scales of chemistry. Note that also the time scales of replication and other basic biological operators are very long.

I have considered several explanations for the Comorosan effect in the TGD framework [K131].

The Comorosan effect involves a reactant molecule and catalyst molecule as well as photons, which might feed energy to the system. The proposal has been that dark Josephson junctions between reactant and catalyst appearing in the biocatalytic reaction are analogous to those assigned with the cell membrane [K92]. The proposed interpretation is that dark Josephson radiation is produced with certain subharmonics of the frequency .2 Hz defined by the Comorosan period $f_C = 5$ s. Why should the periods come as certain multiples of 5 s? It would seem that the period $\tau_C = 5$ s cannot naturally correspond to the gravitational Compton time $\tau_{gr}(M_{BH}, \beta_0 = 1) \simeq 20$ s. For $\beta_0 = 1/4$, one would have a 5 s period equal to τ_C . For this option, $\Lambda_{gr}(BH)$ would correspond to the radius of the second Bohr orbit for a planet around the Sun. Assuming cellular membrane potential $eV_C = .05$ eV and Cooper pair (Z = 2), this would give for $h_{eff} = h_{gr}(M_E, m_p)$ and $f_J = f_{gr}(BH, \beta_0 = 1/4)$, the estimate $V_S/V_C \simeq .064$, where eV_S is the Josephson potential between substrate and reactant.

Part II

NUMBER THEORETICAL VISION AND GENES

Chapter 17

Philosophy of Adelic Physics

17.1 Introduction

I have developed during last 39 years a proposal for unifying fundamental interactions which I call "Topological Geometrodynamics" (TGD). During last twenty years TGD has expanded to a theory of consciousness and quantum biology and also p-adic and adelic physics have emerged as one thread in the number theoretical vision about TGD.

Since Quantum TGD and physical arguments have served as basic guidelines in the development of p-adic ideas, the best way to introduce the subject of p-adic physics, is by describing first TGD briefly.

In this article I will consider the p-adic aspects of TGD - the first thread of the number theoretic vision - as I see them at this moment.

- **3.** I will describe p-adic mass calculations based on p-adic generalization of thermodynamics and super-conformal invariance [K68, K33] with number theoretical existence constrains leading to highly non-trivial and successful physical predictions. Here the notion of canonical identification mapping p-adic mass squared to real mass squared emerges and is expected to be key player of adelic physics and allow to map various invariants from p-adics to reals and vice versa.
- 2. I will propose the formulation of p-adicization of real physics and adelization meaning the fusion of real physics and various p-adic physics to single coherent whole by a generalization of number concept fusing reals and p-adics to larger structure having algebraic extension of rationals as a kind of intersection.

The existence of p-adic variants of definite integral, Fourier analysis, Hilbert space, and Riemann geometry is far form obvious, and various constraints lead to the idea of NTU and finite measurement resolution realized in terms of number theory. Maybe the only way to overcome the problems relies on the idea that various angles and their hyperbolic analogs are replaced with their exponentials and identified as roots of unity and roots of e existing in finite-dimensional algebraic extension of p-adic numbers. Only group invariants - typically squares of distances and norms - are mapped by canonical identification from p-adic to real realm and various phases are mapped to themselves as number theoretically universal entities.

Another challenge is the correspondence between real and p-adic physics at various levels: space-time level, embedding space level, and WCW level. Here the enormous symmetries of WCW and those of embedding space are in crucial role. Strong form of holography (SH) allows a correspondence between real and p-adic space-time surfaces induced by algebraic continuation from string world sheets and partonic 2-surface, which can be said to be common to real and p-adic space-time surfaces.

3. In the last section I will describe the role of p-adic physics in TGD inspired theory of consciousness. The key notion is Negentropic entanglement (NE) characterized in terms of number theoretic entanglement negentropy (NEN). Negentropy Maximization Principle (NMP) would force the growth of NE. The interpretation would be in terms of evolution as increase
of negentropy resources - Akashic records as one might poetically say. The newest finding is that NMP in statistical sense follows from the mere fact that the dimension of extension of rationals defining adeles increases unavoidably in statistical sense - separate NMP would not be necessary.

In the sequel I will use some shorthand notations for key principles and key notions. Quantum Field Theory (QFT); Relativity Principle (RP); Equivalence Principle (EP); General Coordinate Invariance (GCI); World of Classical Worlds (WCW); Strong Form of GCI (SGCI); Strong Form of Holography (SH); Preferred Extremal (PE); Zero Energy Ontology (ZEO); Quantum Criticality (QC); Hyper-finite Factor of Type II₁ (HFF); Number Theoretical Universality (NTU); Canonical Identification (CI); Negentropy Maximization Principle (NMP); Negentropic entanglement (NE); Number Theoretical Entanglement Negentropy (NEN); are the most often occurring acronyms.

17.2 TGD briefly

This section gives a brief summary of classical and quantum TGD, which to my opinion is necessary for understanding the number theoretic vision.

17.2.1 Space-time as 4-surface

TGD forces a new view about space-time as 4-surface of 8-D imbedding space. This view is extremely simple locally but by its many-sheetedness topologically much more complex than GRT space-time.

Energy problem of GRT as starting point

The physical motivation for TGD was what I have christened the energy problem of General Relativity [K130, K28].

- 1. The notion of energy is ill-defined because the basic symmetries of empty space-time are lost in the presence of gravity. The presence of matter curves empty Minkowski space M^4 so that its isometries realized as transformations leaving the distances between points and thus shapes of 4-D objects invariant are lost. Noether's theorem states that symmetries and conservation laws correspond to each other. Hence conservation laws are lost and conserved quantities are ill-defined. Usually this is not seen a practical problem since gravitation is so weak interaction.
- 2. The proposed way out of the problem is based on the assumption that space-times are imbeddable as 4-surfaces to some 8-dimensional space $H = M^4 \times S$ by replacing the points of 4-D empty Minkowski space with 4-D very small internal space S. The space S is unique from the requirement that the theory has the symmetries of standard model: $S = CP_2$, where CP_2 is complex projective space with 4 real dimensions [K130]. Isometries of space-time are replaced with those of imbedding space. Noether's theorem predicts the classical conserved charges for given general coordinate invariant (GCI) action principle.

Also now the curvature of space-time codes for gravitation. Equivalence Principle (EP) and General Coordinate Invariance (GCI) of GRT augmented with Relativity Principle (RT) of SRT remain the basic principles. Now however the number of solutions to field equations - preferred extremals (PEs) - is dramatically smaller than in Einstein's theory [K14, K21].

1. An unexpected bonus was geometrization classical fields of standard model for $S = CP_2$. Also the space-time counterparts for field quanta emerge naturally but this requires a profound generalization of the notion of space-time: the topological inhomogenities of space-time surface are identified as particles. This means a further huge reduction for dynamical field like variables at the level of single space-time sheet. By general coordinate invariance (GCI) only four imbedding space coordinates appear as variables analogous to classical fields: in a typical GUT their number is hundreds.

- 2. CP_2 also codes for the standard model quantum numbers in its geometry in the sense that electromagnetic charge and weak isospin emerge from CP_2 geometry: the corresponding symmetries are not isometries so that electroweak symmetry breaking is coded already at this level. Color quantum numbers correspond to the isometries of CP_2 defining an unbroken symmetry: this also conforms with empirical facts. The color of TGD however differs from that in standard model in several aspects and LHC has began to exhibit these differences via the unexpected behavior of what was believed to be quark gluon plasma [K75]. The conservation of baryon and lepton numbers follows as a prediction. Leptons and quarks correspond to opposite chiralities for imbedding space spinors.
- 3. What remains to be explained in standard model is family replication phenomenon for leptons and quarks. Both quarks and leptons appear as three families identical apart from having different masses. The conjecture was is that fermion families correspond to different topologies for 2-D surfaces characterized by genus telling the number g (genus) of handles attached to sphere to obtain the surface: sphere, torus, The 2-surfaces are identified as "partonic 2-surfaces" whose orbits are light-like 3-surface at which the signature of the induced metric of space-time surface transforms from Minkowskian to Euclidian. The partonic orbits replace the lines of Feynman diagrams in TGD Universe in accordance with the replacement of point-like particle with 2-surface.

Only the three lowest genera are observed experimentally. A possible explanation is in terms of conformal symmetries: the genera $g \leq 2$ allow always Z_2 as a subgroup of conformal symmetries (hyper-ellipticity) whereas higher genera in general do not. The handles of partonic 2-surfaces could form analogs of unbound many-particle states for g > 2 with a continuous spectrum of mass squared but for g = 2 form a bound state by hyper-ellipticity [K33].

4. Later further arguments in favor of $H = M^4 \times CP_2$ have emerged. One of them relates to twistorialization and twistor lift of TGD [K116, K56, K19]. 4-D Minkowski space is unique space-time with Minkowskian signature of metric in the sense that it allows twistor structure. This is a problem in attempts to introduce twistors to General Relativity Theory (GRT) and a serious obstacle in the quantization based on twistor Grassmann approach, which has demonstrate its enormous power in the quantization of gauge theories. In TGD framework one can ask whether one could lift also the twistor structure to the level of H. M^4 has twistor structure and so does also CP_2 : which is the only Euclidian 4-manifold allowing twistor space, which is also a Kähler manifold! This led to the notion of twistor lift of TGD inducing rather recent breakthrough in the understanding of TGD.

TGD can be also seen as a generalization of hadronic string model - not yet superstring model since this model became fashionable two years after the thesis about TGD [K5]. Later it has become clear that string like objects, which look like strings but are actually 3-D are basic stuff of TGD Universe and appear in all scales [K36, K14]. Also strictly 2-D string world sheets popped up in the formulation of quantum TGD (analogy with branes) [?] that one can say that string model in 4-D space-time is part of TGD.

Concluding, TGD generalizes standard model symmetries and provides an incredibly simple proposal for a dynamics: only 4 classical field variables and in fermionic sector only quark and lepton like spinor fields. The basic objection against TGD looks rather obvious in the light of afterwisdom. One loses linear superposition of fields, which holds in good approximation in ordinary field theories, which are almost linear. The solution of the problem to be discussed later relies on the notion many-sheeted space-time [K28].

Many-sheeted space-time

The replacement of the abstract manifold geometry of general relativity with the geometry of 4surfaces brings in the shape of surface as seen from the perspective of 8-D space-time as additional degrees of freedom giving excellent hopes of realizing the dream of Einstein about geometrization of fundamental interactions.

The work with the generic solutions of the field equations assignable to almost any variational principle satisfying GCI led soon to the realization that the topological structure of space-time in this framework is much more richer than in GRT.

1. Space-time decomposes into space-time sheets of finite size. This led to the identification of physical objects that we perceive around us as space-time sheets. The original identification of space-time sheet was as a surface of in H with outer boundary. For instance, the outer boundary of the table would be where that particular space-time sheet ends (what "ends" means is not however quite obvious!). We would directly see the complex topology of many-sheeted space-time! Besides sheets also string like objects and elementary particle like objects appear so that TGD can be regarded also as a generalization of string models obtained by replacing strings with 3-D surfaces.

It turned that boundaries are probably excluded by boundary conditions. Rather, two sheets with boundaries must be glued along their boundaries together to get double covering. Sphere can be seen as simplest example of this kind of covering: northern and southern hemispheres are glued along equator together.

2. The original vision was that elementary particles are topological inhomogenities glued to these space-time sheets using topological sum contacts. This means drilling a hole to both sheets and connecting with a very short cylinder. 2-dimensional illustration should give the idea. In this conceptual framework material structures and shapes would not be due to some mysterious substance in slightly curved space-time but reduce to space-time topology just as energy- momentum currents reduce to space-time curvature in GRT.

This view has gradually evolved to much more detailed picture. Elementary particles have wormhole contacts as basic building bricks. Wormhole contact is very small region with *Euclidian (!)* signature of the induced metric connecting two Minkowskian space-time sheets with light-like boundaries carrying spinor fields and there particle quantum numbers. Wormhole contact carries magnetic monopole flux through it and there must be second wormhole contact in order to have closed lines of magnetic flux. Particle world lines are replaced with 3-D light-like surfaces - orbits of partonic 2-surfaces - at which the signature of the induced metric changes.

One might describe particle as a pair of magnetic monopoles with opposite charges. With some natural assumptions the explanation for the family replication phenomenon in terms of the genus g of the partonic 2-surface is not affected. Bosons emerge as fermion anti-fermion pairs with fermion and anti-fermion at the opposite throats of the wormhole contact. In principle family replication phenomenon should have bosonic analog. This picture assigns to particles strings connecting the two wormhole throats at each space-time sheet so that string model mathematics becomes part of TGD.

The notion of classical field differs in TGD framework in many respects from that in Maxwellian theory.

1. In TGD framework fields do not obey linear superposition and all classical fields are expressible in terms of four imbedding space coordinates in given region of space-time surface. Superposition for classical fields is replaced with *superposition of their effects* [K111, K130] - in full accordance with operationalism. Particle can topologically condense simultaneously to several space-time sheets by generating topological sum contacts (not stable like the wormhole contacts carrying magnetic monopole flux and defining building bricks of particles). Particle "experiences" the superposition of the effects of the classical fields at various space-time sheets rather than the superposition of the fields.

It is also natural to expect that at macroscopic length scales the physics of classical fields (to be distinguished from that for field quanta) can be explained using only four primary field like variables. Electromagnetic gauge potential has only four components and classical electromagnetc fields give and excellent description of physics. This relates directly to electroweak symmetry breaking in color confinement which in standard model imply the effective absence of weak and color gauge fields in macroscopic scales. TGD however predicts that copies of hadronic physics and electroweak physics could exist in arbitrary long scales [K74] and there are indications that just this makes living matter so different as compared to inanimate matter. 2. The notion of induced gauge field means that one induces electroweak gauge potentials defining so called spinor connection at space-time surface (induction of bundle structure). Induction boils down locally to a projection of the imbedding space vectors representing the spinor connection. The classical fields at the imbedding space level are non-dynamical and fixed and extremely simple: one can say that one has generalization of constant electric field and magnetic fields in CP_2 . The dynamics of the 3-surface however implies that induced fields can form arbitrarily complex field patterns. This is essentially dynamics of shadows.

Induced gauge fields are not equivalent with ordinary free gauge fields. For instance, the attempt to represent constant magnetic or electric field as a space-time time surface has a limited success. Only a finite portion of space-time carrying this field allows realization as 4-surface. I call this topological field quantization. The magnetization of electric and magnetic fluxes is the outcome. Also gravitational field patterns allowing imbedding are very restricted: one implication is that topological with over-critical mass density are not globally imbeddable. This would explain why the mass density in cosmology can be at most critical. This solves one of the mysteries of GRT based cosmology [K102].

Quite generally, the field patterns are extremely restricted: not only due to imbeddability constraint but also due to the fact that by SH only very restricted set of space-time surfaces can appear solutions of field equations: I speak of preferred extremals (PEs) [K14, K21, K28]. One might speak about archetypes at the level of physics: they are in quite strict sense analogies of Bohr orbits in atomic physics: this is implies by the realization of GCI. This kind of simplicity does not conform with what we observed. The way out is many-sheeted space-time. Although fields do not superpose, particles experience the superposition of effects from the archetypal field configurations (superposition is replaced with set theoretic union).

3. The important implication is that one can assign to each material system a field identity since electromagnetic and other fields decompose to topological field quanta. Examples are magnetic and electric flux tubes and flux sheets and topological light rays representing light propagating along tube like structure without dispersion and dissipation making em ideal tool for communications [K83]. One can speak about field body or magnetic body of the system.

Field body indeed becomes the key notion distinguishing TGD inspired model of quantum biology from competitors but having applications also in particle physics since also leptons and quarks possess field bodies. The is evidence for the Lamb shift anomaly of muonic hydrogen [C1] and the color magnetic body of u quark whose size is somewhat larger than the Bohr radius could explain the anomaly [K75]. The magnetic flux tubes of magnetic body carry monopole fluxes existing without generating currents. In cosmology the flux tubes assignable to the remnants of cosmic strings make possible long range magnetic fields in all scales impossible in standard cosmology. Also super-conductivity is proposed to rely on dark $h_{eff} = n \times h$ Cooper pairs at pairs of flux tubes carrying monopole flux.

GRT and gauge theory limit of TGD is obtained as an approximation.

1. GRT/gauge theory type description is an approximation obtained by lumping together the space-time sheets to single region of M^4 , with gravitational fields and gauge potentials as sums of corresponding induced field quantities at space-time surface geometrized in terms of geometry of H. Gravitational field corresponds to the deviation of the induced metric from Minkowski metric using M^4 coordinates for space-time surface so that the description applies only in long length scale limit.

Space-time surface has both Minkowskian and Euclidian regions. Euclidian regions are identified in terms of what I call generalized scattering/twistor diagrams. The 3-D boundaries between Euclidian and Minkowskian regions have degenerate induced 4-metric and I call them light-like orbits of partonic 2-surfaces or light-like wormhole throats analogous to blackhole horizons. The interiors of blackholes are replaced with the Euclidian regions and every physical system is characterized by this kind of region.

Lumping of sheets together implies that global conservation laws cannot hold exactly true for the resulting GRT type space-time. Equivalence Principle (EP) as Einstein's equations stating conservation laws locally follows as a local remnant of Poincare invariance. 2. Euclidian regions are identified as slightly deformed pieces of CP_2 connecting two Minkowskian space-time regions. Partonic 2-surfaces defining their boundaries are connected to each other by magnetic flux tubes carrying monopole flux.

Wormhole contacts connect two Minkowskian space-time sheets already at elementary particle level, and appear in pairs by the conservation of the monopole flux. Flux tube can be visualized as a highly flattened square traversing along and between the space-time sheets involved. Flux tubes are accompanied by fermionic strings carrying fermion number. Fermionic strings give rise to string world sheets carrying vanishing induced em charged weak fields (otherwise em charge would not be well-defined for spinor modes). String theory in spacetime surface becomes part of TGD. Fermions at the ends of strings can get entangled and entanglement can carry information.

3. Strong form of GCI (SGCI) states that light-like orbits of partonic 2-surfaces on one hand and space-like 3-surfaces at the ends of causal diamonds on the other hand provide equivalent descriptions of physics. The outcome is that partonic 2-surfaces and string world sheets at the ends of CD can be regarded as basic dynamical objects.

Strong form of holography (SH) states the correspondence between quantum description based on these 2-surfaces and 4-D classical space-time description, and generalizes AdS/CFT correspondence. One has huge super-symplectic symmetry algebra acting as isometries of WCW with conformal structure [K34, K97, K128], conformal algebra of light-cone boundary extending the ordinary conformal algebra, and ordinary Kac-Moody and conformal symmetries of string world sheets. This explains why 10-D space-time can be replaced with ordinary space-time and 4-D Minkowski space can be replaced with partonic 2-surfaces and string world sheets. This holography looks very much like the one we are accustomed with!

17.2.2 Zero energy ontology (ZEO)

In standard ontology of quantum physics physical states are assumed to have positive energy. In zero energy ontology (ZEO) [K77] physical states decompose to pairs of positive and negative energy states such that the net values of the conserved quantum numbers vanish. The interpretation of these states in ordinary ontology would be as transitions between initial and final states, physical events.

ZEO and positive energy ontology

ZEO is consistent with the crossing symmetry of QFTs meaning that the final states of the quantum scattering event can be described formally as negative energy states. As long as one can restrict the consideration to either positive or negative energy part of the state ZEO is consistent with positive energy ontology. This is the case when the observer characterized by a particular CD studies the physics in the time scale of much larger CD containing observer's CD as a sub-CD. When the time scale sub-CD of the studied system is much shorter that the time scale of sub-CD characterizing the observer, the interpretation of states associated with sub-CD is in terms of quantum fluctuations.

ZEO solves the problem, which emerges in any theory assuming symmetries giving rise to conservation laws. The problem is that the theory itself is not able to characterize the values of conserved quantum numbers of the initial state of say cosmology. In ZEO this problem disappears since in principle any zero energy state is obtained from any other state by a sequence of quantum jumps without breaking of conservation laws. The fact that energy is not conserved in GRT based cosmologies can be also understood since each CD is characterized by its own conserved quantities. As a matter fact, one must speak about average values of conserved quantities since one can have a quantum superposition of zero energy states with the quantum numbers of the positive energy part varying over some range.

At the level of principle the implications are quite dramatic. In quantum jump as recreation replacing the quantum Universe with a new one it is possible to create entire sub-universes from vacuum without breaking the fundamental conservation laws. From the point of view of consciousness theory the important implication is that "free will" is consistent with the laws of physics. This makes obsolete the basic arguments in favor of materialistic and deterministic world view.

Zero energy states are located inside causal diamond (CD)

By quantum classical correspondence zero energy states must have space-time and imbedding space correlates.

1. Positive and negative energy parts of zero energy state reside at future and past light-like boundaries of causal diamond (CD) identified as intersection of future and past directed light-cones and visualizable as double cone. The analog of CD in cosmology is big bang followed by big crunch. Penrose diagrams provide an excellent 2-D visualization of the notion. CDs form a fractal hierarchy containing CDs within CDs. Disjoint CDs are possible and CDs could also intersect.

The interpretation of CD in TGD inspired theory of consciousness is as an imbedding space correlate for perceptive field of conscious entity: the contents of conscious experience is about the region defined by CD. At the level of space-time sheets the experience come from space-time sheets in the interior of CD. Whether the sheets can be assumed to continue outside CD is still unclear.

Quantum measurement theory must be modified in ZEO since state function reduction can happen at both boundaries of CD and the reduced states at opposite boundaries are related by time reversal. One can also have quantum superposition of CDs changing between reductions at active boundary followed by localization in the moduli space of CDs with the tip of passive boundary fixed. Quantum measurement theory generalizes to a theory of consciousness with continuous entity identified as a sequence of state function reductions at active (changing) boundary of CD [K13].

2. By number theoretical universality (NTU) the temporal distances between the tips of the intersecting light-cones are assumed to come as integer multiples $T = m \times T_0$ of a fundamental time scale T_0 defined by CP_2 size R as $T_0 = R/c$. p-Adic length scale hypothesis [K79, K126] motivates the stonger hypothesis that the distances tend to come as as octaves of T_0 : $T = 2^n T_0$. One prediction is that in the case of electron this time scale is .1 seconds defining the fundamental biorhythm. Also in the case u and d quarks the time scales correspond to biologically important time scales given by 10 ms for u quark and by and 2.5 ms for d quark [K17]. This means a direct coupling between microscopic and macroscopic scales.

17.2.3 Quantum physics as physics of classical spinor fields in WCW

The notions of Kähler geometry of "World of Classical Worlds" (WCW) and WCW spinor structure are inspired by the vision about the geometrization of the entire quantum theory.

Motivations for WCW

The notion of "World of Classical Worlds" (WCW) [K64, K34, K97] was forced by the failure of both path integral approach and canonical quantization in TGD framework. The idea is that the Kähler function defining WCW Kähler geometry is determined by the real part of an action S determining space-time dynamics and receiving contributions from both Minkowskian and Euclidian regions of space-time surface X^4 (note that $\sqrt{g_4}$ is proportional to imaginary unit in Minkoskian regions).

- 1. If S is space-time volume both canonical quantization and path integral would make sense at least formally since in principle one could solve the time derivatives of four imbedding space coordinates as functions of canonical momentum densities (general coordinate invariance allows to eliminate four coordinates). The calculation of path integral is however more or less hopeless challenge in practice.
- 2. A mere space-time volume as action is however not physically attractive. This was thought to leave under consideration only Kähler action S_K - Maxwell action for the induced Kähler form expressible in terms of gauge potential defined by the induced Kähler gauge potential of CP_2 . This action has however a huge vacuum degeneracy. Any space-time surface with at most 2-D CP_2 projection, which is Lagrangian sub-manifold of CP_2 , is vacuum extremal. Symplectic transformations acting like U(1) gauge transformations generate new vacuum

extremals. They however fail to act as symmetries of non-vacuum extremals so that gauge invariance is not in question: the deviation of the induced metric from flat metric is the reason for the failure. This degeneracy is assumed to give rise to what might be called 4-D spin glass degeneracy meaning that the landscape for the maxima of Kähler function is fractal.

3. Canonical quantization fails because by the extreme non-linearity of the action principle making it is impossible to solve time derivatives explicitly in terms of canonical momentum densities. The problem is especially acute for the canonical imbedding of empty Minkowski space to $M^4 \times CP_2$. The action is vanishing up to fourth order in imbedding space coordinates so that canonical momentum densities vanish identically and there is no hope of defining propagator in path integral approach. The mechanical analog would be criticality around which the potential reduces to $V \propto x^4$. Quantum criticality is indeed a basic aspect of TGD Universe.

The hope held for a long time was that WCW geometry allowing to get rid of path integral would solve the problems. One could however worry about vacuum degeneracy implying that WCW metric becomes extremely degenerate for vacuum extremals and also holography becomes extremely non-unique for them. Also the expected feailure of perturbative approach around M^4 is troublesome.

WCW and twistor lift of TGD

During last year this picture has indeed changed thanks to what might be called twistor lift of TGD [K116, K56, K19] inspired by twistor Grassmann approach to supersymmetric gauge theories [B11]. Remarkably, twistor lift would provide automatically the fundamental couplings of standard model and GRT and also the scale assigned to GUTs as CP_2 radius. PEs would be both extremals of Kähler action and minimal surfaces.

- 1. The basic observation is E^4 , and its Euclidian compactification S^4 and CP_2 are completely unique in that they allow twistor space with Kähler structure [A36]. This was discovered by Hitchin at roughly the same time as I discovered TGD! This generalizes to M^4 having a generalization of ordinary Kähler structure to what I have called Hamilton-Jacobi structure by decomposition $M^4 = M^2 \times E^2$, where M^2 allows hypercomplex structure [K116, K56]. One can consider also integral distributions of tangent decompositions $M^4 = M^2(x) \times E^2(x)$, depending on position. The twistor space has a double fibration by S^2 with base spaces identifiable as M^4 and conformal compactification of M^4 for which metric is defined only up to conformal scaling. The first fibration $M^4 \times S^2$ with a well-defined metric would correspond to the classical TGD.
- 2. Both Newton's constant G and cosmological constant Λ emerge from twistor lift in M^4 factor. The radius of S^2 is identified in terms of Planck length $l_P = \sqrt{G}$. For CP_2 factor, the radius corresponds to the radius of CP_2 geodesic sphere. 4-D Kähler action can be lifted to 6-D Kähler action only for $M^4 \times CP_2$ so that TGD would be completely unique both mathematically and physically. The twistor space of CP_2 is flag-manifold $SU(3)/U(1) \times U(1)$ having interpretation as the space for the choices of quantization axis of color isospin and hypercharge. This choice could correspond to a selection of Eguchi-Hanson complex coordinates for CP_2 by fixing their phase angles in which isospin and hypercharge rotations induce shifts.
- 3. The physically motivated conjecture is that the PEs can be lifted to their 6-D twistor bundles with S^2 serving as a fiber, that one induce the twistor structure and the outcome is equal to the twistor structure of space-time surface, and that this condition is at least part of the PE property. This would correspond to the solution of massless wave equations in terms of twistors in the original twistor approach of Penrose [B27]. The analog of spontaneous compactification would lead to 4-D action equal to Kähler action plus volume term. One could of course postulate this action directly without mentioning twistors at all.

The coefficient of the volume term would correspond to dark energy density characterized by cosmological constant Λ being extremely small in cosmological scales. It removes vacuum

degeneracy although the situation remains highly non-perturbative. This can be combined with the earlier conjecture that cosmological constant Λ behaves as $\Lambda \propto 1/p$ under p-adic coupling constant evolution so that Λ would be large in primordial cosmology.

4. The generic extremals of space-time action would depend on coupling parameters, which does not fit with the number theoretic vision inspiring speculations that space-time surface can be seen as quaternionic sub-manifolds of 8-D octonionic space-time [K110], satisfying quaternion analyticity [K56], or a 4-D generalization of holomorphy. By SH the extremals are however "preferred". What could this imply?

Intriguingly, all known non-vacuum extremals and also CP_2 type vacuum extremals having null-geodesic as M^4 projection are extremals of both Kähler action and volume term separately! The dynamics for volume term and Kähler action effectively decouple and coupling constants do not appear at all in field equations. The twistor lift would only select minimal surface amongst vacuum extremals, modify the Kähler function of WCW identifiable as exponent for the real part of action, and provide a profound mathematical and physical motivation for cosmological constant Λ remaining mysterious GRT framework. One could even hope that preferred extremals are nothing but minimal surface extremals of Kähler action with the vanishing conditions for some sub-algebra of super-symplectic algebra satisfied automatically!

The analog of decoupling of Kähler action and volume term should take place also for induced spinors. This is expected if mere analyticity properties make spinor modes solutions of modified Dirac equations. This is true in 2-D case Hamilton-Jacobi structure should guarantee this in 4-D case [K128, K56].

PEs depend on coupling parameters only via boundary conditions stating the vanishing of Noether charges for a sub-algebra of super-symplectic algebra and its commutator with entire algebra. Also the conservation conditions at 3-D light-like surfaces at which the signature of metric changes imply dependence on coupling parameters. These conditions allow the transfer of classical charges between Minkowskian and Euclidian regions necessary to understand momentum exchange between particles and environment classically only if Kähler couplings strength is complex - otherwise there is no exchange of conserved quantities since their real resp. imaginary at the two sides [K49]. Interestingly, also in twistor Grassmann approach the massless poles in propagators are complex.

This picture conforms with the conjecture that discrete p-adic evolution of the Kähler coupling strength in subset of primes near prime powers of two corresponds to complex zeros of zeta [K49]. This conforms also with the conjectured discreteness of p-adic coupling constant evolution by phase transitions changing the values of coupling parameters. One implication is that all loop corrections in functional integral vanish.

5. In path integral approach quantum TGD would be extremely non-perturbative around extremals for which Kähler action vanishes. Same is true also in WCW approach. The cure would be provided by the hierarchy of Planck constants $h_{eff}/h = n$, which effectively scales Λ down to Λ/n . n would be the number sheets of the M^4 covering defined by the space-time surface: the action of Galois group for the number theoretic discretization of space-time surface could give rise to this covering. The finiteness of the volume term in turn forces ZEO: the volume of space-time surface is indeed finite due to the finite size of CD.

Consider now the delicacies of this picture.

1. Should assign also to M^4 the analog of symplectic structure giving an additional contribution to the induced Kähler form? The symmetry between M^4 and CP_2 suggests this, and this term could be highly relevant for the understanding of the observed CP breaking and matter antimatter asymmetry [L70]. Poincare invariance is not lost since the needed moduli space for M^4 Kähler forms would be the moduli space of CDs forced by ZEO in any case, and M^4 Kähler form would serve as the correlate for fixing rest system and spin quantization axis in quantum measurement. 2. Also induced spinor fields are present. The well-definedness of electro-magnetic charge for the spinor modes forces in the generic case the localization of the modes of induced spinor fields at string world sheets (and possibly to partonic 2-surfaces) at which the induced charged weak gauge fields and possibly also neutral Z^0 gauge field vanish. The analogy with branes and super-symmetry force to consider two options.

Option I: The *fundamental* action principle for space-time surfaces contains besides 4-D action also 2-D action assignable to string world sheets, whose topological part (magnetic flux) gives rise to a coupling term to Kähler gauge potentials assignable to the 1-D boundaries of string world sheets containing also geodesic length part. Super-symplectic symmetry demands that modified Dirac action has 1-, 2-, and 4-D parts: spinor modes would exist at both string boundaries, string world sheets, and space-time interior. A possible interpretation for the interior modes would be as generators of space-time super-symmetries [K99].

This option is not quite in the spirit of SH and string tension appears as an additional parameter. Also the conservation of em charge forces 2-D string world sheets carrying vanishing induced W fields and this is in conflict with the existence of 4-D spinor modes unless they satisfy the same condition. This looks strange.

Option II: Stringy action and its fermionic counterpart are effective actions only and justified by SH. In this case there are no problems of interpretation. SH requires only that the induced spinor fields at string world sheets determine them in the interior much like the values of analytic function at curve determine it in an open set of complex plane. At the level of quantum theory the scattering amplitudes should be determined by the data at string world sheets. If induced W fields at string world sheets are vanishing, the mixing of different charge states in the interior of X^4 would not make itself visible at the level of scattering amplitudes! In this case 4-D spinor modes do not define space-time super-symmetries.

3. Why the string world sheets coding for effective action should carry vanishing weak gauge fields? If M^4 has the analog of Kähler structure [L70], one can speak about Lagrangian sub-manifolds in the sense that the sum of the symplectic forms of M^4 and CP_2 projected to Lagrangian sub-manifold vanishes. Could the induced spinor fields for effective action be localized to generalized Lagrangian sub-manifolds? This would allow both string world sheets and 4-D space-time surfaces but SH would select 2-D Lagrangian manifolds. At the level of effective action the theory would be incredibly simple.

Induced spinor fields at string world sheets could obey the "dynamics of avoidance" in the sense that *both* the induced weak gauge fields W, Z^0 and induced Kähler form (to achieve this U(1) gauge potential must be sum of M^4 and CP_2 parts) would vanish for the regions carrying induced spinor fields. They would coupleonly to the *induced em field* (!) given by the R_{12} part of CP_2 spinor curvature [K22] for D = 2, 4. For D = 1 at boundaries of string world sheets the coupling to gauge potentials would be non-trivial since gauge potentials need *not* vanish there. Spinorial dynamics would be extremely simple and would conform with the vision about symmetry breaking of weak group to electromagnetic gauge group.

The projections of canonical currents of Kähler action to string world sheets would vanish, and the projections of the 4-D modified gamma matrices would define just the induced 2-D metric. If the induced metric of space-time surface reduces to an orthogonal direct sum of string world sheet metric and metric acting in normal space, the flow defined by 4-D canonical momentum currents is parallel to string world sheet. These conditions could define the "boundary" conditions at string world sheets for SH.

This admittedly speculative picture has revolutionized the understanding of both classical and quantum TGD during last year. [K56, K19, K28]. In particular, the construction of singlesheeted PEs as minimal surfaces allows a kind of lego like engineering of more complex PEs [L35]. The minimal surface equations generalize Laplace equation of Newton's gravitational theory to non-linear massless d'Alembert equation with gravitational self-coupling. One obtains the analog of Schwartschild solution and radiative solutions describing also gravitational radiation [K28]. An open question is whether classical theory makes sense if also the analog of Kähler form in M^4 is allowed.

Identification of WCW

The notion of WCW [K64, K34, K97] was inspired by the super-space approach of Wheeler in which 3-geometries are the basic geometric entities.

1. In TGD framework 3-surfaces take this role. Einstein's program for geometrizing classical physics is generalized to a geometrization of entire quantum physics. Hermitian conjugation corresponds to complex conjugation in infinite-dimensional context so that WCW must have Kähler geometry. The geometrization of fermionic statistics/oscillator operators is in terms of gamma matrices of WCW expressible as linear combinations of oscillator operators for second quantized induced spinor field. Formally purely classical spinor modes of WCW represent many fermion states as functionals of 3-surface. One can also interpret gamma matrices as generators of super-conformal symmetries in accordance with the fact that also SUSY involves Clifford algebra.

In ZEO the entanglement coefficients between positive and negative energy parts of zero energy states determine the S-matrix so that S-matrix would be coded by the modes of WCW spinor fields. Twistor approach to TGD [K56] suggests that the S-matrix reduces completely to the symmetries defined by the multi-local (locus corresponds to partonic 2-surface) generators of the Yangian associated with the super-symplectic algebra.

- 2. ZEO forces to identify 3-surfaces as pairs of 3-surfaces with members at the opposite boundaries of CD. SH reduces them to a collection of partonic 2-surfaces at boundaries of CD plus number theoretic discretization in space-time interior. Basic geometric objects are pairs of initial and final states (coordinates for both in mechanical analogy) rather than initial states with initial value conditions (coordinates and velocities in mechanical analogy) and initial value problem transforms to boundary value problem. Processes rather than states become the basic elements of ontology: this has far reaching consequences in biology and neuroscience.
- 3. The realization of GCI requires that the definition of WCW Kähler function assigns to a "physically" 3-surface a unique 4-surface for 4-D general coordinate transformations to act: "physically" could mean "apart from transformations acting as gauge transformations" not affecting the action and conserved classical charges. The outcome is holography.
- 4. Strong form of holography (SH) would emerge as follows. The condition that light-like 3surfaces defining boundaries between Euclidian and Minkowskian regions are basic geometric entities equivalent with pairs of space-like 3-surfaces at the ends of given causal diamond CD implies SH: partonic 2-surfaces and their 4-D tangent space data should code the physics. One could also speak about almost/effective 2-dimensionality. Tangent space data could in turn be coded by string world sheets. Number theoretical discretitization of space-time interior with preferred coordinates in the extension of rationals could give meaning for "almost".
- 5. Kähler metric is expressible both in terms of second derivatives of Kähler function K [K64] and as anticommutators of WCW gamma matrices expressible as linear combinations of fermionic oscillator operators. This suggests a close relationship between space-time dynamics and spinor dynamics.

Super-symplectic symmetry between the action defining space-time surfaces (Kähler action plus volume term) and modified Dirac action would realize this relationship. This is achieved if the modified gamma matrices are defined by the canonical momentum currents of 2-D action associated with string world sheets. These currents are parallel to the string world sheets. This implies the analog of AdS/CFT correspondence requiring only that induced spinor modes at string world sheets determine them in space-time interior (this is like analytic continuation). The localization of spinor modes at string world sheets is *not* required as I believed first.

The geometry of loop spaces developed by Freed [A27] serves as a model in the construction of WCW Kähler geometry [K97].

- 1. The existence of loop space Riemann connection requires maximal isometry group identifiable as Kac-Moody group so that Killing vector fields span the entire tangent space of the loop space.
- 2. In TGD framework the properties of Kähler action lead to the idea that WCW is union of homogenous or even symmetric spaces of symplectic algebra acting at the boundary of $\delta CD \subset \delta CD_+ \cup \delta CD_-$, $\delta CD_\pm \subset \delta M_\pm^4 \times CP_2$. ZEO requires that the conserved quantum numbers for physical states are opposite for the positive and negative energy parts of the states at the two opposite boundary parts of CD. The symmetric spaces G/H in the union are labelled by zero modes, which do not appear in the line element as differentials but only as parameters of the metric. Conserved Noether charges of isometries and symplectic invariants of examples of zero modes as also the super-symplectic Noether charges invariant under complex conjugation of WCW coordinates.
- 3. Homogenous spaces of the symplectic group G are obtained by dividing by a subgroup H. An especially attractive option is suggested by the fractal structure of the symplectic algebra containing an infinite hierarchy of sub-algebras G_n for which conformal weights are n > 0multiples of those for G. For this option $H = G_n$ is isomorphic to G and one could have infinite hierarchies of inclusions analogous to the hierarchy of inclusions of hyperfinite factors of type II_1 (HFFs). PE property requires almost 2-dimensionality and elimination of huge number of degrees of freedom. The natural condition is that the Noether charges of G_n vanish at the ends of CD. A stronger condition is that also the Noether charges for $[G, G_n]$ vanish. This implies effective normal algebra property and G/G_n acts effectively like group.

The inclusion of HFFs would define measurement resolution with included factor acting like gauge algebra. Measurement resolution would be naturally determined by the number theoretic discretization of the space-time surface so that physics as geometry and number theory visions would meet each other.

4. This inclusion hierarchy can be identified in terms of quantum criticality (QC). The transitions $n \to kn$ increasing the value of n > 0 reduce QC since pure gauge symmetries are reduced, and new physical super-symplectic degrees of freedom emerge. QC also requires that Kähler couplings strength analogous to temperature is analogous to critical temperature so that the quantum theory is uniquely defined if their is only one critical temperature. Spectrum for α_K seems more plausible and the possibility that Kähler coupling strength depends on the level of the number theoretical hierarchy defined by the allowed extensions of rationals can be considered [K49].

WCW spinor structure

The basic idea is geometrization of quantum states by identifying them as modes of WCW spinor fields [K128, K97]. This requires definition of WCW spinors and WCW spinor structure, WCW gamma matrices and Dirac operator, etc..

The starting point is the definition of WCW gamma matrices using a representation analogous to the usual vielbein representation as linear combinations of flat space gamma matrices. The conceptual leap is the observation that there is no need to assume that the counterparts of flat space gamma matrices have vectorial quantum numbers. Instead, they are identified as fermionic oscillator operators for second quantized free induced spinor fields at space-time surface.

This allows geometrization of the fermionic statistics since WVW spinors for a given 3surface are analogous to fermionic Fock states. One can also say that spinor structure follows as a square root of metric and also that the spinor basis defines a geometric correlate of Boolean mind [K32]. The dependence of WCW spinor field on 3-surface represents the bosonic degrees of freedom not reducible to many-fermion states. For instance, most of hadron mass would be associated with these degrees of freedom.

Quantum TGD involves Dirac equations at space-time level, imbedding space level, and level of WCW. The dynamics of the induced spinor fields is related by super-symmetry to the action defining space-time surfaces as preferred extremals. [K128, K97].

1. The gamma matrices in the equation - modified gamma matrices - are determined by contractions of the canonical momentum currents of Kähler action with the imbedding space gamma matrices. The localization at string world sheets for which only induced neutral weak fields or only em field are non-vanishing is accompanied by the integrability condition that various conserved currents run along string world sheets: one can speak of sub-flow. I

2. Modified Dirac equation can be solved exactly just like in the case of string models using holomorphy and the properties of complexified modified gamma matrices. This is expected to be true also in 4-D case by Hamilton-Jacobi structure. If the dynamics of avoidance is realized the modified Dirac equation would be essentially free Dirac equation and holomorphy would allow to solve it.

At the level of WCW one obtains also the analog of massless Dirac equation as the analog of super Virasoro conditions of Super Virasoro algebra.

- 1. The fermionic counterparts of super-conformal gauge conditions assignable with sub-algebra G_n of supersymplectic conformal symmetry associated with the both light-cone boundary (light-like radial coordinate), with conformal symmetries of light-cone boundary, and with string world sheets.
- 2. The ground states of supersymplectic representations satisfy massless imbedding space Dirac equation in imbedding space so that Dirac equations in WCW, in imbedding space, and at string world sheets are involved. In twistorialization also massless M^8 Dirac equation emerges in the tangent space M^8 of imbedding space assignable to the partonic 2-surfaces and generalizes the 4-D light-likeness with its 8-D counterpart applying to states with M^4 mass. Here octonionic representation of imbedding space gamma matrices emerges naturally and allows to speak about 8-D analogs of Pauli's sigma matrices [K116].

17.2.4 Quantum criticality, measurement resolution, and hierarchy of Planck constants

The notions of quantum criticality (QC), finite measurement resolution, and hierarchy of Planck constants proposed to give rise to dark matter as phases of ordinary matter are central for TGD [?, K127, K50].

These notions relate closely to the strong form of holography (SH) implied by strong form of general coordinate invariance (SGCI). In adelic physics all this would relate closely to the hierarchy of extensions of rationals serving as a correlate for number theoretical evolution.

Finite measurement resolution and fractal inclusion hierarchy of super-symplectic algebras

The fractal hierarchy of isomorphic sub-algebras of supersymplectic algebra - call it g - defines an excellent candidate for the realization of finite the measurement resolution. Similar hierarchies can be assigned also for the extended super-conformal algebra assignable with light-like boundaries of CD and with Kac-Moody and conformal algebras assignable to string world sheets.

An interesting possibility is that the the conformal weights assignable to infinitesimal scaling operator of the light-like radial coordinate of light-cone boundary correspond to zeros of Riemann zeta [K126] [L28]. A kind of dual spectrum would correspond to conformal weights that correspond to logarithms for powers of primes. One can identify the conformal weight as negative of the pole of fermionic zeta $z_F = \zeta(s)/\zeta(2s)$ natural in TGD framework. The real part of conformal weight for the generators is $h_R = -1/4$ for "non-trivial" poles and positive integer h = n > 0 for "trivial" poles. There is also a pole for h = -1. Hence one obtains tachyonic ground states, which must be assumed also in p-adic mass calculations [K68].

Also the generators of Yangian algebra [K116] integrating the algebras assignable to various partonic 2-surfaces to a multi-local algebra are labelled by a non-negative integer n analogous to conformal weight and telling the number of partonic 2-surfaces involved with the action of the generator. Also this algebra has similar fractal hierarchy of sub-algebras so that the considerations that follow might apply also to it. Now that number of partonic 2-surface would play the role of measurement resolution.

As noticed, there are also other algebras, which allow conformal hierarchy if one can restrict the conformal weights to be non-negative. The first of them generates generalized conformal transformations of light-cone boundary depending on light-like radial coordinate as parameter: also now radial conformal weights for generators can have zeros of zeta as spectrum. As a special case one obtains infinite-dimensional group of isometries of light-cone boundary. Second one corresponds to ordinary conformal and Kac-Moody symmetries for induced spinor fields acting on string world sheets. Also here similar hierarchy of sub-algebras can be considered. In the following argument one restricts to super-symplectic algebra assumed to act as isometries of WCW.

Consider now how the finite measurement resolution could be realized as an infinite hierarchy of super-symplectic gauge symmetry breakings. The physical picture relies on quantum criticality of TGD Universe. The levels of the hierarchy labelled by positive integer n and a ball at the top of ball at... serves as a convenient metaphor.

1. The sub-algebra g_n for which conformal weights of generators (whose commutators give the sub-algebra) are positive integer multiples for those of the entire algebra g defines the algebra acting as pure gauge algebra defining a sub-group of symplectic group. The action of g_n as gauge algebra would mean that it affects on degrees of freedom below the measurement resolution. One can assign to this algebra a coset space G/G_n of the entire symplectic group G and of subgroup G_n . This coset space would describe the dynamical degrees of freedom. If the subgroup were a normal subgroup, the coset space would be a group. This is not the case now since the commutator $[g, g_n]$ of the entire algebra with the sub-algebra does not belong to g_n .

However, if one poses stronger - physically very attractive - gauge conditions stating that not only g_n but also the commutator algebra $[g, g_n]$ annihilates the physical states and that corresponding classical Noether charges vanish, one obtains effectively a normal subgroup and one has good hopes that coset space acts effectively as group, which is finite-dimensional as far as conformal weights are considered.

- 2. n > 0 is essential for obtaining effective normal algebra property. Without this assumption the commutator $[g, g_n]$ would be entire g. If the spectrum of supersymplectic conformal weights is integer valued it is not obvious why one should pose the restriction $n \ge 1$.
- 3. In this framework pure conformal invariance could reduce to a finite-dimensional gauge symmetry. A possible interpretation would be in terms of Mc-Kay correspondence [A43] assigning to the inclusions of HFFs labelled by integer $n \geq 3$ a hierarchy of simply laced Lie-groups. Since the included algebra would naturally correspond to degrees of freedom not visible in the resolution used, the interpretation as a dynamical gauge group is suggestive. The dynamical gauge group could correspond to *n*-dimensional Cartan algebra acting in conformal degrees of freedom identifiable as a simply laced Lie group. This would assign a infinite hierarchy of dynamical gauge symmetries to the broken conformal gauge invariance acting as symmetries of dark matter. This still leaves infinite number of degrees of freedom assignable to the imbedding space Hamiltonians and spectrum generated by zeros of zeta but this might have interpretation in terms of gauging so that additional vanishing conditions for Noether charges are suggestive.

Dark matter as large phases with large gravitational Planck constant $h_{eff} = h_{qr}$

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 [K101, K84].

1. The proposal is that a Schrödinger equation results from a fractal hydrodynamics. Manysheeted space-time however suggests that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems and that only the generalizations of Bohr orbits are involved. The space-time sheets in question would carry dark matter. 2. Nottale's hypothesis would predict a gigantic value of \hbar_{gr} . Equivalence Principle and the independence of gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0 = 2r_S/v_0$ (typically astrophysical scale) 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 [K101].

One could criticize the hypothesis since it treats the masses M and m asymmetrically: this is only apparently true [?].

3. 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). The cross section of the flux tube corresponds to a sphere $S_i^2 \subset CP_2$, i = I, II [K19]. S_I^2 is homologically non-trivial carrying Kähler magnetic monopole flux. S_{II}^2 is homologically trivial carrying Kähler magnetic flux but non-vanishing electro-weak flux [K19].

The flux tubes of type I have both Kähler magnetic energy and dark energy due to the volume action. Flux tubes of type II would have only the volume energy. Both flux tubes could be remnants of cosmic string phase of primordial cosmology. The energy of these flux quanta would be correlated for galactic dark matter and volume action and also magnetic tension would give rise to negative "pressure" forcing accelerated 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 flux tubes identifiable also as dark energy.

4. Both theoretical consistency and certain experimental findings from astrophysics [E3, E5] and biology [K31, K20] suggest the identification $h_{eff} = n \times h = h_{gr}$. 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) [K97]. 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 modified Dirac action is present, part of the interior degrees of freedom associated with the fermionic part of conformal algebra become physical.

Fermionic oscillator operators could generate super-symmetries and sparticles could correspond 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 an ordinary high frequency graviton ($E = h f_{high} = h_{eff} f_{low}$) or to a bunch of n low energy gravitons.

Hierarchies of quantum criticalities, Planck constants, and dark matters

Quantum criticality is one of the corner stone assumptions of TGD. In the original approach the value of Kähler coupling strength α_K together with CP_r radius R fixed quantum TGD and is analogous to critical temperature. Twistor lift [K19] brings in additional coupling constant Λ obeying p-adic coupling constant evolution and Planck length l_G , which like CP_2 radius would not obey coupling constant evolution (as also G). The values of these parameters should be fixed by quantum criticality. What else does quantum criticality mean is however far from obvious, and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology [K64, K128, K97].

1. Criticality is characterized by long range correlations and sensitivity to external perturbations and living systems define an excellent example of critical systems - even in the scale of populations since without sensitivity and long range correlations cultural evolution and society would not be possible. For a physicist with the conceptual tools of existing theoretical physics the recent information society in which the actions of people at different side of globe are highly correlated, should look like a miracle. 2. The hierarchy of Planck constants with dark matter identified as phases of ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant is one of the "almost-predictions" of TGD is definitely something essentially new physics. The phase transition transforming ordinary matter to dark matter in this sense generates long range quantal correlations and even macroscopic quantum coherence.

Finding of a universal mechanism generating dark matter have been a key challenge during last ten years. Could quantum criticality having classical or perhaps even thermodynamical criticality as its correlate be always accompanied by the generation of dark matter? If this were the case, the recipe would be stupifyingly simple: create a critical system! Dark matter would be everywhere and we would have observed its effects for centuries! Magnetic flux tubes (possibly carrying monopole flux) define the space-time correlates for long range correlations at criticality and would carry the dark matter. They are indeed key players in TGD inspired quantum biology.

- 3. Change of symmetry is assigned with criticality as also conformal symmetry (in 2-D case). In TGD framework conformal symmetry is extended and infinite hierarchy of breakings of conformal symmetry so that a sub-algebras of various conformal algebras with conformal weights coming as integer multiples of integer n defining h_{eff} would occur.
- 4. Phase separation is what typically occurs at criticality and one should understand also this. The strengthening of this hypothesis with the assumption $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is is the gravitational Planck constant originally introduced by Nottale [K85, ?]. In the formula v_0 has dimensions of velocity, and will be proposed to be determined by a condition relating the size of the system with mass M to the radius within which the wave function of particle m with $h_{eff} = h_{gr}$ is localized in the gravitational field of M.

The condition $h_{eff} = h_{gr}$ implies that the integer n in h_{eff} is proportional to the mass of the particle. The implication is that particles with different masses reside at flux tubes with different Planck constant and separation of phases indeed occurs.

5. What is remarkable is that neither gravitational Compton length nor cyclotron energy spectrum depends on the mass of the particle. This universality could play key role in living matter. One can assign Planck constant also to other interactions such as electromagnetic interaction so that one would have $h_{em} = Z_1 Z_2 e^2 / v_0$. The phase transition could take place when the perturbation series based on the coupling strength $\alpha = Z_1 Z_2 e^2 / \hbar$ ceases to converge. In the new phase perturbation series would converge since the coupling strength is proportional to $1/h_{eff}$. Hence criticality and separation into phases serve as criteria as one tries to see whether the earlier proposals for the mechanisms giving rise to large h_{eff} phases make sense. One can also check whether the systems to which large h_{eff} has been assigned are indeed critical.

One example of criticality is super-fluidity. Superfluids exhibit rather mysterious looking effects such as fountain effect [D13] and what looks like quantum coherence of superfluid containers, which should be classically isolated. These findings serve as a motivation for the proposal that genuine superfluid portion of superfluid corresponds to a large h_{eff} phase near criticality at least and that also in other phase transition like phenomena a phase transition to dark phase occurs near the vicinity [?].

But how does quantum criticality relate to number theory and adelic physics? $h_{eff}/h = n$ has been identified as the number of sheets of space-time surface identified as a covering space of some kind. Number theoretic discretization defining the "spine" for a monadic space-time surface [L46] defines also a covering space with Galois group for an extension of rationals acting as covering group. Could n be identifiable as the order for a sub-group of Galois group? If this is the case, the proposed rule for h_{eff} changing phase transitions stating that the reduction of n occurs to its factor would translate to spontaneous symmetry breaking for Galois group and spontaneous - symmetry breakings indeed accompany phase transitions.

TGD variant of AdS/CFT duality

AdS/CFT duality [B19] has provided a powerful approach in the attempts to understand the nonperturbative aspects of super-string theories. The duality states that conformal field theory in *n*-dimensional Minkowski space M^n identifiable as a boundary of n+1-dimensional space AdS_{n+1} is dual to a string theory in $AdS_{n+1} \times S^{9-n}$.

As a mathematical discovery AdS/CFT duality is extremely interesting but it seems that it need not have much to do with physics as such. From TGD point of view the reason is obvious: the notion of conformal invariance is quite too limited. In TGD framework conformal invariance is extended to a super-symplectic symmetry in $\delta M_{\pm}^4 \times CP_2$, whose Lie-algebra has the structure of conformal algebra. Also ordinary super-conformal symmetries associated with string world sheets are present as well as generalization of 2-D conformal symmetries to their analogs at light-cone boundary and light-like orbits of partonic 2-surfaces. In this framework AdS/CFT duality is expected to be modified.

The matrix elements $G_{K\overline{L}}$ of Kähler metric of WCW can be expressed in two manners. As contractions of the derivatives $\partial_K \partial_{\overline{L}} K$ of the Kähler function of WCW with isometry generators or as anticommutators $\{\Gamma_K, \Gamma_{\overline{L}}\}$ of WCW gamma matrices identified as supersymplectic Noether super charges assignable to fermionic strings connecting partonic 2-surfaces. Kähler function is identified as real part of the action: if coupling parameters are real it reduces to the action for the Euclidian space-time regions with 4-D CP_2 projection and otherwise contains contributions from both Minkowskian and Euclidian regions. The action defines the modified gamma matrices appearing in modified Dirac action as contractions of canonical momentum currents with imbedding space gamma matrices.

This observation suggests that there is a super-symmetry between action and modified Dirac action. The problem is that induced spinor fields naive of SH and also well-definedness of em charge demand the localization of induced spinor modes at 2-D string world sheets. This simply cannot be true. On the other hand, SH only requires that the data about induced spinor fields and space-time surface at the string world sheets is enough to construct the modes in space-time interior.

This leaves two options if one assumes that SH is exact (recall however that the number theoretic interpretation for the hierarchy of Planck constants suggests that the number-theoretic spin of monadic space-time surface represents additional discrete data needed besides that assignable to string world sheets to describe dark matter). As found in the section 17.2.3, there are two options.

Option I: The analog of brane hierarchy is realized at the level of fundamental action. There is a separate fundamental 2-D action assignable with string world sheets - area and topological magnetic flux term - as also world line action assignable to the boundaries of string world sheets. By previous argument string tension should be determined by the value of the cosmological constant Λ obeying -adic coupling constant evolution rather than by G: otherwise there is no hope about gravitationally bound states above Planck scale. String tension would appear as an additional fundamental coupling parameter (perhaps fixed by quantum criticality). This option does not quite conform with the spirit of SH.

Option II: 4-D space-time action and corresponding modified Dirac action defining fundamental actions are expressible as effective actions assignable to string world sheets and their boundaries. String world sheet effective action action could be expressible as string area for the effective metric defined by the anti-commutators of modified gamma matrices at string world sheet. If the sum of the induced Kähler forms of M^4 and CP_2 vanishes at string world sheets the effective metric would be the induced 2-D metric: this together with the observed CP breaking could provide a justification for the introduction of the analog of Kähler form in M^4 . String tension would be dynamical rather than determined by l_P and depend on Λ , l_P , R and α_K . This representation of Kähler action would be one aspect of the analog of AdS/CFT duality in TGD framework.

Both options would allow to understand how strings connecting partonic 2-surfaces give rise to the formation of gravitationally bound states. Bound states of macroscopic size are possible only if one allows hierarchy of Planck constants and this is required also by the (extremely) small value of Λ (in cosmic scales).

Consider the concerete realizations for this vision.

1. SGCI requires effective 2-dimensionality. In given UV and IR resolutions partonic 2-surfaces and string world sheets are assignable to a finite hierarchy of CDs inside CDs with given CD characterized by a discrete scale coming as an integer multiple of a fundamental scale (essentially CP_2 size). A would closely relate to the size scale of CD. String world sheets have boundaries consisting of either light-like curves in induced metric at light-like wormhole throats and space-like curves at the ends of CD whose M^4 projections are light-like. These braids carrying fermionic quantum numbers intersect partonic 2-surfaces at discrete points.

2. This implies a rather concrete analogy with $AdS_5 \times S_5$ duality, which describes gluons as open strings. In zero energy ontology (ZEO) string world sheets are indeed a fundamental notion and the natural conjecture is that these surfaces are minimal surfaces, whose area by quantum classical correspondence depends on the quantum numbers of the external particles.

String tension of gravitational flux tubes

For Planckian cosmic strings only quantum gravitational bound states of length of order Planck length are possible. There must be a mechanism reducing the string tension. The *effective* string tension assignable to magnetic flux tubes must be inversely proportional to $1/h_{eff}^2$, $h_{eff} = n \times h = h_{gr} = 2\pi GMm/v_0$ in order to obtain gravitationally bound states in macroscopic length scales identified as structures for which partonic 2-surfaces are connected by flux tubes accompanied by fermionic strings.

The reason is that the size scale of (quantum) gravitationally bound states of masses Mand m is given by grvitational Compton length $\Lambda_{gr} = GM/v_0$ [K101, K85, ?] assignable to the gravitational flux tubes connecting the masses M and m. If the string tension is of order Λ_{gr}^2 this is achieved since the typical length of string would be Λ_{gr} . Gravitational string tension must be therefore of order $T_{gr} \sim 1/\Lambda_{gr}^2$. How could this be achieved? One can imagine several options and here only the option based on the assumptions

- 1. Twistor lift makes sense.
- 2. Fundamental action is 4-D for both space-time and fermionic degrees of freedom and 2-D string world sheet action is an effective action realizing SH. Note effective action makes also possible braid statistics, which does not make sense at fundamental level.
- 3. Also M^4 carries the analog of Kähler form and the sum of induced Kähler forms from M^4 and CP_2 vanishes at string world sheets and also weak gauge fields vanishes at string world sheets leaving only em field.

is considered since it avoids all the objections that I have been able to invent.

For the twistor lift of TGD [K19] predicting cosmological constant Λ depending on p-adic length scale $\Lambda \propto 1/p$ the gravitational strings would be naturally homologically trivial cosmic strings. These vacuum extremals of Kähler action transform to minimal surface extremals with string tension given by $\rho_{vac}S$, where ρ_{vac} the density of dark energy assignable to the volume term of the action and S the transverse area of the flux tube. One should have $\rho_{vac}S = 8\pi\Lambda S/G = 1/\Lambda_{gr}^2$ so that one would have

$$8\pi\Lambda S = \frac{G}{\Lambda_{qr}^2}$$

۶

A for flux tubes (characterizing the size of CDs containing them) would depend on the gravitational coupling Mm.

17.2.5 Number theoretical vision

Physics as infinite-D spinor geometry of WCW and physics as generalized number theory are the two basic vision about TGD. The number theoretical vision involves three threads [K107, K110, K106].

 The first thread [K107] involves the notion of number theoretical universality NTU: quantum TGD should make sense in both real and p-adic number fields (and their algebraic extensions induced by extensions of rationals). p-Adic number fields are needed to understand the spacetime correlates of cognition and intentionality [K79, K57, K80].

p-Adic mass calcuations lead to the notion of a p-adic length scale hierarchy quantifying the notion of the many-sheeted space-time [K79, K57]. One of the first applications was the calculation of elementary particle masses [K68]. The basic predictions are only weakly model

independent since only p-adic thermodynamics for Super Virasoro algebra are involved. Not only the fundamental mass scales would reduce to number theory but also particle masses are predicted correctly under rather mild assumptions and are exponentially sensitive to the p-adic length scale predicted by p-adic length scale hypothesis. Also predictions such as the possibility of neutrinos to have several mass scales were made on the basis of number theoretical arguments and have found experimental support [K68, K33].

- 2. Second thread [K110] is inspired by the dimensions D = 1, 2, 4, 8 of the basic objects of TGD and assumes that classical number fields are in a crucial role in TGD. 8-D imbedding space would have octonionic structure and space-time surfaces would have associative (quaternionic) tangent space or normal space. String world sheets could correspond to commutative surfaces. Also the notion of $M^8 - H$ -duality is part of this thread and states that quaternionic 4-surfaces of M^8 containing preferred M^2 in its tangent space can be mapped to PEs in H by assigning to the tangent space CP_2 point parametrizing it. M^2 could be replaced by integrable distribution of $M^2(x)$. If PEs are also quaternionic one has also H - Hduality allowing to iterate the map so that PEs form a category. Also quaternion analyticity of PEs is a highly attractive hypothesis [K116]. For instance, it might be possible to interpret string world sheets and partonic 2-surfaces appearing in strong form of holography (SH) as co-dimension 2 surfaces analogous to poles of analytic function in complex plane. Light-like 3-surfaces might be seen as analogs of cuts. The coding of analytic function by its singularities could be seen as analog of SH.
- 3. The third thread [K106] corresponds to infinite primes and leads to several speculations. The construction of infinite primes is structurally analogous to a repeated second quantization of a supersymmetric arithmetic quantum field theory with free particle states characterized by primes. The many-sheeted structure of TGD space-time could reflect directly the structure of infinite prime coding it. Space-time point would become infinitely structured in various p-adic senses but not in real sense (that is cognitively) so that the vision of Leibniz about monads reflecting the external world in their structure is realized in terms of algebraic holography. Space-time becomes algebraic hologram and realizes also Brahman=Atman idea of Eastern philosophies.

17.3 p-Adic mass calculations and p-adic thermodynamics

p-Adic mass calculations carried for the first time around 1995 were the stimulus eventually leading to the number theoretical vision as a kind dual for the geometric vision about TGD. In this secton I will roughly describe the calculations [K33, K68] and the questions and challenges raised by them.

17.3.1 p-Adic numbers

Like real numbers, p-adic numbers (http://tinyurl.com/hmgqtoh) can be regarded as completions of the rational numbers to a larger number field [K57]. Each prime p defines a p-adic number field allowing the counterparts of the usual arithmetic operations.

1. The basic difference between real and p-adic numbers is that p-adic topology is ultra-metric. Ultrametricity means that the distance function d(x, y) (the counterpart of |x - y| in the real context) satisfies the inequality

$$d(x,z) \le Max\{d(x,y), d(y,z)\} ,$$

(Max(a, b) denotes maximum of a and b) rather than the usual triangle inequality

$$d(x,z) \le d(x,y) + d(y,z)$$

2. The topology defined by p-adic numbers is compact-open. Hence the generalization of manifold obtained by gluing together n-balls fails because smallest open n-balls are just points and one has totally disconnected topology.

- 3. p-Adic numbers are not well-ordered like real numbers. Therefore one cannot assign orientation to the p-adic number line. This in turn leads to difficulties with attempts to define definite integrals and the notion of differential form although indefinite integral is well-defined. These difficulties serve as important guidelines in the attempts to understand what p-adic physics is and also how to fuse real and various p-adic physics to a larger structure.
- 4. p-Adic numbers allow an expansion in powers of p analogous to the decimal expansion

$$x = \sum_{n \ge 0} x_n p^n$$

and the number of terms in the expansion can be infinite so that p-adic number need not be finite as a real number. The norm of the p-adic number (counterpart of |x| for real numbers) is defined as

$$N_p(x) = \sum_{n \ge 0} x_n p^n = p^{-n_0}$$

and depends only very weakly on p-adic number. The ultra-metric distance function can be defined as $d_p(x, y) = N_p(x - y)$.

5. p-Adic numbers allow a generalization of the differential calculus. The basic rules of the p-adic differential calculus are the same as those of the ordinary differential calculus. There is however one important new element: the set of the functions having vanishing p-adic derivative consists of so called pseudo constants, which are analogs of real valued piecewise constant functions. In the real case only constant functions have vanishing derivative. This implies that p-adic differential equations are non-deterministic. This non-determinism is identified as a counterpart of the non-determinism of cognition and imagination [K80].

17.3.2 Model of elementary particle

p-Adic mass calculations [K33, K68] rely heavily on a topological model for elementary particle and it is appropriate to describe it before going to the summary of calculations.

Family replication phenomenon topologically

One of the basic ideas of TGD approach to particle physics has been genus-generation correspondence: boundary components of the 3-surface should be carriers of elementary particle numbers and the observed particle families should correspond to various boundary topologies.

With the advent of zero energy ontology (ZEO) this picture has changed somewhat.

1. The wormhole throats identified as light-like 3-surfaces at with the induced metric of the space-time surface changes its signature from Minkowskian to Euclidian correspond to the light-like orbits of partonic 2-surfaces. One cannot of course exclude the possibility that also boundary components allow to satisfy boundary conditions without assuming vacuum extremal property of nearby space-time surface.

The intersections of the wormhole throats with the light-like boundaries of causal diamonds (CDs) identified as intersections of future and past directed light cones ($CD \times CP_2$ is actually in question but I will speak about CDs) define special partonic 2-surfaces and the conformal moduli of these partonic 2-surfaces appear in the elementary particle vacuum functionals [K33] naturally. A modification of the original simple picture came from the proposed identification of physical particles as bound states of two wormhole contacts connected by tubes carrying monopole fluxes.

2. For generalized scattering diagrams stringy trouser vertices are replaced with vertices at which the ends of light-like wormhole throats meet. This vertex is the analog of 3-vertex for Feynman diagrams in particle physics lengths scales and for the biological replication (DNA and even cell) in macroscopic length scales.

In this picture the interpretation of the analog of trouser vertex is in terms of propagation of same particle along two different paths. This interpretation is mathematically natural since vertices correspond to 2-manifolds rather than singular 2-manifolds, which are just splitting to two disjoint components. Second complication comes from the weak form of electric-magnetic duality forcing to identify physical particles as weak strings with magnetic monopoles at their ends and one should understand also the possible complications caused by this generalization.

These modifications force to consider several options concerning the identification of light fermions and bosons and one can end up with a unique identification only by making some assumptions. Masslessness of all wormhole throats - also those appearing in internal lines - and dynamical SU(3) symmetry for particle generations are attractive general enough assumptions of this kind. Bosons and their possible spartners would correspond to wormhole contacts with fermion and anti-fermion at the throats of the contact. The expectation was the free fermions and their possible spartners correspond to CP_2 type vacuum extremals with single wormhole throat. It however turned however that dynamical SU(3) symmetry forces to identify massive (and possibly topologically condensed) fermions as pairs of (g, g) type wormhole contacts. The existence of higher boson families would mean breaking of quark and lepton universality and there are indications for this kind of anomaly [K74].

The notion of elementary particle vacuum functional

Obviously one must know something about the dependence of the elementary particle state functionals on the geometric properties of the boundary component and in the sequel an attempt to construct what might be called elementary particle vacuum functionals (EPVFs), is made. The basic assumptions underlying the construction are the following ones [K33].

- 1. EPVFs depend on the geometric properties of the two-surface X^2 representing elementary particle.
- 2. EPVFs possess extended Diff invariance: all 2-surfaces on the orbit of the 2-surface X^2 correspond to the same value of the vacuum functional. This condition is satisfied if vacuum functionals have as their argument, not X^2 as such, but some 2- surface Y^2 belonging to the unique orbit of X^2 (determined by the principle selecting PE as a generalized Bohr orbit [K64, K14, K21]) and determined in general coordinate invariant manner.
- 3. ZEO allows to select uniquely the partonic 2-surface as the intersection of the wormhole throat at which the signature of the induced 4-metric changes with either the upper or lower boundary of $CD \times CP_2$. This is essential since otherwise one one could not specify the vacuum functional uniquely.
- 4. Vacuum functionals possess conformal invariance and therefore for a given genus depend on a finite number of variables specifying the conformal equivalence class of Y^2 .
- 5. Vacuum functionals satisfy the cluster decomposition property: when the surface Y^2 degenerates to a union of two disjoint surfaces (particle decay in string model inspired picture), vacuum functional decomposes into a product of the vacuum functionals associated with disjoint surfaces.
- 6. EPVFs are stable against the decay $g \to g_1 + g_2$ and one particle decay $g \to g 1$. This process corresponds to genuine particle decay only for stringy diagrams. For generalized scattering diagrams the interpretation is in terms of propagation along two different paths simultaneously.

In [K33] the construction of EPVFs is described in detail. This requires some basic concepts related to the description of the space of the conformal equivalence classes of Riemann surfaces and the concept of hyper-ellipticity. Since theta functions will play a central role in the construction of the vacuum functionals, also their basic properties are needed. Also possible explanations for the experimental absence of the higher fermion families are considered. Concerning p-adic mass calculations, the key question is how to construct p-adic variants of EPVFs.

17.3.3 p-Adic mass calculations

p-Adic thermodynamics

Consider first the basic ideas of p-adic thermodynamics.

1. p-Adic valued mass squared is identified as as thermal mass in p-adic thermodynamics. Boltzmann weights exp(-E/T) do not make sense if one just replaces exponent function with the p-adic variant of its Taylor series. The reason is that exp(x) has p-adic norm equal to 1 for all acceptable values of the argument x (having p-adic norm smaller than one) so that partition function does not have the usual exponential convergence property. Nothing however prevents from consider Boltzmann weights as powers p^n making sense for integer values of n. Here the p-adic norm approaches zero for $n \to +\infty$: thus the correspondences $e^{-E/T} \leftrightarrow p^{E/T_p}$.

The values of E/T_p must be quantized to integers. This is guaranteed if E is integer valued in suitable unit of energy and $1/T_p$ has integer valued spectrum using same unit for T_p . Super-conformal invariance guarantees integer valued spectrum of E, which in the recent case corresponds to mass squared. These number theoretical conditions are very powerful and lead to the quantization of also thermal mass squared for given p-adic prime p.

- 2. The p-adic mass squared is mapped to real number by canonical identification $I : \sum x_n p^n \to \sum x_n p^{-n}$ or its variant for rationals. Canonical identification is continuous and maps powers of p^n to their inverses. One modification of canonical identification maps rationals m/n in their representation in which m and n have no common divisors to I(m)/I(n). The predictions of calculations depend in some cases on which variant one uses but rational option looks the most reasonable choice.
- 3. p-Adic length scale hypothesis states that preferred p-adic primes correspond to powers of 2: $p \simeq 2^k$, but smaller than 2^k . The values of k form with $p = 2^k 1$ is prime Mersenne prime are especially favored. The nearer the prime p to 2^k , the more favored p is physically. One justification for the hypothesis is that preferred primes have been selected by an evolutionary process.
- 4. It turns out that p-adic temperature is $T_p = 1$ for fermions. For gauge bosons $T_p \leq 1/2$ seems to be necessary assumption for gauge bosons implying that the contribution to mass squared is very small so that super-symplectic contribution assignable to the wormhole magnetic flux tube dominates for weak bosons. For canonical identification $m/n \to I(m)/I(n)$ second order contribution to fermionic mass squared is very small.
- 5. The large values of p-adic prime p guarantee that the p-adic thermodynamics converves extremely rapidly. For $m/n \to I(m)/I(n)$ already the second order contribution is extremely small since the expansion for the real mass squared is in terms of 1/p and for electron with $p = M_{127}$ one has $p \sim 10^{38}$. Hence the calculations are essentially exact and errors are those of the model. It is quite possible that calculations could be done exactly using exact expressions for the super-symplectic partition functions generalized to p-adic context. The success of the p-adic mass calculations is especially remarkable because p-adic length scale hypothesis $p \simeq 2^k$ predicts exponential sensitivity of the particle mass scale on k.

Symmetries

The number theoretical existence of p-adic thermodynamics requires powerful symmetries to guarantee integer valued spectrum for the thermalized contribution to the mass squared.

1. Super-conformal symmetry with integer valued conformal weights for Virasoro scaling generator L_0 is essential because it predicts in string models that mass squared is apart from ground state contribution integer valued in suitable units. In TGD framework fermionic string world sheets are characterized by super-conformal symmetry. This gives the p-adic thermodynamics assumed in the calculations. One could however assign Super Virasoro algebra also to super-symplectic algebra having its analog as sub-algebra with positive integer conformal weights. Same applies to the extended conformal algebra of light-cone boundary. 2. TGD however predicts also generalization of conformal symmetry associated with light-cone boundary involving ordinary complex conformal weights and the conformal weight associated with the light-like radial coordinate. For the latter conformal weights for the generators of supersymmetry might be given by $h = -s_n/2$. s_n zero of zeta or pole h = -s = -1 of zeta.

Also super-symplectic symmetries would have similar radial spectrum of conformal weights. Conformal confinement requiring that the conformal weights of states are real implies that the spectrum of conformal weights for physical states consists of non-negative integers as for ordinary superconformal invariance.

It is not clear whether thermalization occurs in these degrees of freedom except perhaps for trivial conformal weights. These degrees of freedom need not therefore contribute to thermal masses of leptons and quarks but would give dominating contribution to hadron masses and weak boson masses. The negative conformal weights predicted by h = -s/2 hypothesis predicts that ground state weight is negative for super-symplectic representations and must be compensated for massless states.

The assumption that ground state conformal weight is negative and thus tachyonic is essential in case of p-adic mass calculations [K68], and only for massless particles (graviton, photon, gluons) it vanishes or is of order O(1/p). This could be achieved if the ground state of super-symplectic representation has h = 0.

3. Modular invariance [K33] assignable to partonic 2-surfaces is a further assumption similar to that made made in string models. This invariance means that for a given genus the dynamical degrees of freedom of the partonic 2-surface correspond to finite-dimensional space of Teichmueller parameters. For genus g = 0 this space is trivial.

Also modular invariance for string world sheets can be considered. By SH the information needed in mass calculations should be assignable to partonic 2-surfaces: the assumption is that one can assign this information to single partonic 2-surface. Stringy contribution would be seen only in scattering amplitudes.

This might be true only effectively: the recent view about elementary particles is that they are pairs of wormhole contacts connected by flux tubes defining a closed monopole flux and wormhole throats of contact have same genus for light states. Furthermore the quantum numbers of particle are associated with single throat for fermions and with opposite throats of single contact for bosons. The second wormhole contact would carry neutralizing weak charges to realize the finite range of weak interactions as "weak confinement".

The number of genera is infinite and one must understand why only three quark and lepton generations are observed. An attractive explanation is in terms of symmetry. For the three lowest genera the partonic 2-surfaces are always hyper-elliptic and have thus global conformal Z_2 symmetry. For higher genera this is not true always and EPVFs constructed from the assumption of modular invariance vanish for the hyper-elliptic surfaces. This suggests that the higher genera are very massive or can be interpreted as many-particle states of handles, which are not bound states but have continuous mass squared.

Contributions to mass squared

There are several contributions to the p-adic thermal mass squared come from the degrees of freedom, which are thermalized.

Super-conformal degrees of freedom associated with string world sheets are certainly thermalized. p-Adic mass calculations strongly suggest that the number of super-conformal tensor factors is N = 5 but also N = 4 and N = 6 can be considered marginally.

I have considered several identifications of tensor factors and not found a compelling alternative. If one assumes that super-symplectic degrees of freedom do not contribute to the thermal mass, string world sheets should explain masses of elementary fermions. Here charged lepton masses are the test bench. One other hand, if super-symplectic degrees of freedom contribute one obtains additional tensor factor assignable to h = -s/2, s trivial zero of zeta). Only one tensor factor emerges since Hamiltonians correspond to the products of functions of the coordinates of light-cone boundary and CP_2).

- 1. $SU(2)_L \times U(1)$ gives 2 tensor factors. SU(3) gives 1 tensor factor. The two transversal degrees of freedom for string world sheet suggest 2 degrees of freedom corresponding to Abelian group E^2 . Rotations however transforms these degrees to each other so that 1 tensor factor should emerge. This gives 4 tensor factors. Could it correspond to the degrees of freedom parallel to string at its end assignable to wormhole throat? Could normal vibrations of partonic 2surface? This would N = 5 tensor factors. Another possibility is that the fifth tensor factor comes from super-symplectic Super-Virasoro algebra defined by trivial conformal weights.
- 2. Super-symplectic contributions need not be present for ordinary elementary fermions. For weak bosons they could give string tension assignable to the magnetic flux tube connecting the wormhole contacts. It is not clear whether this contribution is thermalized. This contribution might be present only for the phases with $h_{eff} = n \times h$. This contribution would dominate in hadron masses.
- 3. Color degrees of freedom contribute to the ground state mass squared since ground state corresponds to an imbedding space spinor mode massless in 8-D sense. The mass squared contribution corresponds to an eigenvalue of CP_2 spinor d'Alembertian. Its eigenvalues correspond to color multiplets and only the covariantly constant right handed neutrino is color singlet. For the other modes the color representation is non-trivial and depends on weak quantum numbers of the fermion. The construction of the massless state from a tachyonic ground state with conformal weight $h_{vac} = -3$ must involve colored super-Kac Moody generators compensating for the anomalous color charge so that one obtains color single for leptons and color triplet for quarks as massless state.
- 4. Modular degrees of freedom give a contribution depending on the genus g of the partonic 2surface. This contribution is estimated by considering p-adic variants of elementary particle vacuum functionals Ω_{vac} [K68] expressible as products of theta functions with the structure of partition function. Theta functions are expressible as sums of exponent functions exp(X)with X defined as a contraction of the matrix Ω_{ij} defined by Teichmueller parameters between integer valued vectors.

In ZEO the interpretation of Ω_{vac} is as a complex square root of partition functional (quantum theory as complex square root of thermodynamics in ZEO). The integral of $|\Omega|^2$ over allowed moduli has interpretation as partition function. The exponential $exp(Re(X)) = p^{Re(X)/log(p)}$ has interpretation as an exponential of "Hamiltonian" defined by the vacuum conformal weight defined by moduli. T = log(p) is identified as p-adic temperature as in ordinary p-adic thermodynamics.

NTU requires that the integration over the moduli parameters reduces to a sum over number theoretically universal moduli parameters. The exponents exp(X) must exist p-adically. PE property alone could guarantee this. The exponentials appearing in theta functions should reduce to products $p^k p^{iy} = exp(k/log(p))p^{iy}$ with k is integer and p^{iy} a root of unity. The vacuum expectation value of Re(X) contributing to the mass squared is obtained from the standard formula as logarithmic temperature derivative of the "integral" $\int |\Omega_{vac}|^2$. The formula is same as for the Super-Virasoro contributions apart from the integration reducing to a sum.

The considerations of the section 17.4.2 [L28] suggest that for given p-adic prime p the exponent k + iy corresponds to a linear combinations of poles of fermionic zeta $z_F(s) = \zeta(s)/\zeta(2s)$ in the class C(p) with non-negative integer coefficients. This class corresponds essentially to the conformal weights of a fractal sub-algebra of super-symplectic algebra. It could give rise also to the complex values of action so that Riemann zeta would define the core of TGD.

The general dependence of the contribution of genus g to mass squared on g follows from the functional form of EPVF as a product theta functions serving as building brick partition functions apart from overall multiplicative constant and gives a nice agreement with the observed charged lepton mass ratios. The basic feature of the formula is exponential dependence on g.

5. The super-symplectic stringy contribution assignable to the magnetic flux tube dominates for weak bosons and is analogous to the stringy contribution to the hadron masses. p-Adic mass calculations leave open several questions. What is the precise origin of preferred p-adic primes and of p-adic length scale hypothesis? How to understand the preferred number N = 5 of Super-Kac-Moody tensor factors? How to calculate the contribution of super-symplectic degrees of freedom - are they thermalized? Why only 3 lowest genera are light and what are the masses of the predicted bosonic higher genera implying breaking of fermion universality.

17.3.4 p-Adic length scale hypothesis

p-Adic length scale hypothesis [K1, K79] has served as a basic hypothesis of p-adic TGD for several years. This hypothesis states that the scales $L_p = \sqrt{pl}$, $l = 1.376 \cdot 10^4 \sqrt{G}$ are fundamental length scale at p-adic condensate level p. The original interpretation of the hypothesis was following:

- 1. Above the length scale L_p p-adicity sets on and effective course grained space-time or imbedding space topology is p-adic rather than ordinary real topology. Imbedding space topology seems to be more appropriate identification.
- 2. The length scale L_p serves as a p-adic length scale cutoff for the quantum field theory description of particles. This means that space-time begins to look like Minkowski space so that the QFT $M^4 \rightarrow CP_2$ becomes a realistic approximation. Below this length scale string like objects and other particle like 3-surfaces are important.
- 3. It is un-natural to assume that just single p-adic field would be chosen from the infinite number of possibilities. Rather, there is an infinite number of cutoff length scales. To each prime p there corresponds a cutoff length scale L_p above which p-adic quantum field theory $M^4 \rightarrow CP_2$ makes sense and one has a hierarchy of p-adic QFTs. These different p-adic field theories correspond to different hierarchically levels possibly present in the topological condensate. Hierarchical ordering $< p_1 < p_2 < ...$ means that only the surface $p_1 < p_2$ can condense on the surface p_2 . The condensed surface can in practice be regarded as a point like particle at level p_2 described by the p-adic conformal field theory below length scale L_{p_2} .

The recent view inspired by adelic physics is that preferred p-adic primes correspond to so called ramified primes for the algebraic extension of rationals defining the adele [K126]. Weak form of Negentropy Maximization Principle (WNMP) [K73] in turn allows to conclude that the length scales corresponding to powers of primes are preferred. Therefore p-adic length scale hypothesis generalizes. There is evidence for 3-adic time scales in biology [I127, I128] and 3-adic time scales can be also assigned with Pythagorean scale in geometric theory of harmony [K91] [L16].

17.3.5 Mersenne primes and Gaussian Mersennes are special

Mersenne primes and their complex counterparts Gaussian Mersennes pop up in p-adic mass calculations and both elementary particle physics, biology [K88], and astrophysics and cosmology [K71] provide support for them.

Mersenne primes

One can also consider the milder requirement that the exponent $\lambda = 2^{\epsilon L_0}$ represents trivial scaling represented by unit in good approximation for some p-adic topology. Not surprisingly, this is the case for $L_0 = mp^k$ since by Fermat's theorem $a^p \mod p = 1$ for any integer a, in particular a = 2. This is also the case for $L_0 = mk$ such that $2^k \mod p = 1$ for p prime. This occurs if $2^k - 1$ is Mersenne prime: in this case one has $2^{L_0} = 1 \mod p$ so that the sizes of the fractal sub-algebras are exponentially larger than the sizes of $L_0 \propto p^n$ algebras. Note that all scalings a^{L_0} are near to unity for $L_0 = p^n$ whereas now only a = 2 gives scalings near unity for Mersenne primes. Perhaps this extended fractality provides the fundamental explanation for the special importance of Mersenne primes.

In this case integrated scalings 2^{L_0} leave the states almost invariant so that even a stronger form of the breaking of the exact conformal invariance would be in question in the super-symplectic case. The representation would be defined by the generators for which conformal weights are odd multiples of n $(M_n = 2^n - 1)$ and L_{-kn} , k > 0 would generate zero norm states only in order $O(1/M_n)$.

Gaussian Mersennes are also special

If one allows also Gaussian primes then the notion of Mersenne prime generalizes: Gaussian Mersennes are of form $(1 \pm i)^n - 1$. In this case one could replace the scaling operations by scaling combined with a twist of $\pi/4$ around some symmetry axis: $1 + i = \sqrt{2}exp(i\pi/4)$ and generalized p-adic fractality would mean that for certain values of n the exponentiated operation consisting of n basic operations would be very near to unity.

- 1. The integers k associated with the lowest Gaussian Mersennes are following: 2,3,5,7,11, 19,29,47,73,79,113. k = 113 corresponds to the p-adic length scale associated with the atomic nucleus and muon. Thus all known charged leptons, rather than only e and τ , as well as nuclear physics length scale, correspond to Mersenne primes in the generalized sense.
- 2. The primes k = 151, 157, 163, 167 define perhaps the most fundamental biological length scales: k = 151 corresponds to the thickness of the cell membrane of about ten nanometers and k = 167 to cell size about 2.56 μm . This observation also suggests that cellular organisms have evolved to their present form through four basic evolutionary stages. This also encourages to think that $\sqrt{2}exp(i\pi/4)$ operation giving rise to logarithmic spirals abundant in living matter is fundamental dynamical symmetry in bio-matter.

Logarithmic spiral provides the simplest model for biological growth as a repetition of the basic operation $\sqrt{2}exp(i\pi/4)$. The naive interpretation would be that growth processes consist of k = 151, 157, 163, 167 steps involving scaling by $\sqrt{2}$. This however requires the strange looking assumption that growth starts from a structure of size of order CP_2 length. Perhaps this exotic growth process is associated with pair of MEs or magnetic flux tubes of opposite time orientation and energy emergenging CP_2 sized region in a mini big bang type process and that the resulting structure serves as a template for the biological growth.

3. k = 239, 241, 283, 353, 367, 379, 457 associated with the next Gaussian Mersennes define astronomical length scales. k = 239 and k = 241 correspond to the p-adic time scales .55 ms and 1.1 ms: basic time scales associated with nerve pulse transmission are in question. k = 283 corresponds to the time scale of 38.6 min. An interesting question is whether this period could define a fundamental biological rhythm. The length scale L(353) corresponds to about 2.6×10^6 light years, roughly the size scale of galaxies. The length scale $L(367) \simeq \times 3.3 \times 10^8$ light years is of same order of magnitude as the size scale of the large voids containing galaxies on their boundaries (note the analogy with cells). $T(379) \simeq 2.1 \times 10^{10}$ years corresponds to the lower bound for the order of the age of the Universe. $T(457) \sim 10^{22}$ years defines a completely superastronomical time and length scale.

17.3.6 Questions

The proposed picture leaves open several questions.

- 1. Could the descriptions by both real and p-adic thermodynamics be possible? Could they be equivalent (possibly in finite measurement resolution) as is suggested by NTU? The consistency of these descriptions would imply temperature quantization and p-adic length scale hypothesis not possible in purely real context.
- 2. What could the extension of conformal symmetry to supersymplectic symmetry mean? One possible view is that super-symplectic symmetries correspond to dark degrees of freedom and that only the super-symplectic ground states with negative conformal weights affect the p-adic thermodynamics, which applies only to fermionic degrees of freedom at string world sheets. Super-symplectic degrees of freedom would give the dominant contribution to hadron masses and could contribute also to weak gauge boson masses. N = 5 for the needed number

of tensor factors is however a strong constraint and perhaps most naturally obtained when also the super-symplectic Virasoro associated with the trivial zeros of zeta is thermalized.

- 3. What happens in dark sectors. Preferred extremal property is proposed to mean that the states are annihilated by super-symplectic sub-algebra isomorphic to the original algebra and its commutator with the entire algebra. The conjecture is that this gives rise to Kac-Moody algebras as dynamical symmetries maybe ADE type algebras, whose Dynkin diagrams characterize the inclusion of HFFs. Does this give an additional tensor factor to super-Virasoro algebra?
- 4. Superconformal symmetry true in the sense that Super Virasoro conditions hold true. Partition function however depends on mass squared only rather than the entire scaling generator L_0 as thought erratically in the first formulation of p-adic calculation. This does not mean breaking of conformal invariance. Super Virasoro conditions hold true although partition function is for the vibrational part of L_0 determining the mass squared spectrum.

17.4 p-Adicization and adelic physics

This section is devoted to the challenges related to p-adicization and adelization of physics in which the correspondence between real and p-adic numbers via canonical identification serves as the basic building brick. Also the problems associated with p-adic variants of integral, Fourier analysis, Hilbert space, and Riemann geometry should be solved in a way respecting fundamental symmetries and their p-adic variants must be met. The notion of number theoretical universality (NTU) plays a key role here. One should also answer to questions about the origin of preferred primes and p-adic length scale hypothesis.

17.4.1 Challenges

The basic challenges encountered are construction of the p-adic variants of real number based physics, understanding their relationship to real physics, and the fusion of various physics to single coherent whole.

The p-adicization of real physics is not just a straightforward formal generalization of scattering amplitudes of existing theories but requires a deeper understanding of the physics involved. The interpretation of p-adic physics as correlate for cognition and imagination is an important guideline and will be discussed l in more detail in separate section.

Definite integral and Fourier analysis are basic elements of standard physics and their generalization to the p-adic context defines a highly non-trivial challenge. Also the p-adic variants of Riemann geometry and Hilbert space are suggestive. There are however problems.

1. There are problems associated with p-adic definite integral. Riemann sum does not make sense since it approaches zero if the p-adic norm of discretization unit approaches zero. The problems are basically due to the absence of well-orderedness essential for the definition of definite integral and differential forms and their integrals.

Residue integration might make sense in finite angle resolution. For algebraic extension containing $e^{i\pi/n}$ the number theoretically universal approximation $i\pi = n(e^{i\pi/n} - 1)$ could be used. In twistor approach integrations reduce to multiple residue integrations and since twistor approach generalizes in TGD framework, this approach to integration is very attractive.

Positivity is a central notion in twistor Grassmannian approach [B12]. Since canonical identification maps p-adic numbers to non-negative real numbers, there is a strong temptation to think that positivity relates to NTU [L31].

2. There are problems with Fourier analysis. The naive generalization of trigonometric functions by replacing e^{ix} with its p-adic counterpart is not physical. Same applies to e^x . Algebraic extensions are needed to get roots of unity ad e as counterparts of the phases and discretization is necessary and has interpretation in terms of finite resolution for angle/phase and its hyperbolic counterpart. 3. The notion of Hilbert space is problematic. The naive generalization of Hilbert space norm square $|x|^2 = \sum x_n \overline{x}_n$ for state $(x_1, x_2, ...)$ can vanish p-adically. Also here NTU could help. State would contain as coefficients only roots of e and unity and only the overall factor could be p-adic number. Coefficients could be restricted to the algebraic numbers generating the algebraic extension of rational numbers and would not contain powers of p or even ordinary p-adic numbers expect in the overall normalization factor.

Second challenge relates to the relationship between real and p-adic physics. Canonical identification (CI) $\sum x_n p^n \to \sum x_n p^{-n}$ or some of its variants should play an important role. CI is expected to map the invariants appearing in scattering amplitudes to their real counterparts.

- 1. Real and p-adic variants of space-time surfaces should exist and relate to each other somehow. Is this relationship local and involve CI at space-time level or imbedding space level? Or is it only a global and non-local assignment of preferred real extremals to their p-adic counterparts? Or is between these extreme options and involves algebraic discretization of the space-time surface weakening the strong form of SH as already proposed? How do real and p-adic imbedding spaces relate to each other and can this relationship induce local correspondence between preferred extremals (PEs) [K14, K21, K19]?
- 2. NTU in some sense is a highly suggestive approach to these questions and would suggest that canonical identification applies to isometry invariants whereas angles and hyperbolic angles, or rather the corresponding "phases" belonging to an extension of p-adics containing roots of *e* and roots of unity are mapped to themselves. Note that the roots of *e* define extensions of rationals, which induce finite dimensional algebraic extensions of p-adic numbers. This would make possible to define imbedding space in accordance with NTU. Also the Hilbert space could be defined by requiring that its points correspond to number theoretically universal angles expressible in terms of roots of unity.
- 3. What about real and p-adic variants of WCW? Are they needed at all? Or could their existence be used as a powerful constraint on real physics? The representability of WCW as a union of infinite-dimensional symmetric spaces labelled by zero modes suggests that the same description applies at the level of WCW and imbedding space.

One cannot circumvent the question about how to generalize functional integral from real WCW to p-adic WCWs. In particular, what is the p-adic variant of the action defining the dynamics of space-time surfaces. In the case of exponent of action the p-adic variant could be defined by assuming algebraic universality: again the roots of e and of unity would be in central role. Also the Kähler structure of WCW implying that Gaussian and metric determinants cancel each other in functional integral, would be absolutely crucial.

One must remember that the exponents of action for scattering amplitudes for the stationary phase extremal cancel from the path integral representation of scattering amplitudes. Also now this mechanism would allow to get rid of the poorly defined exponent for single minimum. If there is sum over scattering amplitudes assignable to different maxima, normalization sould give ratios of these exponents for different extrema/maxima and only these ratios should belong to the extension of rationals.

The zero modes of WCW metric are invariants of supersymplectic group so that canonical identification could relate their real and p-adic variants. Zero modes could break NTU and would be behind p-adic thermodynamics and dependence of mass scale on p-adic prime.

The third challenge relates to the fusion of p-adic physics and real physics to a larger structure. Here a generalization of number concept obtained by glueing reals and various p-adics together along an extension of rational numbers inducing the extensions of p-adic numbers is highly suggestive. Adeles associated with the extension of rationals are highly attractive and closely related notion. Real and various p-adic physics would be correlates for sensory and cognitive aspects of the same universal physics rather than separate physics in this framework. One important implication of this view is that real entropy and p-adic negentropies characterize the same entanglement with coefficients in an extension of rationals.

NTU for hyperbolic and ordinary phases is definetely the central idea. How the invariance of angles under conformal transformations does relate to this? Could one perhaps define a discretized version of conformal symmetry preserving the phases defined by the angles between vectors assignable with the tangent spaces of discretized geometric structures and thus respecting NTU? Of should one apply conformal symmetry at Lie algebra level only?

17.4.2 NTU and the correspondence between real and p-adic physics

p-Adic real correspondence is certainly the basic problem of p-adicization and adelization. One can make several general questions about p-adic real correspondence and canonical identification inspired by p-adic mass calculations.

How generally p-adic real correspondence does apply? Could canonical identification for group invariants combined with direct identification of ordinary and hyperbolic phases identified as roots of unity and *e* apply at WCW and imbedding space level having maximally symmetric geometries? Could this make sense even at space-time level as a correspondence induced from imbedding space level [L46]? Does canonical identification apply locally for the discretizations of space-time surface or only globally for the parameters characterizing PEs (string world sheets and partonic 2-surfaces by SH), which are general coordinate invariant and Poincare invariant quantities?

The following vision seems to be the most feasible one found hitherto.

- 1. Preservation of symmetries and continuity compete. Lorenz transformations do not commute with canonical identification. This suggests that canonical identification applies only to Lorentz invariants formed from quantum numbers. This is enough in the case of scattering amplitudes. Canonical identification applies only to isometry invariants at the level of WCW and the phases/exponents of ordinary/hyperbolic angles correspond to numbers in the algebraic extension common to extensions of rationals and various p-adics.
- 2. Canonical identification applies at the level of momentum space and maps p-adic Lorentz invariants of scattering amplitudes to their real counterparts. Phases of angles and their hyperbolic counterparts should correspond to parameters defining extension and should be mapped as such to their p-adic counterparts.
- 3. The constraints coming from GCI and symmetries do not allow local correspondence but allow to consider its discretized version at space-time leve induced by the correspondence at the level of imbedding space.

This requires the restriction of isometries and other symmetries to algebraic subgroups defined by the extension of rationals. This would imply reduction of symmetry due to finite cognitive/measurement resolution and should be acceptable. If one wants to realize the ideas about imagination, discretization must be applied also for the space-time interior meaning partial breaking of SH and giving rise to dark matter degrees freedom in TGD sense. SH could apply in real sector for realizable imaginations only. Note that the number of algebraic points of space-time surface is expected to be relatively small.

The correspondence must be considered at the level of imbedding space, space-time, and WCW.

- 1. At the level of imbedding space p-adic–real correspondence is induced by points in extension of rationals and is totally discontinuous. This requires that space-time dimension is smaller than imbedding space dimension.
- 2. At space-time level the correspondence involves field equations derivable from a local variational principle make sense also p-adically although the action itself is ill-defined as 4-D integral. The notion of p-adic PE makes sense by strong form of holography applied to 2surfaces in the intersection. p-Adically however only the vanishing of Noether currents for a sub-algebra of the super-symplectic algebra might make sense. This condition is stronger than the vanishing of Noether charges defined by 3-D integrals.
- 3. Correspondence at the level of WCW can make sense and reduces to that for string world sheets and partonic 2-surfaces by SH. Real and p-adic 4-surfaces would be obtained by algebraic continuation as PEs from 2-surfaces by assuming that the space-time surface contains

subset of points of imbedding space belonging to the extension of rationals [L46]. p-Adic pseudo constants make p-adic continuation easy. Real continuation need not exist always. p-Adic WCW would be considerably larger than real WCW and make possible a predictive quantum theory of imagination and cognition.

What I have called intersection of realities and p-adicities can be identified as the set of 2-surfaces plus algebraic discretization of space-time interior. Also the values of induced spinor fields at the points of discretization must be given. The parameters characterizing the extremals (say coefficients of polynomials) - WCW coordinates - would be in extension of rationals inducing a finite-D extension of p-adic number fields.

The hierarchy of algebraic extensions induces an evolutionary hierarchy of adeles. The interpretation could be as a mathematical correlate for cosmic evolution realized at the level of the core of WCW defined by the intersection? 2-surfaces could be called space-time genes.

4. Also the p-adic variant Kähler action or at least the exponent of Kähler action defining vacuum functional should be obtainable by algebraic continuation. The weakest condition states that the ratios of action exponents for the maxima of Kähler function to the sum of action exponents for maxima belong to the extension. Without this condition the hopes of satisfying NTU seem rather meager.

17.4.3 NTU at space-time level

What about NTU at space-time level? NTU requires a correspondence between real and p-adic numbers and the details of this corresponds have been a long standing problem.

1. The recent view about the correspondence between real PEs to their p-adic counterparts does not demand discrete local correspondence assumed in the earlier proposal [K129]. The most abstract approach would give up the local correspondence at space-time level altogether, and restrict the preferred coordinates of WCW (having maximal group of isometries) to numbers in the extension of rationals considered. WCW would be discretized.

Intuitively a more realistic view is a correspondence at space-time level in the sense that real and p-adic space-time sheets intersect at points belonging to the extension of rationals and defining "cognitive representations". Only some p-adic space-time surfaces would have real counterpart.

- 2. The strongest form of NTU would require that the allowed points of imbedding space belonging an extension of rationals are mapped as such to corresponding extensions of p-adic number fields (no canonical identification). At imbedding space level this correspondence would be extremely discontinuous. The "spines" of space-time surfaces would however contain only a subset of points of extension, and a natural resolution length scale could emerge and prevent the fluctuation. This could be also seen as a reason for why space-times surfaces must be 4-D. The fact that the curve $x^n + y^n = z^n$ has no rational points for n > 2, raises the hope that the resolution scale could emerge spontaneously.
- 3. The notion of monadic geometry discussed in detail in [L46] would realize this idea. Define first a number theoretic discretization of imbedding space in terms of points, whose coordinates in group theoretically preferred coordinate system belong to the extension of rationals considered. One can say that these algebraic points are in the intersection of reality and various p-adicities. Overlapping open sets assigned with this discretization define in the real sector a covering by open sets. In p-adic sector compact-open-topology allows to assign with each point 8th Cartesian power of algebraic extension of p-adic numbers. These compact open sets define analogs for the monads of Leibniz and p-adic variants of field equations make sense inside them.

The monadic manifold structure of H is induced to space-time surfaces containing discrete subset of points in the algebraic discretization with field equations defining a continuation to space-time surface in given number field, and unique only in finite measurement resolution. This approach would resolve the tension between continuity and symmetries in p-adic–real correspondence: isometry groups would be replaced by their sub-groups with parameters in extension of rationals considered and acting in the intersection of reality and p-adicities.

The Galois group of extension acts non-trivially on the "spines" of space-time surfaces. Hence the number theoretical symmetries act as physical symmetries and define the orbit of given space-time surface as a kind of covering space. The coverings assigned to the hierarchy of Planck constants would naturally correspond to Galois coverings and dark matter would represent number theoretical physics.

This would give rise to a kind of algebraic hierarchy of adelic 4-surfaces identifiable as evolutionary hierarchy: the higher the dimension of the extension, the higher the evolutionary level.

17.4.4 NTU and WCW

p-Adic-real correspondence at the level of WCW

It has not been obvious whether one should perform p-adicization and adelization at the level of WCW. Minimalist could argue that scattering amplitudes are all we want and that their padicization and adelization by algebraic continuation can be tolerated only if it can give powerful enough constraints on the amplitudes.

- 1. The anti-commutations for fermionic oscillator operators are number theoretically universal. Supersymmetry suggests that also WCW bosonic degrees of freedom satisfy NTU. This could mean that the coordinates of p-adic WCW consist of super-symplectic invariants mappable by canonical identification to their real counterparts plus phases and their hyperbolic counterparts expressible as genuinely algebraic numbers common to all number fields. This kind of coordinates are naturally assignable to symmetric spaces [L46].
- 2. Kähler structure should be mapped from p-adic to real sector and vice versa. Vacuum functional identified as exponent of action should be NTU. Algebraic continuation defined by SH involves p-adic pseudo constants. All p-adic continuations by SH should correspond to the same value of exponent of action obtained by algebraic continuation from its real value. The degeneracy associated with p-adic pseudo-constants would be analogous to gauge invariance imagination in TGD inspired theory of consciousness.
- 3. Ist it possible have NTU for WCW functional integration? Or is it enough to realize NTU for scattering amplitudes only. What seems clear that functional integral must reduce to a discrete sum. Physical intuition suggests a sum over maxima of Kähler function forming a subset of PEs representing stationary points. One cannot even exclude the possibility that the set of PEs is discrete and that one can sum over all of them.

Restriction to maximum/stationary phase approximation gives rise to sum over exponents multiplied with Gaussian determinants. The determinant of Kähler metric however cancels the Gaussian determinants, and one obtains only a sum over the exponents of action.

The breaking of strong NTU could happen: consider only p-adic mass calculations. This breaking is however associated with the parts of quantum states assignable to the boundaries of CD, not with the vacuum functional.

NTU for functional integral

Number theoretical vision relies on NTU. In fermionic sector NTU is necessary: one cannot speak about real and p-adic fermions as separate entities and fermionic anti-commutation relations are indeed number theoretically universal.

What about NTU in case of functional integral? There are two opposite views.

1. One can define p-adic variants of field equations without difficulties if preferred extremals are minimal surface extremals of Kähler action so that coupling constants do not appear in the solutions. If the extremal property is determined solely by the analyticity properties as it is for various conjectures, it makes sense independent of number field. Therefore there would be no need to continue the functional integral to p-adic sectors. This in accordance with the philosophy that thought cannot be put in scale. This would be also the option favored by pragmatist.

2. Consciousness theorist might argue that also cognition and imagination allow quantum description. The supersymmetry NTU should apply also to functional integral over WCW (more precisely, its sector defined by CD) involved with the definition of scattering amplitudes.

1. Key observations

The general vision involves some crucial observations.

- 1. Only the expressions for the scatterings amplitudes should should satisfy NTU. This does not require that the functional integral satisfies NTU.
- 2. Since the Gaussian and metric determinants cancel in WCW Kähler metric the contributions form maxima are proportional to action exponentials $exp(S_k)$ divided by the $\sum_k exp(S_k)$. Loops vanish by quantum criticality.
- 3. Scattering amplitudes can be defined as sums over the contributions from the maxima, which would have also stationary phase by the double extremal property made possible by the complex value of α_K . These contributions are normalized by the vacuum amplitude.

It is enough to require NTU for $X_i = exp(S_i) / \sum_k exp(S_k)$. This requires that $S_k - S_l$ has form $q_1 + q_2i\pi + q_3log(n)$. The condition brings in mind homology theory without boundary operation defined by the difference $S_k - S_l$. NTU for both S_k and $exp(S_k)$ would only values of general form $S_k = q_1 + q_2i\pi + q_3log(n)$ for S_k and this looks quite too strong a condition.

4. If it is possible to express the 4-D exponentials as single 2-D exponential associated with union of string world sheets, vacuum functional disappears completely from consideration! There is only a sum over discretization with the same effective action and one obtains purely combinatorial expression.

2. What does one mean with functional integral?

The definition of functional integral in WCW is one of the key technical problems of quantum TGD [K126]. NTU states that the integral should be defined simultaneously in all number fields in the intersection of real and p-adic worlds defined by string world sheets and partonic 2-surfaces with WCW coordinates in algebraic extension of rationals and allowing by strong holography continuation to 4-D space-time surface. NTU is powerful constraint and could help in this respect.

1. Path integral is not in question. Rather, the functional integral is analogous to Wiener integral and perhaps allows identification as a genuine integral in the real sector. In p-adic sectors algebraic continuation should give the integral and here number theoretical universality gives excellent hopes. The integral would have exactly the same form in real and p-adic sector and expressible solely in terms of algebraic numbers characterizing algebraic extension and finite roots of e and roots of unity $U_n = exp(i2\pi/n)$ in algebraic extension of p-adic numbers.

Since vacuum functional exp(S) is exponential of complex action S, the natural idea is that only rational powers e^q and roots of unity and phases $exp(i2\pi q)$ are involved and there is no dependence on p-adic prime p! This is true in the integer part of q is smaller than p so that one does not obtain e^{kp} , which is ordinary p-adic number and would spoil the number theoretic universality. This condition is not possible to satisfy for all values of p unless the value of Kähler function is smaller than 2. One might consider the possibility that the allow primes are above some minimum value.

The minimal solution to NTU conditions is that the ratios of action exponentials for maxima of Kähler function to the sum of these exponentials belong to the extension of rationals considered.

2. What does one mean with functional integral? TGD is expected to be an integrable in some sense. In integrable QFTs functional integral reduces to a sum over stationary points of the action: typically only single point contributes - at least in good approximation.

For real α_K and Λ vacuum functional decomposes to a product of exponents of real contribution from Euclidian regions ($\sqrt{g_4}$ real) and imaginary contribution Minkowskian regions ($\sqrt{g_4}$ imaginary). There would be no exchange of momentum between Minkowskian and Euclidian regions. For complex values of α_K [K49] situation changes and Kähler function as real part of action receives contributions from both Euclidian and Minkowskian regions. The imaginary part of action has interpretation as analog of Morse function and action as it appears in QFTs. Now saddle points must be considered.

PEs satisfy extremely strong conditions [K14, K19]. All classical Noether charges for a sub-algebra associated with super-symplectic algebra and isomorphic to the algebra itself vanish at both ends of CD. The conformal weights of this algebra are n > 0-ples of those for the entire algebra. What is fascinating that the condition that the preferred extremals are minimal surface extremals of Kähler action could solve these conditions and guarantee also NTU at the level of space-time surfaces. Supersymplectic boundary conditions at the ends of CD would however pose number theoretic conditions on the coupling parameters. In p-adic case the conditions should reduce to purely local conditions since p-adic charges are not well-defined as integrals.

3. In TGD framework one is constructing zero energy states rather calculating the matrix elements of S-matrix in terms of path integral. This gives certain liberties but a natural expectation is that functional integral as a formal tool at least is involved.

Could one *define* the functional integral as a discrete sum of contributions of standard form for the preferred extremals, which correspond to maxima in Euclidian regions and associated stationary phase points in Minkowskian regions? Could one assume that WCW spinor field is concentrated along single maximum/stationary point.

Quantum classical correspondence suggests that in Cartan algebra isometry charges are equal to the quantal charges for quantum states expressible in number theoretically universal manner in terms of fermionic oscillator operators or WCW gamma matrices? Even stronger condition would be that classical correlation functions are identical with quantal ones for allowed space-time surfaces in the quantum superposition. Could the reduction to a discrete sum be interpreted in terms of a finite measurement resolution?

4. In QFT Gaussian determinants produce problems because they are often poorly defined. In the recent case they could also spoil the NTU based on the exceptional properties of *e*. In the recent case however Gaussian determinant and metric determinant for Kähler metric cancel each other and this problem disappears. One could obtain just a sum over products of roots of *e* and roots of unity. Thus also Kähler structure seems to be crucial for the dream about NTU.

17.4.5 Breaking of NTU at the level of scattering amplitudes

NTU in strong sense could be broken at the level of scattering amplitudes. At space-time level the breaking does not look natural in the recent framework. Consider only p-adic mass calculations predicting that mass scale depends on p-adic prime. Also for the action strong form of NTU might fail for small p-adic primes since the value of the real part of action would be larger than than p. Should one allow this? What does one actually mean with NTU in the case of action?

Canonical identification is an important element of p-adic mass calculations and might also be needed to map p-adic variants of scattering amplitudes to their real counterparts. The breaking of NTU would take place, when the canonical real valued image of the p-adic scattering amplitude differs from the real scattering amplitude. The interpretation would be in terms of finite measurement resolution. By the finite measurement/cognitive resolution characterized by p one cannot detect the difference.

The simplest form of the canonical identification is $x = \sum_n x_n p^n \to \sum x_n p^{-n}$. Product xy and sum x + y do not in general map to product and sum in canonical identification. The

interpretation would be in terms of a finite measurement resolution: $(xy)_R = x_R y_R$ and $(x+y)_R = x_R + y_R$ only modulo finite measurement resolution. p-Adic scattering amplitudes are obtained by algebraic continuation from the intersection by replacing algebraic number valued parameters (such as momenta) by general p-adic numbers. The real images of these amplitudes under canonical identification are in general not identical with real scattering amplitudes the interpretation being in terms of a finite measurement resolution.

In p-adic thermodynamics NTU in the strong sense fails since thermal masses depend on p-adic mass scale. NTU can be broken by the fermionic matrix elements in the functional integral so that the real scattering amplitudes differ from the canonical images of the p-adic scattering amplitudes. For instance, the elementary particle vacuum functionals in the space of Teichmueller parameters for the partonic 2-surfaces and string world sheets should break NTU [K33].

17.4.6 NTU and the spectrum of Kähler coupling strength

During years I have made several attempts to understand coupling evolution in TGD framework. The most convincing proposal has emerged rather recently and relates the spectrum of $1/\alpha_K$ to that for the zeros of Riemann zeta [K49] and to the evolution of the electroweak U(1) couplings strength.

1. The first idea dates back to the discovery of WCW Kähler geometry defined by Kähler function defined by Kähler action (this happened around 1990) [K64]. The only free parameter of the theory is Kähler coupling strength α_K analogous to temperature parameter α_K postulated to be is analogous to critical temperature. Whether only single value or entire spectrum of of values α_K is possible, remained an open question.

About decade ago I realized that Kähler action is *complex* receiving a real contribution from space-time regions of Euclidian signature of metric and imaginary contribution from the Minkoswkian regions. Euclidian region would give Kähler function and Minkowskian regions analog of QFT action of path integral approach defining also Morse function. Zero energy ontology (ZEO) [K130] led to the interpretation of quantum TGD as complex square root of thermodynamics so that the vacuum functional as exponent of Kähler action could be identified as a complex square root of the ordinary partition function. Kähler function would correspond to the real contribution Kähler action from Euclidian space-time regions. This led to ask whether also Kähler coupling strength might be complex: in analogy with the complexification of gauge coupling strength in theories allowing magnetic monopoles. Complex α_K could allow to explain CP breaking. I proposed that instanton term also reducing to Chern-Simons term could be behind CP breaking.

The problem is that the dynamics in Minkowskian and Euclidian regions decouple completely and if Euclidian regions serve as space-time correlates for physical objects, there would be no exchanges of classical charges between physical objects. Should one conclude that α_K must be complex?

- 2. p-Adic mass calculations for 2 decades ago [K68] inspired the idea that length scale evolution is discretized so that the real version of p-adic coupling constant would have discrete set of values labelled by p-adic primes. The simple working hypothesis was that Kähler coupling strength is renormalization group (RG) invariant and only the weak and color coupling strengths depend on the p-adic length scale. The alternative ad hoc hypothesis considered was that gravitational constant is RG invariant. I made several number theoretically motivated ad hoc guesses about coupling constant evolution, in particular a guess for the formula for gravitational coupling in terms of Kähler coupling strength, action for CP_2 type vacuum extremal, p-adic length scale as dimensional quantity. Needless to say these attempts were premature and a hoc.
- 3. The vision about hierarchy of Planck constants $h_{eff} = n \times h$ and the connection $h_{eff} = h_{gr} = GMm/v_0$, where $v_0 < c = 1$ has dimensions of velocity [?] forced to consider very seriously the hypothesis that Kähler coupling strength has a spectrum of values in one-one correspondence with p-adic length scales. A separate coupling constant evolution associated with h_{eff} induced by $\alpha_K \propto 1/\hbar_{eff} \propto 1/n$ looks natural and was motivated by the idea that

Nature is theoretician friendly: when the situation becomes non-perturbative, Mother Nature comes in rescue and an h_{eff} increasing phase transition makes the situation perturbative again.

Quite recently the number theoretic interpretation of coupling constant evolution [K126] [L28] in terms of a hierarchy of algebraic extensions of rational numbers inducing those of p-adic number fields encouraged to think that $1/\alpha_K$ has spectrum labelled by primes and values of h_{eff} . Two coupling constant evolutions suggest themselves: they could be assigned to length scales and angles which are in p-adic sectors necessarily discretized and describable using only algebraic extensions involve roots of unity replacing angles with discrete phases.

- 4. Few years ago the relationship of TGD and GRT was finally understood [K121]. GRT spacetime is obtained as an approximation as the sheets of the many-sheeted space-time of TGD are replaced with single region of space-time. The gravitational and gauge potential of sheets add together so that linear superposition corresponds to set theoretic union geometrically. This forced to consider the possibility that gauge coupling evolution takes place only at the level of the QFT approximation and α_K has only single value. This is nice but if true, one does not have much to say about the evolution of gauge coupling strengths.
- 5. The analogy of Riemann zeta function with the partition function of complex square root of thermodynamics suggests that the zeros of zeta have interpretation as inverses of complex temperatures $s = 1/\beta$. Also $1/\alpha_K$ is analogous to temperature. This led to a radical idea to be discussed in detail in the sequel.

Could the spectrum of $1/\alpha_K$ reduce to that for the zeros of Riemann zeta or - more plausibly - to the spectrum of poles of fermionic zeta $\zeta_F(ks) = \zeta(ks)/\zeta(2ks)$ giving for k = 1/2 poles as zeros of zeta and as point s = 2? ζ_F is motivated by the fact that fermions are the only fundamental particles in TGD and by the fact that poles of the partition function are naturally associated with quantum criticality whereas the vanishing of ζ and varying sign allow no natural physical interpretation.

The poles of $\zeta_F(s/2)$ define the spectrum of $1/\alpha_K$ and correspond to zeros of $\zeta(s)$ and to the pole of $\zeta(s/2)$ at s = 2. The trivial poles for s = 2n, n = 1, 2, ... correspond naturally to the values of $1/\alpha_K$ for different values of $h_{eff} = n \times h$ with n even integer. Complex poles would correspond to ordinary QFT coupling constant evolution. The zeros of zeta in increasing order would correspond to p-adic primes in increasing order and UV limit to smallest value of poles at critical line. One can distinguish the pole s = 2 as extreme UV limit at which QFT approximation fails totally. CP_2 length scale indeed corresponds to GUT scale.

6. One can test this hypothesis. $1/\alpha_K$ corresponds to the electroweak U(1) coupling strength so that the identification $1/\alpha_K = 1/\alpha_{U(1)}$ makes sense. One also knows a lot about the evolutions of $1/\alpha_{U(1)}$ and of electromagnetic coupling strength $1/\alpha_{em} = 1/[\cos^2(\theta_W)\alpha_{U(1)}]$. What does this predict?

It turns out that at p-adic length scale k = 131 ($p \simeq 2^k$ by p-adic length scale hypothesis, which now can be understood number theoretically [K126]) fine structure constant is predicted with .7 per cent accuracy if Weinberg angle is assumed to have its value at atomic scale! It is difficult to believe that this could be a mere accident because also the prediction evolution of $\alpha_{U(1)}$ is correct qualitatively. Note however that for k = 127 labelling electron one can reproduce fine structure constant with Weinberg angle deviating about 10 per cent from the measured value of Weinberg angle. Both models will be considered.

7. What about the evolution of weak, color and gravitational coupling strengths? Quantum criticality suggests that the evolution of these couplings strengths is universal and independent of the details of the dynamics. Since one must be able to compare various evolutions and combine them together, the only possibility seems to be that the spectra of gauge coupling strengths are given by the poles of $\zeta_F(w)$ but with argument w = w(s) obtained by a global conformal transformation of upper half plane - that is Möbius transformation (see http://tinyurl.com/gwjs85b) with real coefficients (element of GL(2, R)) so that one as $\zeta_F((as + b)/(cs + d))$. Rather general arguments force it to be and element of GL(2, Q), GL(2, Z) or maybe even SL(2, Z) (ad - bc = 1) satisfying additional constraints. Since TGD

predicts several scaled variants of weak and color interactions, these copies could be perhaps parameterized by some elements of SL(2, Z) and by a scaling factor K.

Could one understand the general qualitative features of color and weak coupling contant evolutions from the properties of corresponding Möbius transformation? At the critical line there can be no poles or zeros but could asymptotic freedom be assigned with a pole of cs + dand color confinement with the zero of as + b at real axes? Pole makes sense only if Kähler action for the preferred extremal vanishes. Vanishing can occur and does so for massless extremals characterizing conformally invariant phase. For zero of as + b vacuum function would be equal to one unless Kähler action is allowed to be infinite: does this make sense?. One can however hope that the values of parameters allow to distinguish between weak and color interactions. It is certainly possible to get an idea about the values of the parameters of the transformation and one ends up with a general model predicting the entire electroweak coupling constant evolution successfully.

To sum up, the big idea is the identification of the spectra of coupling constant strengths as poles of $\zeta_F((as + b/)(cs + d))$ identified as a complex square root of partition function with motivation coming from ZEO, quantum criticality, and super-conformal symmetry; the discretization of the RG flow made possible by the p-adic length scale hypothesis $p \simeq k^k$, k prime; and the assignment of complex zeros of ζ with p-adic primes in increasing order. These assumptions reduce the coupling constant evolution to four real rational or integer valued parameters (a, b, c, d). In the sequel this vision is discussed in more detail.

17.4.7 Other applications of NTU

NTU in the strongest form says that all numbers involved at "basic level" (whatever this means!) of adelic TGD are products of roots of unity and of power of a root of *e*. This is extremely powerful physics inspired conjecture with a wide range of possible mathematical applications.

- 1. For instance, vacuum functional defined as an exponent of action for preferred externals would be number of this kind. One could define functional integral as adelic operation in all number fields: essentially as sum of exponents of action for stationary preferred extremals since Gaussian and metric determinants potentially spoiling NTU would cancel each other leaving only the exponent.
- 2. The implications of NTU for the zeros of Riemann zeta [L28] will be discussed in more detail in the Appendix. Suffice it to say that the observations about Fourier transform for the distribution of loci of non-trivial zeros of zeta together with NTU leads to explicit proposal for the algebraic for of zeros of zeta. The testable proposal is that zeros decompose to disjoint classes C(p) labelled by primes p and the condition that p^{iy} is root of unity in given class C(p).
- 3. NTU generalises to all Lie groups. Exponents $exp(in_i J_i/n)$ of lie-algebra generators define generalisations of number theoretically universal group elements and generate a discrete subgroup of compact Lie group. Also hyperbolic "phases" based on the roots $e^{m/n}$ are possible and make possible discretized NTU versions of all Lie-groups expected to play a key role in adelization of TGD.

NTU generalises also to quaternions and octonions and allows to define them as number theoretically universal entities. Note that ordinary p-adic variants of quaternions and octonions do not give rise to a number field: inverse of quaternion can have vanishing p-adic variant of norm squared satisfying $\sum_n x_n^2 = 0$.

NTU allows to define also the notion of Hilbert space as an adelic notion. The exponents of angles characterising unit vector of Hilbert space would correspond to roots of unity.

17.4.8 Going to the roots of p-adicity

The basic questions raised by the p-adic mass calculations concern the origin of preferred p-adic primes and of p-adic length scale hypothesis. One can also ask whether there might be a natural origin for p-adicity at the level of WCW.

Preferred primes as ramified primes for extensions of rationals?

Preferred primes as ramified primes for extensions of rationals?

The intuitive feeling is that the notion of preferred prime is something extremely deep and to me the deepest thing I know is number theory. Does one end up with preferred primes in number theory? This question brought to my mind the notion of *ramification of primes* (http://tinyurl.com/hddljlf) (more precisely, of prime ideals of number field in its extension), which happens only for special primes in a given extension of number field, say rationals. Ramification is completely analogous to the degeneracy of some roots of polynomial and corresponds to criticality if the polynomial corresponds to criticality (catastrophe theory of Thom is one application). Could this be the mechanism assigning preferred prime(s) to a given elementary system, such as elementary particle? I have not considered their role earlier also their hierarchy is highly relevant in the number theoretical vision about TGD.

1. Stating it very roughly (I hope that mathematicians tolerate this sloppy language of physicist): as one goes from number field K, say rationals Q, to its algebraic extension L, the original prime ideals in the so called *integral closure* (http://tinyurl.com/js6fpvr) over integers of K decompose to products of prime ideals of L (prime ideal is a more rigorous manner to express primeness). Note that the general ideal is analog of integer.

Integral closure for integers of number field K is defined as the set of elements of K, which are roots of some monic polynomial with coefficients, which are integers of K having the form $x^n + a_{n-1}x^{n-1} + \ldots + a_0$. The integral closures of both K and L are considered. For instance, integral closure of algebraic extension of K over K is the extension itself. The integral closure of complex numbers over ordinary integers is the set of algebraic numbers.

Prime ideals of K can be decomposed to products of prime ideals of L: $P = \prod P_i^{e_i}$, where e_i is the ramification index. If $e_i > 1$ is true for some i, ramification occurs. P_i :s in question are like co-inciding roots of polynomial, which for in thermodynamics and Thom's catastrophe theory corresponds to criticality. Ramification could therefore be a natural aspect of quantum criticality and ramified primes P are good candidates for preferred primes for a given extension of rationals. Note that the ramification make sense also for extensions of given extension of rationals.

- 2. A physical analogy for the decomposition of ideals to ideals of extension is provided by decomposition of hadrons to valence quarks. Elementary particles becomes composite of more elementary particles in the extension. The decomposition to these more elementary primes is of form $P = \prod P_i^{e(i)}$, the physical analog would be the number of elementary particles of type *i* in the state (http://tinyurl.com/h9528pl). Unramified prime *P* would be analogous a state with *e* fermions. Maximally ramified prime would be analogous to Bose-Einstein condensate of *e* bosons. General ramified prime would be analogous to an *e*-particle state containing both fermions and condensed bosons. This is of course just a formal analogy.
- 3. There are two further basic notions related to ramification and characterizing it. Relative discriminant is the ideal divided by all ramified ideals in K (integer of K having no ramified prime factors) and relative different for P is the ideal of L divided by all ramified P_i :s (product of prime factors of P in L). These ideals represent the analogs of product of preferred primes P of K and primes P_i of L dividing them. These two integers ideals would characterize the ramification.

In TGD framework the extensions of rationals (http://tinyurl.com/h9528pl) and p-adic number fields (http://tinyurl.com/zq22tvb) are unavoidable and interpreted as an evolutionary hierarchy physically and cosmological evolution would gradually proceed to more and more complex extensions. One can say that string world sheets and partonic 2-surfaces with parameters of defining functions in increasingly complex extensions of prime emerge during evolution. Therefore ramifications and the preferred primes defined by them are unavoidable. For p-adic number fields the number of extensions is much smaller for instance for p > 2 there are only 3 quadratic extensions.

How could ramification relate to p-adic and adelic physics and could it explain preferred primes?
- 1. Ramified p-adic prime $P = P_i^e$ would be replaced with its e:th root P_i in p-adicization. Same would apply to general ramified primes. Each un-ramified prime of K is replaced with e = K : L primes of L and ramified primes P with $\#\{P_i\} < e$ primes of L: the increase of algebraic dimension is smaller. An interesting question relates to p-adic length scale. What happens to p-adic length scales. Is p-adic prime effectively replaced with e:th root of p-adic prime: $L_p \propto p^{1/2}L_1 \rightarrow p^{1/2e}L_1$? The only physical option is that the p-adic temperature for P would be scaled down $T_p = 1/n \rightarrow 1/ne$ for its e:th root (for fermions serving as fundamental particles in TGD one actually has $T_p = 1$). Could the lower temperature state be more stable and select the preferred primes as maximimally ramified ones? What about general ramified primes?
- 2. This need not be the whole story. Some algebraic extensions would be more favored than others and p-adic view about realizable imaginations could be involved. p-Adic pseudo constants are expected to allow p-adic continuations of string world sheets and partonic 2-surfaces to 4-D preferred extremals with number theoretic discretization. For real continuations the situation is more difficult. For preferred extensions and therefore for corresponding ramified primes the number of real continuations realizable imaginations would be especially large.

The challenge would be to understand why primes near powers of 2 and possibly also of other small primes would be favored. Why for them the number of realizable imaginations would be especially large so that they would be winners in number theoretical fight for survival?

Can one make this picture more concrete? What kind of algebraic extensions could be considered?

- 1. In p-adic context a proper definition of counterparts of angle variables as phases allowing definition of the analogs of trigonometric functions requires the introduction of algebraic extension giving rise to some roots of unity. Their number depends on the angular resolution. These roots allow to define the counterparts of ordinary trigonometric functions the naive generalization based on Taylors series is not periodic and also allows to defined the counterpart of definite integral in these degrees of freedom as discrete Fourier analysis. For the simplest algebraic extensions defined by $x^n 1$ for which Galois group is abelian are are unramified so that something else is needed. One has decomposition $P = \prod P_i^{e(i)}$, e(i) = 1, analogous to *n*-fermion state so that simplest cyclic extension does not give rise to a ramification and there are no preferred primes.
- 2. What kind of polynomials could define preferred algebraic extensions of rationals? Irreducible polynomials are certainly an attractive candidate since any polynomial reduces to a product of them. One can say that they define the elementary particles of number theory. Irreducible polynomials have integer coefficients having the property that they do not decompose to products of polynomials with rational coefficients. It would be wrong to say that only these algebraic extensions can appear but there is a temptation to say that one can reduce the study of extensions to their study. One can even consider the possibility that string world sheets associated with products of irreducible polynomials are unstable against decay to those characterize irreducible polynomials.
- 3. What can one say about irreducible polynomials? Eisenstein criterion (http://tinyurl. com/47kxjz states following. If $Q(x) = \sum_{k=0,..,n} a_k x^k$ is n:th order polynomial with integer coefficients and with the property that there exists at least one prime dividing all coefficients a_i except a_n and that p^2 does not divide a_0 , then Q is irreducible. Thus one can assign one or more preferred primes to the algebraic extension defined by an irreducible polynomial Q of this kind in fact any polynomial allowing ramification. There are also other kinds of irreducible polynomials since Eisenstein's condition is only sufficient but not necessary.

Furthermore, in the algebraic extension defined by Q, the prime ideals P having the above mentioned characteristic property decompose to an *n*:th power of single prime ideal P_i : $P = P_i^n$. The primes are maximally/completely ramified.

A good illustration is provided by equations $x^2 + 1 = 0$ allowing roots $x_{\pm} = \pm i$ and equation $x^2 + 2px + p = 0$ allowing roots $x_{\pm} = -p \pm \sqrt{p}p - 1$. In the first case the ideals associated with

 $\pm i$ are different. In the second case these ideals are one and the same since $x_{+} == -x_{-} + p$: hence one indeed has ramification. Note that the first example represents also an example of irreducible polynomial, which does not satisfy Eisenstein criterion. In more general case the n conditions on defined by symmetric functions of roots imply that the ideals are one and same when Eisenstein conditions are satisfied.

4. What is so nice that one could readily construct polynomials giving rise to given preferred primes. The complex roots of these polymials could correspond to the points of partonic 2-surfaces carrying fermions and defining the ends of boundaries of string world sheet. It must be however emphasized that the form of the polynomial depends on the choices of the complex coordinate. For instance, the shift $x \to x + 1$ transforms $(x^n - 1)/(x - 1)$ to a polynomial satisfying the Eisenstein criterion. One should be able to fix allowed coordinate changes in such a manner that the extension remains irreducible for all allowed coordinate changes.

Already the integral shift of the complex coordinate affects the situation. It would seem that only the action of the allowed coordinate changes must reduce to the action of Galois group permuting the roots of polynomials. A natural assumption is that the complex coordinate corresponds to a complex coordinate transforming linearly under subgroup of isometries of the imbedding space.

In the general situation one has $P = \prod P_i^{e(i)}$, $e(i) \ge 1$ so that alo now there are preferred primes so that the appearance of preferred primes is completely general phenomenon.

The origin of p-adic length scale hypothesis?

p-Adic length scale hypothesis emerged from p-adic length scale hypothesis. A possible generalization of this hypothesis is that p-adic primes near powers of prime are physically favored. There indeed exists evidence for the realization of 3-adic time scale hierarchies in living matter [I128] (http://tinyurl.com/jbh9m27) and in music both 2-adicity and 3-adicity could be present: this is discussed in TGD inspired theory of music harmony and genetic code [K91]. See also [L50, L38].

One explanation would be that for preferred primes the number of p-adic space-time sheets representable also as real space-time sheets is maximal. Imagined worlds would be maximally realizable. Preferred p-adic primes would correspond to ramified primes for extensions with the property that the number of realizable imaginations is especially large for them. Why primes satisfying p-adic length scale hypothesis or its generalization would appear as ramified primes for extensions, which are winners in number theoretical evolution?

Also the weak form of NMP (WNMP) applying also to the purely number theoretic form of NMP [K73] might come in rescue here.

- 1. Entanglement negentropy for a NE [K73] characterized by n-dimensional projection operator is the $log(N_p(n))$ for some p whose power divides n. The maximum negentropy is obtained if the power of p is the largest power of prime divisor of p, and this can be taken as definition of number theoretical entanglement negentropy (NEN). If the largest divisor is p^k , one has $N = k \times log(p)$. The entanglement negentropy per entangled state is N/n = klog(p)/n and is maximal for $n = p^k$. Hence powers of prime are favoured, which means that p-adic length scale hierarchies with scales coming as powers of p are negentropically favored and should be generated by NMP. Note that $n = p^k$ would define a hierarchy of $h_{eff}/h = p^k$. During the first years of h_{eff} hypothesis I believe that the preferred values obey $h_{eff} = r^k$, r integer not far from $r = 2^{11}$. It seems that this belief was not totally wrong.
- 2. If one accepts this argument, the remaining challenge is to explain why primes near powers of two (or more generally p) are favoured. $n = 2^k$ gives large entanglement negentropy for the final state. Why primes $p = n_2 = 2^k r$ would be favored? The reason could be following. $n = 2^k$ corresponds to p = 2, which corresponds to the lowest level in p-adic evolution since it is the simplest p-adic topology and farthest from the real topology and therefore gives the poorest cognitive representation of real PE as p-adic PE (Note that p = 1 makes formally sense but for it the topology is discrete).

- 3. WNMP [K73, K123] suggests a more feasible explanation. The density matrix of the state to be reduced is a direct sum over contributions proportional to projection operators. Suppose that the projection operator with largest dimension has dimension n. Strong form of NMP would say that final state is characterized by n-dimensional projection operator. WNMP allows "free will" so that all dimensions n - k, k = 0, 1, ..., n - 1 for final state projection operator are possible. 1-dimensional case corresponds to vanishing entanglement negentropy and ordinary state function reduction isolating the measured system from external world.
- 4. The negentropy of the final state per state depends on the value of k. It is maximal if n-k is power of prime. For $n = 2^k = M_k + 1$, where M_k is Mersenne prime n-1 gives the maximum negentropy and also maximal p-adic prime available so that this reduction is favoured by NMP. Mersenne primes would be indeed special. Also the primes $n = 2^k r$ near 2^k produce large entanglement negentropy and would be favored by NMP.
- 5. This argument suggests a generalization of p-adic length scale hypothesis so that p = 2 can be replaced by any prime.

17.5 p-Adic physics and consciousness

p-Adic physics as physics of cognition and imagination is an important thread in TGD inspired theory of consciousness. In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of $n = h_{eff}/h$ if identified as a factor of the dimension of Galois group extension of rationals defining the adeles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

17.5.1 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

- 1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant "small" state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.
- 2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The

sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

One can identify several rather abstract state function reductions selecting a sector of WCW.

- 1. There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in M^4 strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.
- 2. Also a localization to an extension of rationals defining the adeles should occur. Could the value of $n = h_{eff}/h$ be observable? The value of n for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of n at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixe value of n at passive boundary.

The measured value of n could be larger or smaller than the value of n at the passive boundary of CD but in statistical sense n would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

3. A further abstract choice corresponds to the the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and reincarnation as time-reversed self.

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

1. Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of n: this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of CP_2) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

2. Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of n) takes place for a fixed CD - a kind of self measurement possible

for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome would not be an eigenstate of density matrix. An interpretation as a realization of intention would be approriate.

- 3. If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.
- 4. Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.
- 5. If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences "big" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action and "small" measurement - measurement at space-time level - reaction.

Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long at it evolves.

Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. What stability could mean will be discussed in the next section. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

- 1. Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.
- 2. By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J40] could be understood as a sharing of mental images between brain hemispheres, which are not themselves entangled.

3. At the level of 8-dimensional imbedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime M_{127}), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

17.5.2 NMP and self

The view about Negentropy Maximization Principle (NMP) [K73] has co-evolved with the notion of self and I have considered many variants of NMP.

- 1. The original formulation of NMP was in positive energy ontology and made same predictions as standard quantum measurement theory. The new element was that the density matrix of sub-system defines the fundamental observable and the system goes to its eigenstate in state function reduction. As found, the localizations at to WCW sectors define what might be called self-measurements and identifiable as active volitions rather than reactions.
- 2. In p-adic physics one can assign with rational and even algebraic entanglement probabilities number theoretical entanglement negentropy (NEN) satisfying the same basic axioms as the ordinary Shannon entropy but having negative values and therefore having interpretation as information. The definition of p-adic negentropy (real valued) reads as $S_p = -\sum P_k log(|P_k|_p)$, where $|.|_p$ denotes p-adic norm. The news is that $N_p = -S_p$ can be positive and is positive for rational entanglement probabilities. Real entanglement entropy S is always non-negative.

NMP would force the generation of negentropic entanglement (NE) and stabilize it. NNE resources of the Universe - one might call them Akashic records- would steadily increase.

3. A decisive step of progress was the realization is that NTU forces all states in adelic physics to have entanglement coefficients in some extension of rationals inducing finite-D extension of p-adic numbers. The same entanglement can be characterized by real entropy S and p-adic negentropies N_p , which can be positive. One can define also total p-adic negentropy: $N = \sum_p N_p$ for all p and total negentropy $N_{tot} = N - S$.

For rational entanglement probabilities it is easy to demonstrate that the generalization of adelic theorem holds true: $N_{tot} = N - S = 0$. NMP based on N_{tot} rather than N would not say anything about rational entanglement. For extensions of rationals it is easy to find that N - S > 0 is possible if entanglement probabilities are of form X_i/n with $|X_i|_p = 1$ and n integer [L42]. Should one identify the total negentropy as difference $N_{tot} = N - S$ or as $N_{tot} = N$?

Irrespective of answer, large p-adic negentropy seems to force large real entropy: this nicely correlates with the paradoxical finding that living systems tend to be entropic although one would expect just the oppositecite [L42]: this relates in very interesting manner to the work of biologists Jeremy England [I159]. The negentropy would be cognitive negentropy and not visible for ordinary physics.

4. The latest step in the evolution of ideas NMP was the question whether NMP follows from number theory alone just as second law follows form probability theory! This irritates theoretician's ego but is victory for theory. The dimension n of extension is positive integer and cannot but grow in statistical sense in evolution! Since one expects that the maximal value of negentropy (define as N-S) must increase with n. Negentropy must increase in long run.

Number theoretic entanglement can be stable

Number theoretical Shannon entropy can serve as a measure for genuine information assignable to a pair of entanglement systems [K73]. Entanglement with coefficients in the extension is always negentropic if entanglement negentropy comes from p-adic sectors only. It can be negentropic if negentropy is defined as the difference of p-adic negentropy and real entropy.

The diagonalized density matrix need not belong to the algebraic extension since the probabilities defining its diagonal elements are eigenvalues of the density matrix as roots of N:th order polynomial, which in the generic case requires n-dimensional algebraic extension of rationals. One can argue that since diagonalization is not possible, also state function reduction selecting one of the eigenstates is impossible unless a phase transition increasing the dimension of algebraic extension used occurs simultaneously. This kind of NE could give rise to cognitive entanglement.

There is also a special kind of NE, which can result if one requires that density matrix serves a universal observable in state function reduction. The outcome of reduction must be an eigen space of density matrix, which is projector to this subspace acting as identity matrix inside it. This kind NE allows all unitarily related basis as eigenstate basis (unitary transformations must belong to the algebraic extension). This kind of NE could serve as a correlate for "enlightened" states of consciousness. Schrödingers cat is in this kind of state stably in superposition of dead and alive and state basis obtained by unitary rotation from this basis is equally good. One can say that there are no discriminations in this state, and this is what is claimed about "enlightened" states too.

The vision about number theoretical evolution suggests that NMP forces the generation of NE resources as NE assignable to the "passive" boundary of CD for which no changes occur during sequence of state function reductions defining self. It would define the unchanging self as negentropy resources, which could be regarded as kind of Akashic records. During the next "re-incarnation" after the first reduction to opposite boundary of CD the NE associated with the reduced state would serve as new Akashic records for the time reversed self. If NMP reduces to the statistical increase of $h_{eff}/h = n$ the consciousness information contents of the Universe increases in statistical sense. In the best possible world of SNMP it would increase steadily.

Does NMP reduce to number theory?

The heretic question that emerged quite recently is whether NMP is actually needed at all! Is NMP a separate principle or could NMP reduced to mere number theory [K73]? Consider first the possibility that NMP is not needed at all as a separate principle.

- 1. The value of $h_{eff}/h = n$ should increase in the evolution by the phase transitions increasing the dimension of the extension of rationals. $h_{eff}/h = n$ has been identified as the number of sheets of some kind of covering space. The Galois group of extension acts on number theoretic discretizations of the monadic surface and the orbit defines a covering space. Suppose n is the number of sheets of this covering and thus the dimension of the Galois group for the extension of rationals or factor of it.
- 2. It has been already noticed that the "big" state function reductions giving rise to death and reincarnation of self could correspond to a measurement of $n = h_{eff}$ implied by the measurement of the extension of the rationals defining the adeles. The statistical increase of n follows automatically and implies statistical increase of maximal entanglement negentropy. Entanglement negentropy increases in statistical sense.

The resulting world would not be the best possible one unlike for a strong form of NMP demanding that negentropy does increases in "big" state function reductions. n also decrease temporarily and they seem to be needed. In TGD inspired model of bio-catalysis the phase transition reducing the value of n for the magnetic flux tubes connecting reacting bio-molecules allows them to find each other in the molecular soup. This would be crucial for understanding processes like DNA replication and transcription.

3. State function reduction corresponding to the measurement of density matrix could occur to an eigenstate/eigenspace of density matrix only if the corresponding eigenvalue and eigenstate/eigenspace is expressible using numbers in the extension of rationals defining the adele considered. In the generic case these numbers belong to N-dimensional extension of the original extension. This can make the entanglement stable with respect to state the measurements of density matrix. A phase transition to an extension of an extension containing these coefficients would be required to make possible reduction. A step in number theoretic evolution would occur. Also an entanglement of measured state pairs with those of measuring system in containing the extension of extension would make possible the reduction. Negentropy could be reduced but higher-D extension would provide potential for more negentropic entanglement and NMP would hold true in the statistical sense.

4. If one has higher-D eigen space of density matrix, p-adic negentropy is largest for the entire subspace and the sum of real and p-adic negentropies vanishes for all of them. For negentropy identified as total p-adic negentropy SNMP would select the entire sub-space and NMP would indeed say something explicit about negentropy.

Or is NMP needed as a separate principle?

Hitherto I have postulated NMP as a separate principle [K73]. Strong form of NMP (SNMP) states that Negentropy does not decrease in "big" state function reductions corresponding to death and re-incarnations of self.

One can however argue that SNMP is not realistic. SNMP would force the Universe to be the best possible one, and this does not seem to be the case. Also ethically responsible free will would be very restricted since self would be forced always to do the best deed that is increase maximally the negentropy serving as information resources of the Universe. Giving up separate NMP altogether would allow to have also "Good" and "Evil".

This forces to consider what I christened weak form of NMP (WNMP). Instead of maximal dimension corresponding to N-dimensional projector self can choose also lower-dimensional subspaces and 1-D sub-space corresponds to the vanishing entanglement and negentropy assumed in standard quantum measurement theory. As a matter fact, this can also lead to larger negentropy gain since negentropy depends strongly on what is the large power of p in the dimension of the resulting eigen sub-space of density matrix. This could apply also to the purely number theoretical reduction of NMP.

WNMP suggests how to understand the notions of Good and Evil. Various choices in the state function reduction would correspond to Boolean algebra, which suggests an interpretation in terms of what might be called emotional intelligence [K123]. Also it turns out that one can understand how p-adic length scale hypothesis - actually its generalization - emerges from WNMP [K126].

1. One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and external world. The dimension of the sub-space depends on which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad? Recall that WNMP allows only the possibility to generate NNE but does not force it. WNMP would be like God allowing the possibility to do good but not forcing good deeds.

Self can choose any sub-space of the subspace defined by $k \leq N$ -dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For k = 1 the state function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

For the maximal dimension of this sub-space the negentropy gain is maximal. This deed would be good and by the proposed criterion NE corresponds to conscious experience with positive emotional coloring. Interestingly, there are $2^k - 1$ possible choices, which is almost the dimension of Boolean algebra consisting of k independent bits. The excluded option corresponds to 0-dimensional sub-space - empty set in set theoretic realization of Boolean algebra. This could relate directly to fermionic oscillator operators defining basis of Boolean algebra - here Fock vacuum would be the excluded state. The deed in this sense would be a choice of how loving the attention towards system of external world is. 2. A map of different choices of k-dimensional sub-spaces to k-fermion states is suggestive. The realization of logic in terms of emotions of different degrees of positivity would be mapped to many-fermion states - perhaps zero energy states with vanishing total fermion number. State function reductions to k-dimensional spaces would be mapped to k-fermion states: quantum jumps to quantum states!

The problem brings in mind quantum classical correspondence in quantum measurement theory. The direction of the pointer of the measurement apparatus (in very metaphorical sense) corresponds to the outcome of state function reduction, which is now 1-D subspace. For ordinary measurement the pointer has k positions. Now it must have $2^k - 1$ positions. To the discrete space of k pointer positions one must assign fermionic Clifford algebra of second quantized fermionic oscillator operators. The hierarchy of Planck constants and dark matter suggests the realization. Replace the pointer with its space-time k-sheeted covering and consider zero energy energy states made of pairs of k-fermion states at the sheets of the n-sheeted covering? Dark matter would be therefore necessary for cognition. The role of fermions would be to "mark" the k space-time sheets in the covering.

The cautious conclusion is that NMP as a separate principle is not necessary and follows in statistical sense from the unavoidable increase of $n = h_{eff}/h$ identified as dimension of extension of rationals define the adeles if this extension or at least the dimension of its Galois group is observable.

17.5.3 p-Adic physics as correlate of cognition and imagination

The items in the following list give motivations for the proposal that p-adic physics could serve as a correlate for cognition and imagination.

- 1. By the total disconnectedness of the p-adic topology, p-adic world decomposes naturally into blobs, objects. This happens also in sensory perception. The pinary digits of p-adic number can be assigned to a *p*-tree. Parisi proposed in the model of spin glass [B18] that p-adic numbers could relate to the mathematical description of cognition and also Khrennikov [J2] has developed this idea. In TGD framework that idea is taken to space-time level: p-adic space-time sheets represent thought bubbles and they correlate with the real ones since they form cognitive reprentations of the real world. SH allows a concrete realization of this.
- 2. p-Adic non-determinism due to p-adic pseudo constants suggests interpretation in terms of imagination. Given 2-surfaces could allow completion to p-adic preferred extremal but not to a real one so that pure "non-realizable" imagination is in question.
- 3. Number theoretic negentropy has interpretation as negentropy characterizing information content of entanglement. The superposition of state pairs could be interpreted as a quantum representation for a rule or abstracted association containing its instances as state pairs. Number theoretical negentropy characterizes the relationship of two systems and should not be confused with thermodynamical entropy, which characterizes the uncertainty about the state of single system.

The original vision was that p-adic non-determinism could serve as a correlate for cognition, imagination, and intention. The recent view is much more cautious. Imagination need not completely reduce to p-adic non-determinism since it has also real physics correlates - maybe as partial realizations of SH as in nerve pulse pattern, which does not propagate down to muscles.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition, imagination, and perhaps even intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general could have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

The most feasible view is that the intersections of p-adic and real space-time surfaces define cognitive representations of real space-time surfaces (PEs, [K21, K14, K19]). One could also say

that real space-time surface represents sensory aspects of conscious experience and p-adic spacetime surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics.

The identification of p-adic pseudo constants as correlates of imagination at space-time level is indeed a further natural idea.

- 1. The construction of PEs by SH from the data at 2-surfaces is like boundary value problem with number theoretic discretization of space-time surface as additional data. PE property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2-surfaces completely independently in real context.
- 2. In p-adic sectors the integration constants are replaced with pseudo-constants depending on finite number of pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces. The fixing of the discretization of space-time surface would allow to fix the p-adic pseudo-constants. Once the number theoretic discretization of space-time surface is fixed, the p-adic pseudo-constants can be fixed. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets, partonic 2-surfaces, and number theoretic discretization but not allowed in real context.

Could these p-adic PEs correspond to imaginations, which in general are not realizable? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could one identify non-realistic imaginations as the modes of WCW spinor fields for which 2surfaces are not extendable to real space-time surfaces and are localized to 2-surfaces? Could they allow only a partial continuation to real space-time surface. Could nerve pulse pattern representing imagined motor action and not proceeding to the level of muscles correspond to a partially real PE?

Could imagination and problem solving be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real PEs? If so, p-adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2surfaces, which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

3. An interesting question is why elementary particles are characterized by preferred p-adic primes (primes near powers of 2, in particular Mersenne primes). Could the number of realizable imaginations for these primes be especially large?

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that SH derivable from - you can guess, SGCI (the Big E again!), plays an absolutely central role in it.

17.6 Appendix: Super-symplectic conformal weights and zeros of Riemann zeta

Since fermions are the only fundamental particles in TGD one could argue that the conformal weight of for the generating elements of supersymplectic algebra could be negatives for the poles of fermionic zeta ζ_F . This demands n > 0 as does also the fractal hierarchy of supersymplectic symmetry breakings. NTU of Riemann zeta in some sense is strongly suggested if adelic physics is to make sense.

For ordinary conformal algebras there are only finite number of generating elements ($-2 \le n \le 2$). If the radial conformal weights for the generators of g consist of poles of ζ_F , the situation changes. ζ_F is suggested by the observation that fermions are the only fundamental particles in TGD.

1. Riemann Zeta $\zeta(s) = \prod_p (1/(1-p^{-s}))$ identifiable formally as a partition function $\zeta_B(s)$ of arithmetic boson gas with bosons with energy log(p) and temperature 1/s = 1/(1/2 + iy) should be replaced with that of arithmetic fermionic gas given in the product representation by $\zeta_F(s) = \prod_p (1+p^{-s})$ so that the identity $\zeta_B(s)/\zeta_F(s) = \zeta_B(2s)$ follows. This gives

$$\frac{\zeta_B(s)}{\zeta_B(2s)}$$

 $\zeta_F(s)$ has zeros at zeros s_n of $\zeta(s)$ and at the pole s = 1/2 of zeta(2s). $\zeta_F(s)$ has poles at zeros $s_n/2$ of $\zeta(2s)$ and at pole s = 1 of $\zeta(s)$.

The spectrum of 1/T would be for the generators of algebra $\{(-1/2+iy)/2, n > 0, -1\}$. In padic thermodynamics the p-adic temperature is 1/T = 1/n and corresponds to "trivial" poles of ζ_F . Complex values of temperature does not make sense in ordinary thermodynamics. In ZEO quantum theory can be regarded as a square root of thermodynamics and complex temperature parameter makes sense.

2. If the spectrum of conformal weights of the generating elements of the algebra corresponds to poles serving as analogs of propagator poles, it consists of the "trivial" conformal h = n > 0-the standard spectrum with h = 0 assignable to massless particles excluded - and "non-trivial" h = -1/4 + iy/2. There is also a pole at h = -1.

Both the non-trivial pole with real part $h_R = -1/4$ and the pole h = -1 correspond to tachyons. I have earlier proposed conformal confinement meaning that the total conformal weight for the state is real. If so, one obtains for a conformally confined two-particle states corresponding to conjugate non-trivial zeros in minimal situation $h_R = -1/2$ assignable to N-S representation.

In p-adic mass calculations ground state conformal weight must be -5/2 [K68]. The negative fermion ground state weight could explain why the ground state conformal weight must be tachyonic -5/2. With the required 5 tensor factors one would indeed obtain this with minimal conformal confinement. In fact, arbitrarily large tachyonic conformal weight is possible but physical state should always have conformal weights h > 0.

3. h = 0 is not possible for generators, which reminds of Higgs mechanism for which the naïve ground states corresponds to tachyonic Higgs. h = 0 conformally confined massless states are necessarily composites obtained by applying the generators of Kac-Moody algebra or super-symplectic algebra to the ground state. This is the case according to p-adic mass calculations [K68], and would suggest that the negative ground state conformal weight can be associated with super-symplectic algebra and the remaining contribution comes from ordinary super-conformal generators. Hadronic masses, whose origin is poorly understood, could come from super-symplectic degrees of freedom. There is no need for p-adic thermodynamics in super-symplectic degrees of freedom.

17.6.1 A general formula for the zeros of zeta from NTU

Dyson's comment about Fourier transform of Riemann Zeta [A38] (http://tinyurl.com/hjbfsuv) is interesting from the point of NTU for Riemann zeta.

- 1. The numerical calculation of Fourier transform for the imaginary parts iy of zeros s = 1/2+iy of zeta shows that it is concentrated at discrete set of frequencies coming as $log(p^n)$, p prime. This translates to the statement that the zeros of zeta form a 1-dimensional quasicrystal, a discrete structure Fourier spectrum by definition is also discrete (this of course holds for ordinary crystals as a special case). Also the logarithms of powers of primes would form a quasicrystal, which is very interesting from the point of view of p-adic length scale hypothesis. Primes label the "energies" of elementary fermions and bosons in arithmetic number theory, whose repeated second quantization gives rise to the hierarchy of infinite primes [K106]. The energies for general states are logarithms of integers.
- 2. Powers p^n label the points of quasicrystal defined by points $log(p^n)$ and Riemann zeta has interpretation as partition function for boson case with this spectrum. Could p^n label also the points of the dual lattice defined by iy.
- 3. The existence of Fourier transform for points $log(p_i^n)$ for any vector y_a in class C(p) of zeros labelled by p requires $p_i^{iy_a}$ to be a root of unity inside C(p). This could define the sense in

which zeros of zeta are universal. This condition also guarantees that the factor $n^{-1/2-iy}$ appearing in zeta at critical line are number theoretically universal ($p^{1/2}$ is problematic for Q_p : the problem might be solved by eliminating from p-adic analog of zeta the factor $1-p^{-s}$.

(a) One obtains for the pair (p_i, s_a) the condition $log(p_i)y_a = q_{ia}2\pi$, where q_{ia} is a rational number. Dividing the conditions for (i, a) and (j, a) gives

$$p_i = p_j^{q_{ia}/q_{ja}}$$

for every zero s_a so that the ratios q_{ia}/q_{ja} do not depend on s_a . From this one easily deduce $p_i^M = p_j^N$, where M and N are integers so that one ends up with a contradiction.

(b) Dividing the conditions for (i, a) and (i, b) one obtains

$$\frac{y_a}{y_b} = \frac{q_{ia}}{q_{ib}}$$

so that the ratios q_{ia}/q_{ib} do not depend on p_i . The ratios of the imaginary parts of zeta would be therefore rational number which is very strong prediction and zeros could be mapped by scaling y_a/y_1 where y_1 is the zero which smallest imaginary part to rationals.

(c) The impossible consistency conditions for (i, a) and (j, a) can be avoided if each prime and its powers correspond to its own subset of zeros and these subsets of zeros are disjoint: one would have infinite union of sub-quasicrystals labelled by primes and each p-adic number field would correspond to its own subset of zeros: this might be seen as an abstract analog for the decomposition of rational to powers of primes. This decomposition would be natural if for ordinary complex numbers the contribution in the complement of this set to the Fourier trasform vanishes. The conditions (i, a) and (i, b) require now that the ratios of zeros are rationals only in the subset associated with p_i .

For the general option the Fourier transform can be delta function for $x = log(p^k)$ and the set $\{y_a(p)\}$ contains N_p zeros. The following argument inspires the conjecture that for each p there is an infinite number N_p of zeros $y_a(p)$ in class C(p) satisfying

$$p^{iy_a(p)} = u(p) = e^{\frac{r(p)}{m(p)}i2\pi}$$

where u(p) is a root of unity that is $y_a(p) = 2\pi (m(a) + r(p))/log(p)$ and forming a subset of a lattice with a lattice constant $y_0 = 2\pi /log(p)$, which itself need not be a zero.

In terms of stationary phase approximation the zeros $y_a(p)$ associated with p would have constant stationary phase whereas for $y_a(p_i \neq p)$) the phase $p^{iy_a(p_i)}$ would fail to be stationary. The phase e^{ixy} would be non-stationary also for $x \neq log(p^k)$ as function of y.

- 1. Assume that for x = qlog(p), where q not a rational, the phases e^{ixy} fail to be roots of unity and are random implying the vanishing/smallness of F(x).
- 2. Assume that for a given p all powers p^{iy} for $y \notin \{y_a(p)\}$ fail to be roots of unity and are also random so that the contribution of the set $y \notin \{y_a(p)\}$ to F(p) vanishes/is small.
- 3. For $x = log(p^{k/m})$ the Fourier transform should vanish or be small for $m \neq 1$ (rational roots of primes) and give a non-vanishing contribution for m = 1. One has

$$\begin{aligned} F(x = log(p^{k/m}) &= \sum_{1 \le a \le N(p)} e^{k \frac{M(a,p)}{mN(p)}i2\pi} u(p) ,\\ u(p) &= e^{\frac{r(p)}{m(p)}i2\pi} . \end{aligned}$$

Obviously one can always choose N(a, p) = N(p).

4. For the simplest option N(p) = 1 one would obtain delta function distribution for $x = log(p^k)$. The sum of the phases associated with $y_a(p)$ and $-y_a(p)$ from the half axes of the critical line would give

$$F(x = log(p^n)) \propto X(p^n) \equiv 2cos(n \frac{r(p)}{m(p)} 2\pi)$$
.

The sign of F would vary.

- 5. For $x = log(p^{k/m})$ the value of Fourier transform is expected to be small by interference effects if M(a, p) is random integer, and negligible as compared with the value at $x = log(p^k)$. This option is highly attractive. For N(p) > 1 and M(a, p) a random integer also $F(x = log(p^k))$ is small by interference effects. Hence it seems that this option is the most natural one.
- 6. The rational r(p)/m(p) would characterize given prime (one can require that r(p) and m(p) have no common divisors). F(x) is non-vanishing for all powers $x = log(p^n)$ for m(p) odd. For p = 2, also m(2) = 2 allows to have $|X(2^n)| = 2$. An interesting ad hoc ansatz is m(p) = p or $p^{s(p)}$. One has periodicity in n with period m(p) that is logarithmic wave. This periodicity serves as a test and in principle allows to deduce the value of r(p)/m(p) from the Fourier transform.

What could one conclude from the data (http://tinyurl.com/hjbfsuv)?

1. The first graph gives $|F(x = log(p^k)|$ and second graph displays a zoomed up part of $|F(x = log(p^k)|$ for small powers of primes in the range [2, 19]. For the first graph the eighth peak (p = 11) is the largest one but in the zoomed graphs this is not the case. Hence something is wrong or the graphs correspond to different approximations suggesting that one should not take them too seriously.

In any case, the modulus is not constant as function of p^k . For small values of p^k the envelope of the curve decreases and seems to approach constant for large values of p^k (one has x < 15 $(e^{15} \simeq 3.3 \times 10^6)$).

2. According to the first graph |F(x)| decreases for x = klog(p) < 8, is largest for small primes, and remains below a fixed maximum for 8 < x < 15. According to the second graph the amplitude decreases for powers of a given prime (say p = 2). Clearly, the small primes and their powers have much larger |F(x)| than large primes.

There are many possible reasons for this behavior. Most plausible reason is that the sums involved converge slowly and the approximation used is not good. The inclusion of only 10^4 zeros would show the positions of peaks but would not allow reliable estimate for their intensities.

- 1. The distribution of zeros could be such that for small primes and their powers the number of zeros is large in the set of 10^4 zeros considered. This would be the case if the distribution of zeros $y_a(p)$ is fractal and gets "thinner" with p so that the number of contributing zeros scales down with p as a power of p, say 1/p, as suggested by the envelope in the first figure.
- 2. The infinite sum, which should vanish, converges only very slowly to zero. Consider the contribution $\Delta F(p^k, p_1)$ of zeros not belonging to the class $p_1 \neq p$ to $F(x = log(p^k)) = \sum_{p_i} \Delta F(p^k, p_i)$, which includes also $p_i = p$. $\Delta F(p^k, p_i)$, $p \neq p_1$ should vanish in exact calculation.
 - (a) By the proposed hypothesis this contribution reads as

$$\Delta F(p, p_1) = \sum_a \cos \left[X(p^k, p_1) (M(a, p_1) + \frac{r(p_1)}{m(p_1)}) 2\pi) \right]$$

$$X(p^k, p_1) = \frac{\log(p^k)}{\log(p_1)} .$$

Here a labels the zeros associated with p_1 . If p^k is "approximately divisible" by p^1 in other words, $p^k \simeq np_1$, the sum over finite number of terms gives a large contribution

since interference effects are small, and a large number of terms are needed to give a nearly vanishing contribution suggested by the non-stationarity of the phase. This happens in several situations.

- (b) The number $\pi(x)$ of primes smaller than x goes asymptotically like $\pi(x) \simeq x/log(x)$ and prime density approximately like $1/log(x) - 1/log(x)^2$ so that the problem is worst for the small primes. The problematic situation is encountered most often for powers p^k of small primes p near larger prime and primes p (also large) near a power of small prime (the envelope of |F(x)| seems to become constant above $x \sim 10^3$).
- (c) The worst situation is encountered for p = 2 and $p_1 = 2^k 1$ a Mersenne prime and $p_1 = 2^{2^k} + 1, k \leq 4$ Fermat prime. For $(p, p_1) = (2^k, M_k)$ one encounters $X(2^k, M_k) = (log(2^k)/log(2^k 1))$ factor very near to unity for large Mersennes primes. For $(p, p_1) = (M_k, 2)$ one encounters $X(M_k, 2) = (log(2^k 1)/log(2) \simeq k$. Examples of Mersennes and Fermats are $(3, 2), (5, 2), (7, 2), (17, 2), (31, 2), (127, 2), (257, 2), \dots$ Powers $2^k, k = 2, 3, 4, 5, 7, 8, \dots$ are also problematic.
- (d) Also twin primes are problematic since in this case one has factor $X(p = p_1 + 2, p_1) = \frac{\log(p_1+2)}{\log(p_1)}$. The region of small primes contains many twin prime pairs: (3,5), (5,7), (11,13), (17,19), (29,31),....

These observations suggest that the problems might be understood as resulting from including too small number of zeros.

3. The predicted periodicity of the distribution with respect to the exponent k of p^k is not consistent with the graph for small values of prime unless the periodic m(p) for small primes is large enough. The above mentioned effects can quite well mask the periodicity. If the first graph is taken at face value for small primes, r(p)/m(p) is near zero, and m(p) is so large that the periodicity does not become manifest for small primes. For p = 2 this would require m(2) > 21 since the largest power $2^n \simeq e^{15}$ corresponds to $n \sim 21$.

To summarize, the prediction is that for zeros of zeta should divide into disjoint classes $\{y_a(p)\}$ labelled by primes such that within the class labelled by p one has $p^{iy_a(p)} = e^{(r(p)/m(p))i2\pi}$ so that has $y_a(p) = [M(a, p) + r(p)/m(p))]2\pi/log(p)$.

17.6.2 More precise view about zeros of Zeta

There is a very interesting blog post by Mumford (http://tinyurl.com/zemw27o), which leads to much more precise formulation of the idea and improved view about the Fourier transform hypothesis: the Fourier transform or its generalization must be defined for all zeros, not only the non-trivial ones and trivial zeros give a background term allowing to understand better the properties of the Fourier transform.

Mumford essentially begins from Riemann's "explicit formula" in von Mangoldt's form.

$$\sum_{p} \sum_{n \ge 1} \log(p) \delta_{p^n}(x) = 1 - \sum_{k} x^{s_k - 1} - \frac{1}{x(x^2 - 1)} ,$$

where p denotes prime and s_k a non-trivial zero of zeta. The left hand side represents the distribution associated with powers of primes. The right hand side contains sum over cosines

$$\sum_{k} x^{s_k - 1} = 2 \frac{\sum_k \cos(\log(x)y_k)}{x^{1/2}} \quad .$$

where y_k ithe imaginary part of non-trivial zero. Apart from the factor $x^{-1/2}$ this is just the Fourier transform over the distribution of zeros.

There is also a slowly varying term $1 - \frac{1}{x(x^2-1)}$, which has interpretation as the analog of the Fourier transform term but sum over trivial zeros of zeta at s = -2n, n > 0. The entire expression is analogous to a "Fourier transform" over the distribution of all zeros. Quasicrystal is replaced with union on 1-D quasicrystals.

Therefore the distribution for powers of primes is expressible as "Fourier transform" over the distribution of both trivial and non-trivial zeros rather than only non-trivial zeros as suggested by numerical data to which Dyson [A38] referred to (http://tinyurl.com/hjbfsuv). Trivial zeros give a slowly varying background term large for small values of argument x (poles at x = 0 and x = 1 - note that also p = 0 and p = 1 appear effectively as primes) so that the peaks of the distribution are higher for small primes.

The question was how can one obtain this kind of delta function distribution concentrated on powers of primes from a sum over terms $cos(log(x)y_k)$ appearing in the Fourier transform of the distribution of zeros.

Consider $x = p^n$. One must get a constructive interference. Stationary phase approximation is in terms of which physicist thinks. The argument was that a destructive interference occurs for given $x = p^n$ for those zeros for which the cosine does not correspond to a real part of root of unity as one sums over such y_k : random phase approximation gives more or less zero. To get something nontrivial y_k must be proportional to $2\pi \times n(y_k)/log(p)$ in class C(p) to which y_k belongs. If the number of these y_k :s in C(p) is infinite, one obtains delta function in good approximation by destructive interference for other values of argument x.

The guess that the number of zeros in C(p) is infinite is encouraged by the behaviors of the densities of primes one hand and zeros of zeta on the other hand. The number of primes smaller than real number x goes like

$$\pi(x) = N(primes < x) \sim \frac{x}{\log(x)}$$

in the sense of distribution. The number of zeros along critical line goes like

$$N(zeros < t) = (t/2\pi) \times \log(\frac{t}{2\pi})$$

in the same sense. If the real axis and critical line have same metric measure then one can say that the number of zeros in interval T per number of primes in interval T behaves roughly like

$$\frac{N(zeros < T)}{N(primes < T)} = \log(\frac{T}{2\pi}) \times \frac{\log(T)}{2\pi}$$

so that at the limit of $T \to \infty$ the number of zeros associated with given prime is infinite. This asymption of course makes the argument a poor man's argument only.

17.6.3 Possible relevance for TGD

What this speculative picture from the point of view of TGD?

- 1. A possible formulation for NTU for the poles of fermionic Riemann zeta $\zeta_F = \zeta(s)/\zeta(2s)$ could be as a condition that is that the exponents $p^{ks_a(p)/2} = p^{k/4}p^{iky_a(p)/2}$ exist in a number theoretically universal manner for the zeros $s_a(p)$ for given p-adic prime p and for some subset of integers k. If the proposed conditions hold true, exponent reduces $p^{k/4}e^{k(r(p/m(p))2\pi)}$ requiring that k is a multiple of 4. The number of the non-trivial generating elements of super-symplectic algebra in the monomial creating physical state would be a multiple of 4. These monomials would have real part of conformal weight -1. Conformal confinement suggests that these monomials are products of pairs of generators for which imaginary parts cancel.
- 2. Quasi-crystal property might have an application to TGD. The functions of light-like radial coordinate appearing in the generators of supersymplectic algebra could be of form r^s , s zero of zeta or rather, its imaginary part. The eigenstate property with respect to the radial scaling rd/dr is natural by radial conformal invariance.

The idea that arithmetic QFT assignable to infinite primes is behind the scenes in turn suggests light-like momenta assignable to the radial coordinate have energies with the dual spectrum $log(p^n)$. This is also suggested by the interpretation of ζ as square root of thermodynamical partition function for boson gas with momentum log(p) and analogous interpretation of ζ_F .

The two spectra would be associated with radial scalings and with light-like translations of light-cone boundary respecting the direction and light-likeness of the light-like radial vector. $log(p^n)$ spectrum would be associated with light-like momenta whereas p-adic mass scales would characterize states with thermal mass. Note that generalization of p-adic length scale hypothesis raises the scales defined by p^n to a special physical position: this might relate to ideal structure of adeles.

3. Finite measurement resolution suggests that the approximations of Fourier transforms over the distribution of zeros taking into account only a finite number of zeros might have a physical meaning. This might provide additional understand about the origins of generalized p-adic length scale hypothesis stating that primes $p \simeq p_1^k$, p_1 small prime - say Mersenne primes - have a special physical role.

Chapter 18

ZEO, Adelic Physics, and Genes

18.1 Introduction

Zero energy ontology (ZEO) solving the basic problem of quantum measurement theory has become a cornerstone of quantum TGD, and together with the vision about physics as infinite-D geometry of the "world of classical worlds" (WCW) [K97] and number theoretical vision about physics as adelic physics [L66, L67] fusing the real number based physics of sensory experience and the p-adics physics of cognition and intentionality dictates to high degree the key structures of TGD. In this chapter the implications of the ZEO for the understanding of genetic code are considered.

18.1.1 Summary of Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) [L118] lies behind TGD based quantum measurement theory in turn giving rise to a theory of consciousness by making observed part of system as a conscious entity - self. ZEO solves the basic paradox of quantum measurement theory forcing to give up ontology altogether in the Copenhagen interpretation. ZEO has become a key aspect of the entire TGD based physics.

In this section I will consider more precise mathematical formulation and physical interpretation of ZEO. ZEO forms also the cornerstone of TGD inspired theory of consciousness and quantum biology. I will consider also some related aspects of ZEO such as the notions of free will and intentionality, the notions of memory and precognition as its time reversal, intuitive in contrast to formal reasoning, and remote metabolism as a universal thermodynamical mechanism of metabolism in ZEO based thermodynamics.

18.1.2 About quantum measurement theory in ZEO

The relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision is clarified. The considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them. One can generalize classical cognitive representations as number theoretical discretizations of space-time surfaces in the extension of rationals considered to their quantum counterparts as wave functions in the Galois group of the extension and introduce also fermions as spinors in the group algebra of Galois group. The strongest option is purely number theoretical representations of fermionic Fock spaces in terms of spinors in this group algebra. Presumably however M^8 spinors are required as basic building bricks and have interpretation in terms of octonion structure.

An attractive vision is that number theoretical quantum measurements reduce to measurement cascades involving a sequence of state function reductions reducing the entanglement between wave functions in sub-Galois group H and group G/H and ends up to a prime Galois group for group algebra has prime dimension and represents Hilbert space prime not decomposable to tensor product.

Also time measurement is considered from the number theoretic perspective assuming $M^8 - H$ duality. Clock readings are realized as roots of the rational polynomial determining the space-time surface. Time measurement would involve a localization to a definite extension of rationals,

whose dimension n must be proportional to the temporal distance T between the tips of causal diamond (CD) to guarantee fixed time and energy resolution.

18.1.3 The dynamics of SSFRs as quantum measurement cascades in the group algebra of Galois group

Adelic physics, $M^8 - H$ duality, and zero energy ontology lead (ZEO) to a proposal that the dynamics involved with "small" state function reductions (SSFRs) as counterparts of weak measurements could be basically number theoretical dynamics with SSFRs identified as reduction cascades leading to completely un-entangled state in the space of wave functions in Galois group of extension of rationals identifiable as wave functions in the space of cognitive representations. As a side product a prime factorization of the order of Galois group is obtained.

The result looks even more fascinating if the cognitive dynamics is a representation for the dynamics in real degrees of freedom in finite resolution characterized by the extension of rationals. If cognitive representations represent reality approximately, this indeed looks very natural and would provide an analog for adele formula expressing the norm of a rational as the inverse of the product of is p-adic norms. The results can be applied to the TGD inspired model of genetic code.

18.1.4 DNA and time reversal

The recently (towards end of year 2020) added section about DNA time reversal is written together with Reza Rastmanesh and devoted to the view about DNA inspired by zero energy ontology (ZEO) forming the basis of the quantum measurement theory of Topological Geometrodynamics (TGD) and by the notion of dark DNA inspired by the TGD view about dark matter as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ at magnetic body (MB) - the third key notion distinguishing TGD from standard model. The basic prediction of ZEO is that "big" (ordinary) state function reduction (BSFR) changes the arrow of time meaning "death" and "reincarnation" with opposite arrow of time. This leads to a new view about self-organization.

The time reversals of the basic processes like transcription and replication turn out to be possible only for the conjugate (passive) strand - this is basically due to th CPT theorem in TGD context and chiral selection. By chiral selection enzymes can catalyze processes but not their time reversals. For instance, conjugate strand polymerizes in reverse time direction - this looks like depolymerization in standard time direction. Polymerization of the conjugate strand however occurs in standard time direction but in reverse direction along strand.

The recombination of DNA strands during meiosis is poorly understood. This could correspond to reconnections for the flux tubes associated with the active DNA strands. Time reversal would occur in BSFR and formerly passive conjugate DNA strands would depolymerize to "loose" codons (not independent letters) by the time reversed polymerization, the flux tubes associated with the formerly active strands would suffer reconnections inducing recombination without assistance of enzymes, second BSFR would occur, and be followed by the replication of recombined active strands.

According to the findings of Becker, the direction of the electric field along the body axis determines whether the system is awake or sleeps. By the properties of electric field under time reflection, the arrow of time correlates also with the direction of the electric field. TGD predicts that consciousness is possible even at the level of DNA. Could also DNA have a longitudinal electric field with direction correlating with the arrow of time of DNA at the (magnetic body) MB of DNA. Could there be a switch changing the direction of this electric field?

This inspires a model for the DNA as ferro-electret based on the properties of the negatively charged sticky ends of chromosome and dark DNA codons as proton triplets along a magnetic flux tube parallel to DNA strand. A simple proposal for the time switch based on the analog of Becker's DC currents emerges: proton flow of the dark protons of sticky end to the opposite sticky end would change the arrow of time. The model could generalize also to proteins known to be ferro-electrets and could be accompanied also by their dark analogs.

18.2 Some comments related to Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) lies behind TGD based quantum measurement theory in turn giving rise to a theory of consciousness by making observed part of system as a conscious entity - self [L69]. ZEO solves the basic paradox of quantum measurement theory forcing to give up ontology altogether in the Copenhagen interpretation. ZEO has become a key aspect of the entire TGD based physics.

The basic prediction of ZEO is that ordinary ("big") state function reductions (BSFRs) involve change of the arrow of time. There is a lot of support for this prediction. The recent highly counterintuitive findings of Minev *et all* provided support for the time reversal in atomic systems [L104] [L104]. Fantappie [J33] proposed decades ago time reversal in living systems and introduced syntropy as time reversed entropy. In living matter the generation of more complex molecules from their building bricks can be seen as decay in time reversed direction. Phase conjugate laser beams are known to obey time reversed second law.

Also Libet's findings [J4] related to the active aspects of conscious experience find a nice explanation in terms of the time reversal. The latest application is to the understanding of the mysterious looking findings about earthquakes and volcanic eruptions suggesting that macroscopic quantum jumps involving time reversal are in question [L106]. This suggest that experimental verification of the time reversal and occurrence of macroscopic quantum jumps is possible by studying causal anomalies. For these reasons is important to try to develop the details of the view about ZEO as precise as possible.

In the sequel I will consider more precise mathematical formulation and physical interpretation of ZEO. ZEO forms also the cornerstone of TGD inspired theory of consciousness and quantum biology and I will consider also some related aspects of ZEO such as the notions of free will and intentionality, the notions of memory and precognition as its time reversal, intuitive in contrast to formal reasoning, and remote metabolism as a universal thermodynamical mechanism of metabolism in ZEO based thermodynamics.

18.2.1 General view about ZEO

The details of ZEO - in particular the technical details related to the conservation laws BSFR and SSFR - are from well-understood and the following is an attempt to fix these details by using analogy with cosmology.

Rough view about ZEO

Consider first what ZEO roughly means.

- 1. The realization of ZEO [L120, L69, L86, L117] involves besides the notions of "small" (SSFR) and "big" state function reduction (BSFR) also the notion of causal diamond (CD). CD defines perceptive field of conscious entity as a 8-D region $cd \times CP_2$, where cd is the 4-D causal diamond of M^4 defined as the intersection of future and past directed light-cones.
- 2. At the classical level the basic entity is space-time surface connecting 3-surfaces at the opposite boundaries of CD. The space-time surfaces inside sub-CD continue outside and there is a hierarchy of CDs with largest CD beyond which space-time surfaces do not continue. This defines a space-time correlate for the hierarchy of selves.

Space-time surfaces are preferred extremals of the basic action principle defined by the twistor lift of TGD [L96]. Minimal surfaces with 2-D string world sheets as singularities would be in question. They connect 3-surfaces at the boundaries of CD and are analogous to Bohr orbits so that not any pair is possible and the conditions characterizing preferred extremal property might even imply 1-1 correspondence between these 3-surfaces.

3. Zero energy states are superpositions of preferred extremals. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors. ZEO allows to solve the basic paradox of quantum measurement theory since the non-determinism of quantum jump between zero energy states corresponds to the causality of free will and is not in conflict with the classical

determinism realizing the causality of field equations. Experienced time and geometric time are not same but there is a strong correlation between them.

- 4. In SSFRs the active boundary of CD shifts to future at least in statistical sense. This is preceded by a unitary time evolution generating superposition of CDs with different sizes but having fixed passive boundary and same superposition of 3-surfaces at it. SSFR involves time-localization to single CD with fixed temporal distance between its tips. Essentially time measurement is in question.
- 5. In BSFR the arrow of time changes and one can say that state function reduction measuring set of observables takes place at the active boundary of CD, which becomes a passive boundary at which state does not change during subsequent SSFRs in which CD increases in opposite direction with the former passive boundary becoming an active boundary. The change of the arrow of time in BSFR creates the illusion that instantaneous quantum jump corresponds to a smooth and deterministic time evolution leading to the final state [L104] [L104].

The mathematical and physical details of the picture are not completely nailed down, and the best manner to proceed is to return to basic questions again and again and to challenge the details of the existing picture. In the following I will do my best to invent nasty arguments against ZEO.

ZEO and conservation laws

The geometry of CD breaks Poincare invariance. Lorentz invariance with respect to the either tip of CD is exact symmetry and is extremely attractive in the construction of members of state pairs in ZEO. Classically Poincare invariance is exact and one can deduce expressions for conserved quantities for both bosonic and fermionic sector: the latter have interpretation as operators, whose eigenvalues in Cartan algebra are by quantum classical correspondence (QCC) identified as classical values of conserved quantities.

ZEO involves the somewhat questionable assumption that one can assign well-defined Poincare quantum numbers to both boundaries and that these quantum numbers are opposite: this motivates the term ZEO.

- 1. $M^8 H$ duality [L112] allows to assign to CDs with either boundary fixed a moduli space, which corresponds to Poincare group. The proposal is that Poincare invariance is realized at this level and that the values of conserved charges in Cartan algebra correspond to the Poincare quantum numbers labelling these wave functions. The wave functions at the boundaries of CD could be arranged in representations of Lorentz group acting as exact symmetry of the boundary.
- 2. There is further little nuisance involved. Only time translations, which correspond to a nonnegative time value as distance from the fixed boundary of CD are possible. One would obtain momentum eigenstates restricted to a future or past light-cone. This is of course what happens in TGD based cosmology. Maybe one must just accept this as a physical fact forcing to give up mathematical idealization.

Formally one would replace the plane wave basis with a basis multiplied by characteristic function for future or past light-cone equal to 1 inside the light-cone and vanishing elsewhere. This basis is closed with respect to summation. This would mean that the states are not anymore exact eigenstates of momentum globally but superposition of Lorentz boosts of the basic momentum obtained by Fourier expanding the characteristic function of future/past light-cone.

But what about CD which is intersection of future and past directed light-cones? Can one really assign to both boundaries wave functions defined in entire future (or past) directed light-cone? It seems that this is the case. Zero energy state would be entangled state as a superposition of products of boosted momentum eigenstates with opposite momenta representing the characteristic function of CD.

The usual idea about unitary time evolution for Schrödinger amplitude would be given up inside CD, and replaced by a sequence of unitary time evolutions producing de-localization of the active boundary of CD and followed by a localization.

3. There is still a problem. A complete de-localization for the boundaries of CD is not consistent with the intuitive idea that CD has definite size scale. In wave mechanics the plane waves are only idealizations and in the real world one replaces plane waves with wave packets. Gaussian wave packets have the nice feature that they remain Gaussian in Fourier transformation.

If one has Gaussian wave packet for the temporal distance between the tips of CD concentrated on certain value of time, the Fourier transform for this is Gaussian wave packet concentrated around certain relative energy, which is two times the energy assignable to say passive boundary of CD. Instead of sharp value of time as distance between the tips of CD one would have Gaussian distribution for its value. This is consistent with Lorentz invariance since zero energy states allow superposition over states with varying momenta assignable to say active boundary. The wave function would be essentially Gaussian in energy in the rest system and one can consider also wave functions in Lorentz group leaving the passive boundary of CD invariant.

SSFRs in ZEO

In the proposed picture the sequence of SSFRs could mean gradual widening of the Gaussian wave packet for the value of measured time as the temporal distance between the tips of CD by discrete steps.

The basic condition is that the states at passive boundary of CD identified as superpositions of 3-surfaces remain unaffected during the sequences of SSFRs increasing the size of CD. This corresponds to generalized Zeno effect and in consciousness theory thr unchanging part of zero energy state corresponds to unchanging part of self, one might call it soul. One can imagine two options.

Option I: CD increases statistically in SSFRs but classical energy is conserved for spacetime surfaces connecting its boundaries. Energy density would decreases as CD increases. This does not seem too bad actually: it would be analogous to matter dominated cosmology.

Not only superpositions of 3-surfaces at passive boundary of CD would be conserved but also their 4-D tangent spaces would be unaffected: this is unnecessarily strong a condition for generalized Zeno effect.

Option II: CD increases but classical energies decrease. This looks more plausible- if not the only - option and is strongly favoured by the analogy of CD with expanding cosmology. It also conforms with uncertainty principle. The process would be essentially quantum analog of cooling or analog for what happens for particle in a box expanding adiabatially. The classical energies of the space-time surfaces in zero energy state would thus decrease as CD increases.

Also this option allows the states as superpositions of 3-surfaces to at passive boundary of CD to remain unffected in expansion of CD. The classical energies can however decrease because the space-time surfaces - tangent spaces of space-time surfaces at passive boundary - can change so that also energies can change.

This option is completely analogous to quantum adiabatic change in which the coefficients in the superposition of energy eigenstates are unaffected but energies change.

Option II looks more natural and will be considered in more detail.

- 1. The constraint that SSFRs as quantum measurements are for observables, which commute with observables, whose eigenstate the state at the passive boundary is, poses very strong constraints on what happens SSFR. Furthermore, preferred extremal is analog of Bohr orbit and cannot cannot be arbitrary pair of 3-surfaces. Therefore, when the CD changes, the preferred extremal also changes as a whole meaning also that also energy changes. These conditions could force adiabatic picture and the analog of Uncertainty Principle for classical energies as function of CD size.
- 2. The sequence of SSFRs could be also analogous analogous to what happens for a particle in box as the size of the box increases adiabatically: adiabaticity would actually be a hypothesis about what happens in the steps consisting of unitary evolution and SSFR. In adiabatic approximation the coefficients in the superposition of the energy eigenstates do not change at all: only the energies would change.

- 3. In thermodynamics this kind of process would correspond to a cooling, which could serve as a natural quantum correlate for the cooling in cosmology. In accordance with the idea that quantum TGD in ZEO corresponds to a complex square root of thermodynamics, one could interpret zero energy state as complex square root of thermal partition function for cosmology assignable to CD. The hierarchy of CDs would define Russian doll cosmology.
- 4. A further manner to understand this is in terms of Uncertainty Principle. As the size scale of CD given by temporal distance between its dips increases, the classical energy decreases. Intuitively the reduction of the classical energy is easy to understand. Increasing CD and keeping the 3-surface as such at passive boundary reduces time gradients at the passive boundary and space-time surface becomes more flat. Energy density is proportional to time gradients of coordinates and its therefore reduced. This argument is also used in inflation theories.
- 5. Change is the prerequisite of conscious experience and there would be indeed change also at the passive boundary of CD contributing to conscious experience. But in some sense this contribution the "soul" should *not* be changing! "Adiabaticity" would translate this idea to the language of physics.

What happens to CD in long run? There are two options.

- 1. The original assumption was that the location of formerly passive boundary is not changed. This would mean that the size of CD would increase steadily and the outcome would be eventually cosmology: this sounds counter-intuitive. Classically energy and other Poincare charges are conserved for single preferred extremal could fail in BSFRs due to the fact that zero energy states cannot be energy eigenstates.
- 2. The alternative view suggested strongly $M^8 H$ duality [L58] is that the size of CD is reduced in BSFR so that the new active boundary can be rather near to the new passive boundary. One could say that the reincarnated self experiences childhood. In this case the size of CD can remain finite and its location in M^8 more or less fixed. One can say that the self associated with the CD is in a kind of Karma's cycle living its life again and again. Since the extension of rationals can change in BSFR and since the number of extensions larger than given extension is infinitely larger than those smaller than it, the dimension of extension identifiable in terms of effective Planck constant increases. Since $n = h_{eff}/h_0$ serves as a kind of IQ, one can say that the system becomes more intelligent.

Also the temperature assignable to CD remains finite. In cosmological scales it could correspond to the analog of the temperature assignable to CMB. TGD based view about stars as blackhole like entities [L105] leads to the identification of the Hagedorn temperature assignable to the volume filling flux tube giving rise to star with the Hawking temperature of dark radiation at gravitational flux tubes. Even CMB temperature could be assigned with dark photons at gravitational flux tubes. The asymptotic temperature for CD before BSFR could correspond to this temperature.

One expects that the center of mass coordinates of cm do not appreciably change during the quantum evolution. The hierarchy of CDs would imply that the Universe decomposes effectively to sub-Universes behaving to some degree independently. The view about Karma's cycles provides a more precise formulation of the pre-ZEO idea that systems are artists building themselves as 4-D sculptures. In particular, this applies to mental images in TGD based view about brain. The assumption that stars correspond to repeatedly re-incarnating conscious entities allows to solve several time anomalies in cosmology [L105] so that there would be a direct connection between cosmology and theory of consciousness.

There could be a relationship between quantal flow of geometric time by SSFRs and p-adic variant of time coordinates giving a reason why for p-adicity.

1. TGD predicts geometric time as a real variant and p-adic variants in extensions of various p-adics induced by given extension of rationals (adelic space-time and adelic geometric time). Real and p-adic times share discrete points in the extension of rationals considered: roots of

octonionic polynomials defining space-time surfaces as roots for their "real" and "imaginary" parts in quaternionic sense [L110]. The roots of the real polynomial with rational coefficients giving octonionic polynomial as its continuation define space moments of M^4 linear time assignable to special SSFRs. p-Adic time associated with the p-adic balls assignable the points are not well-ordered. One cannot tell about two moments of time which is earlier and which later.

2. This could relate to the corresponding lack of well ordering related to "clock time" associated with self at given level of evolutionary hierarchy defined by the extension of rationals. The increase of "clock time" as a distance between tips of CD for a sequence of small state function reductions (weak measurements) occurs only in statistical sense and "clock time" can also decrease. The moments of time correspond to roots of the real polynomial define "special moments in the life of self", one might say.

At the limit of infinite-D extension the roots of the polynomial define algebraic numbers forming a dense set in the set of reals. Cognitive representation becomes dense set. These "special moments" need not however become dense.

3. One can raise an interesting question inspired by self inspection. As one types text, it often happen that the letters of the word become in wrong order, change places, and even jump from a word to another one. The experienced order of letters assignable to a sequence of SSFRs is not the same as the order of letters representing the order for the moments of geometric time. When one is tired, the phenomenon is enhanced.

Neuroscientists can certainly propose an explanation for this. But could this be at deeper level quantum effect based on the above mechanism and have a description in terms of padicity assignable to prime p defining a ramified prime for the extension of rationals involved? When one is tired the metabolic resources have petered out and the IQs $n = h_{eff}/h_0$ defined by dimensions of extensions of rationals for the distribution of extensions tend to reduce, cognitive resolution for time becomes lower and mistakes of this kind become worse.

There is a further technical detail involved. For SSFRs the temporal distance between active boundary and passive boundary increases at least in statistical sense. It seems that one must define the inner product in S-matrix elements for the unitary step preceding SSFR using the previous state basis as sub-basis of the new state basis in the case that CD increases. In adiabatic approximation the S-matrix elements would be overlaps for the states with different size of CD and analogous to matrix elements between states of particle in boxes with the same fixed end but different moving end.

BSFRs in ZEO

Details of BSFR are not completely fixed. One can consider two options. Both options must satisfy the condition that the states at passive boundary of CD identified as superpositions of 3-surfaces remain invariant during the sequence of SSFRs. The tangent space-to the space-time surfaces need not however remain invariant. Therefore the classical energies of space-time surfaces can change since the energy densities are proportional to time derivatives of embedding space coordinates.

1. The size of CD increases steadily as was the original proposal and is thus not reduce in BSFRs. The problem with the steady increase seems to be that the size of CD becomes infinite eventually and the state evolves to what looks like cosmology. If the energy assignable with zero energy state is conserved, the energy density of matter inside CD increasing without limit becomes arbitrarily small. Is this a catastrophe?

For TGD inspired cosmology this is the case at the limit of big bang in the sense that the energy density goes like $1/a^2$ (cosmic string dominance) and energy in a co-moving volume vanishes like a, where a is light-cone proper time. One can think that CD defines only perceptive field and that space-time surfaces continue also outside CD up to the maximal size of CD in the hierarchy of selves involved. The zero energy state would have finite energy energy but density of energy would go to zero at the boundary of CD. The perceptive field of conscious entity would increase steadily in size.

As found, energy need not be conserved in the subsequence SSFRs because Gaussian wave packets of CDs around given size are required so that eigenstates of energy are not in question and the reduction of the width of Gaussian in the sequence of SSFRs implies reduction of average energy. Only the superpositions of 3-surfaces at the passive boundary of CD would be conserved.

Even the conservation of energy combined with the increase of CD need not be a catastrophe. In matter dominated cosmology the conservation of mass takes place with respect to cosmological time which corresponds to the proper time measured as temporal distance from the passive tip of CD. This cosmological mass is not energy but closely relates to it. What looks of course counter-intuitive is that every self would evolve to a cosmology.

2. The size of CD could be also reduced in BFSR [L110]. $M^8 - H$ duality and existence of "braney" solutions encourages to take this option serious. The 6-D brane like entities correspond to t = constant sections for linear M^4 time t. They would represent special moments in the life of self. The exceptional 6-D roots of octonionic polynomials as branes would emerge to the perceptive field conscious entity at these moment. Discontinuity of classical space-time evolution as SSFR. Every time-reversed re-incarnation of self would have have "childhood" and experience increase of CD from some minimal size to maximal size.

Since the size of CD can be reduced, it could happen that the CD remains stuck below certain maximal size for ever. The associated mental images would continue living in the geometric past of bigger CD associated with self. The sub-CDs in past would represent memories of self. Cosmos in 4-D sense would be full of life. The interpretation of CD as perceptive field allows this. CD could also increase and become even a cosmology! This picture looks attractive from the view point of consciousness.

- 3. One can however invent an objection against ZEO, one might even speak about paradox.
 - (a) Suppose that in biological death I indeed re-incarnate with opposite arrow of time and continue to live towards geometric past. Suppose also that I re-incarnate as more advanced human being - at least in statistical sense. Human beings have parents. But how can I have parents in the former geometric future, if my parents how have already died live in the former geometric past?
 - (b) The only solution of the paradox seems to be that the magnetic body (MB) the boss - does not disappear in the death of biological body (BB). The MBs of my parents continue their existence and in my biological death means their separation in stanard time direction and meeting in the new time direction. They meet, fall in love, and give rise to my birth but all this in opposite time direction.

This would provide an answer to a long-standing question about whether MBs are preserved in biological death or not. My view has been that biological death is more or less that MB loses interest in my BB and directs attention to something more interesting. One could however argue that also MB is generated in birth and genes code also for it so that it would die. If directing attention corresponds to BSFR MB would continue to exist after biological death. This particular reincarnation - CD - would be like vortex in the flow of time.

(c) Can one find any support for this crazy looking proposal? TGD Universe is fractal and lower levels in the length scale hierarchies are slaves. In particular, bio-chemical level serves as the slave of MB expected to obey kind of shadow dynamics. If the proposed topological dynamics of MBs solving the above paradox has a miniature representation at the level of DNA, one could take the proposal with some seriousness.

In meiosis (http://tinyurl.com/n5eqkdn) germ cells, whose chromosomes are coctails of paternal and maternal chromoses (PCs and MCs), are formed. In fertilization (http: //tinyurl.com/ngzwhcq) - in some sense a (time?) reversal of meiosis - pairs of PCs and MCs are formed. The fusion of paternal and maternal germ cells could be indeed seen in topological sense as a time reversal of replication. The replication of soma cells involves mitosis (http://tinyurl.com/p351kwr) forming pairs of chromosomes of PCs and MCs.

Could the chromosomal dynamics be a miniature version of the proposed dynamics at the level of MB even at the level of organisms? If so, mitosis at the level of MB would correspond to a loose pairing of paternal and maternal MBs - formation of a relationship. Our personal MBs as analogs of germ cells would be coctails of MBs of PCs and MCs formed by reconnection process.

What about replication? In the case of asexual reproduction (http://tinyurl.com/ y8odomtf) one could speak about replication at the level of MB of the entire organism. Also cell - and DNA replication would represent examples of asexual reproduction and in meiosis sexual reproduction of also DNA would take place.

When does BSFR occur? I have imagined several options, which need not exclude each other.

- 1. Could BSFR occur, when there are no observables at the active boundary commuting with those diagonalized at passive boundary. Measurement of observable at means generation of eigenstate in the extension of rationals and it typically occurs that the resulting state is outside the extension. Could BSFR occur when there are no observables in the extension of rationals in question.
- 2. $M^8 H$ duality predicts universal special solutions besides 4-D space-time surfaces. These 6-D analogs of branes correspond to n moments of linear M^4 time, where n is the polynomial whose octonionic continuation defines space-time surfaces in M^4 as roots of its real or imaginary part in quaternionic sense. At these branes 4-D space-time surfaces are glued together along their ends- space-time looks is analogous to piecewise continuous curve in time direction - and they would correspond to "special moments in the life of self" [L110]. When all these moments as special roots of the octonionic polynomial are experienced, BSFR would be the only possibility. The polynomial with rationals coefficients defining the octonionic polynomial defines the extension of rationals used so that this option could be consistent with the first option.
- 3. Is BSFR is forced to occur because there are no preferred extremals connecting the pairs of 3-surfaces exists anymore. Could it happen that the state becomes increasingly classical during the sequence of SSFRs and thus becoming more and more local in WCW (the "world of classical worlds", which is essentially the space of 3-surfaces at either boundary of CD). The unchanging part of the zero energy state associated with the time-reversed state as outcome of BSFR at the new passive boundary would be maximally classical. This might relate to the fact that the world looks so classical. Also the fact BSFRs themselves look classical smooth time evolution ending to the outcome of BSFR, creates the illusion of classicality [L104].

18.2.2 ZEO, life, and consciousness

The most important implications of ZEO relate to consciousness and quantum biology. One can understand act of free will and motor action in terms of BSFR. BSFR corresponds to motor action and its time-reversal. SSFRs correspond to sensory perception in either direction of time [L93]. Model for memory is one prediction and predicts precognition as time reversal of memory [K94] [L121]. Also the relationship between generation of insight and mechanical logic deductions can be understood. In biology ZEO leads to remote metabolism as a universal purely thermodynamical mechanism of metabolism. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors.

Act of free will, intentionality, and ZEO

Act of free will would correspond to BSFR that is quantum jump leading to final state with opposite arrow of time. Final state is a superposition of deterministic time evolution connecting

the 3-surfaces in the superpositions defining initial and the final states. In this picture state function reduction leads to final state inducing time reversed time evolution so that classically the causal order is changed. What in standard picture - say neural activities - causes the outcome, is caused by the outcome. Could it be that mere volitional act with sharp enough intention is needed? The correct deterministic time evolution is dictated by intention as consequence rather than cause!

Here I cannot avoid the temptation to tell about my own strange experiences. At this age one must remember to take the pills every morning. I have the habit of filling my pill dispenser every Monday morning. I do not bother to count the pills one by one. I just take randomly a bunch of them hoping that their number is correct. And it is! Quite too often! Similar thing happens in market when I pay with coins: I do not count the coins but just take a handful of them. The sum of the coins is correct quite too often! Could a mere sharp intention dictate the outcome. Could one learn gradually this kind of sharp intentions.

Could this be crucial for various skills like playing tennis or computer game, where one simply cannot react rapidly by computing the outcome since time does not allow it? Could this explain also mathematical/physical/.. intuition as skill to solve problems by making quantum jump directly to the solution of the problem.

Precognition and ZEO

It seems that neuroscientists are beginning to take remote mental interactions such as precognition, telepathy, and psychokinesis seriously. The popular article entitled "Scientists Discover That The Heart & Brain Respond To Future Events – Before They Happen" (see http://preview.tinyurl. com/y494hw5u) describes changing views of neuroscientists towards precognition.

In ZEO precognitions are naturally time-reversed memories. Classical signals giving rise to sensory experience arrive from geometry future in the standard frame. During sleep state precognition should be possible if sleep corresponds to time-reversed state for the self.

In the associative and computational models of brain our ability to predict the future is taken to be an extrapolation based on memories and experience of earlier life. This looks very reasonable but when one asks how these memories are represented, problems begin to appear. In TGD framework ZEO predicts that memories correspond to mental images in geometric past, in the simplest case, when the original event took place. This solves a huge problem of standard since memory storage becomes brain in 4-D sense rather than in 3-D sense [K94].

ZEO however implies that also time reversed memories are possible. If sleep state correspond to time reversed self about which we do not have direct memories, memories with reversed arrow of time would be possible in this state. Precognition becomes possible if these memories can be communicated to the wake-up state with the ordinary arrow of time. In dreams some parts of brain are awake and they could make possible this communication. The communicated information could be also conscious to some selves above or below us in the hierarchy. Dreams can indeed predict what happens during the next day. The classical book "An Experiment with Time" (see http: //tinyurl.com/jtqysty) of J. W. Dunne tells about precognitive dreams that he experienced.

Intuitive and formal logical reasoning in ZEO

The basic vision is that adelic space-time geometry provides correlates for sensory experience and cognition/imagination. Fermionic degrees of freedom would represent quantal Boolean mind. In ZEO given deterministic time evolution for 3-surface and induced spinor fields would give rise to sensory and cognitive time evolution and to Boolean evolution having interpretation as analog of logical deduction leading from premises to conclusions.

1. The basis of fermionic Fock states can be regarded as Boolean algebra. Superpositions and thus entanglement of fermionic qubits are however possible and one can speak about quantum Boolean logic. In standard view concepts are formally regarded as sets containing the instances of concept as elements. Quantum concepts could be superposition of quantum states representing the instances so that quantum abstraction would be much more complex notion than ordinary abstraction. Non-classical Boolean states would be superpositions of statements identifiable as abstractions. Schrödinger cat would be seen abstraction. "Dead" and "alive" would represent instances of this abstraction.

2. Zero energy states are superpositions of initial and final fermion states and there is also a superposition over 3-surfaces, and could be interpreted as representations for implications. The sum $\sum_{n} S_{mn} |n\rangle$, where S denotes unitary S-matrix, represents a superposition over all transitions $|m\rangle \rightarrow |n\rangle$ allowed by laws of physics. These transitions could be interpreted as logical implications.

One could argue that by diagonalizing S-matrix one obtains only diagonal transitions and the situation is rather trivial: just logical identities. The point is however that in number theoretical physics the diagonalization of S would in general lead outside the extension of rationals determining the adele and is therefore not possible. Same number theoretical mechanism would also stabilize negentropic entanglement and could force BSFR. Only state big state function reduction extending the extension of rationals can reduce this kind of entanglement.

3. Probably every mathematician has pondered the mystery of mathematical insight. How for instance mathematical insight is generated? What eureka experience is basically? Insight would correspond naturally to a big state function reduction leading to a new state reversing the arrow of time.

Truth can be deduced in given system of axioms also mechanically - at least in principle. How does insight relate to a logical deduction leading to a theorem? The final state of quantum jump is superposition of classical time evolutions leading from the final state to geometric past. With respect to standard arrow of time it is superposition of logical deductions leading from various initial states- initial assumptions - to the final state - to the outcome of the deduction. Superposition of states at boundary of CD could be seen as an abstraction. Deterministic time evolutions would represent the mechanical deductions.

Note however that in the time reversed state arbitrary long time evolution in opposite time direction is in principle possible and would correspond to an arbitrary long ordinary deduction or computation [L44]. After that a return to the original arrow of time would take place and provide the solution. The formal deduction leading to the outcome would be indeed forced by the outcome rather than vice versa?

Metabolism in ZEO

ZEO has also deep implications for biology. As already explained, ZEO allows to understand what behaviors, biological functions are at fundamental level.

Why metabolism is needed can be understood in TGD view about dark matter as phases of ordinary matter labelled by the value of effective Planck constant $h_{eff} = n \times h_0$, where n has also interpretation as dimension of extension of rationals giving rise to the extension of adeles [L67, L66]. n serves as a kind of IQ labelling different evolutionary levels and is bound to increase in statistical sense. Not only biology but also self-organization involving also energy feed could be understand in terms of the hierarchy of Planck constant.

In ZEO remote metabolism suggests itself as a completely universal purely thermodynamical mechanism of metabolism. Usually system loses its energy by dissipation. If the arrow of time is non-standard, systems seems to receive energy from environment. Note that the duration of time spent in time reversed state does not matter! What matters is the increment of time between states with same arrow of time! Sleep state could be seen also as a way to collect metabolic energy. BSFR can be seen as an act of free will - motor action and sucking of metabolic energy from "environment" would be very natural.

The interpretation for the return to the original time direction by second BSFR would be as beginning of sensory perceptions in standard arrow of time as sequences of SSFRs. During this period subsystem would be dissipating energy to environment.

18.2.3 Under what conditions does BSFR take place and what happens in it?

In the following the question under what conditions "Big" state function reduction (BSFR) takes place and what happens in it.

Two kinds of state function reductions

The discussion however requires the basic ideas of ZEO as background.

1. "Small" state function reductions (SSFRs)

Small state function reductions (SSFRs) are counterparts of so called "weak measurements", which are rather near to classical measurements in the sense that nothing drastic happens.

- 1. The passive boundary of CD does not shift but changes in size because active boundary shifts and this induces change of size. For state pairs defining zero energy states the members at passive boundary do not change and the coefficients of possibly time-entangled state defined as their superposition do not change. The members of state pairs at active boundary change and this change is induced by unitary time evolution between too SSFRs. This time evolution could be regarded as a generalization of adiabatic time evolution.
- 2. In statistical sense the active boundary shifts towards future and the size of CD increases. The temporal distance between the tips defines clock time in one-one correspondence with SSFRs. Note that the unitary evolution forms a superposition of CDs with different sizes and SSFR means localization to single CD size.
- 3. The moment "Now" of self would naturally correspond to the M^4 hyper-plane dividing CD into two pieces of identical size. The radius of this 3-ball would be r = T/2, where T is the temporal distance between the tips of CD. At this hyperplane expansion of 3-ball with light-velocity would transform to contraction.
- 4. The mental images of self would correspond sub-CDs and also they would shifts towards geometric future in the sequence SSFRs. They would form a kind of log file about the life history of self such that geometric time order would be opposite to subjective time order. Self could remember these experiences by sending signals to geometric future reflecting back in time direction seeing in time direction would be in question.

What is in sharp conflict with natural expectation is that the memories would be stored in geometric future and part of them would become un-changing permanent part for the time reversed re-incarnation of self- kind of Karma.

Note however that self might have also mental images represented as sub-CDs in geometric past.

- $M^8 H$ -duality suggests space-time picture about the "log files".
- 1. 4-D space-time surfaces in complexified M^8 having interpretation as complexified octonions are 4-D roots for octonion valued polynomial obtained as an algebraic continuation of a real polynomial with rational or even algebraic coefficients. $M^8 - H$ correspondence maps thee surfaces to minimal surfaces with 2-D singularities in H [L112, L110].
- 2. Besides this one obtains for any polynomial also special solutions as analogs of branes in M-theory. They have topology of 6-D ball and their projection to M^4 is $t = r_n$ hyperplane intersecting CD and with topology of 3-ball. r_n is a root of P and thus an algebraic number. I have called $t = r_n$ "very special moments in the life of self". Generalized vertices for particle reactions would correspond to partonic 2-surfaces localized at these 6-surfaces. At these surfaces incoming and outgoing partonic orbits would be glued together along their ends. The roots define positions of external particles at the boundaries of CD.
- 3. In SSFRs these balls at the active half of CD would shift towards future and new roots would emerge. These roots would define a geometric representation of the memories of CD as "log file" increasing in size. If there are sub-CDs associate with them, one would have mental images shifting towards future.

2. "Big" state function reductions (BSFRs)

"Big" state function reductions (BSFRs) correspond to ordinary state function reductions (SFRs) in ZEO. In BSFR the roles of active and passive boundaries of CD are changed and the

arrow of geometric time changes since the formerly passive boundary starts to shift to opposite time direction. State function reduction not commuting with the observables defining states at passive boundary as their eigenstates would takes place and the state at passive boundary would be changed. It would be however fixed by quantum dynamics. The findings of Minev *et al* provide support for the change of the arrow of time in ordinary SFR [L104].

The passive boundary can be shifted towards future so that the size of CD would decrease. One can say that the re-incarnate would be experience childhood. Note that also part of the "log file" about often personal experiences of self towards end of its life defining the permanent part of self-hood of the re-incarnate would disappear. The interpretation in terms of Karma is suggestive.

Remark: During a discussion with Marko Manninen, Marko noticed that people who have had near death experience often report that they experienced their entire life like a film during these moments. Could the "log file" representing stored mental images give rise to this experience at the moment of death?

What happens in biological death from TGD perspective?

What happens in biological death can be taken as a guideline in attempts to understand what happens in BSFR.

1. Death certainly occurs if there is no metabolic energy feed to the system. Metabolic energy feed is guaranteed by nutrition using basic molecules as metabolites. Since the increase of h_{eff} quite generally requires energy if other parameters are kept constant and since the reduction of h_{eff} can take spontaneously, the metabolic energy is needed to keep the distribution of values of h_{eff} stationary or even increase it - at least during the growth of organism and perhaps also during the mature age when it would go to increase of h_{eff} at MB.

If the size of CD for at least MB correlates with the maximum value of h_{eff} or its average, the size of CD cannot grow and can be even reduced if the metabolic energy feed is too low. The starving organism withers and its mental abilities are reduced. This could correspond to the reduction of maximum/average value of h_{eff} and also size of CD.

One can argue that if the organism loses metabolic energy feed or is not able to utilize the metabolic energy death and therefore also BSFR must take place.

2. In ZEO self-organization reduces to the second law in reversed direction of geometric time at the level of MB inducing effective change of arrow of time at the level of biological body [L113]. The necessary energy feed correspond to dissipation of energy in opposite time direction. In biological matter energy feed means its extraction from the metabolites fed to the system. One could say that system sends negative energy to the systems able to receive it. A more precise statement is that time reversed subs-system dissipates and metabolites receive the energy but in reversed time direction.

In living matter sub-systems with non-standard arrow of time are necessary since their dissipation is needed to extract metabolic energy. The highest level dissipates in standard time direction and there must be a transfer of energy between different levels. This hierarchy of levels with opposite arrows of geometric time would be realized at the level of MB.

Death as a re-incarnation with opposite arrow of time

These observations suggest that one should consider the reincarnation with opposite arrow of time with wisdom coming from the death of biological systems.

- 1. We know what happens in death and birth in biological systems. What happens in biological death should have analogy at general level. In particular, in death the decay of the system to components should occur. Also the opposite of this process with reversed arrow of time should take place and lead at molecular level to the replication of DNA and RNA and build-up of basic biomolecules and at the cell level to cell replications and development of organs. How these processes could correspond to each other?
- 2. The perceived time corresponds to the hyperplane t = T/2 dividing CD to parts of same size. Here T is the distance between the tips of CD and therefore to maximal diameter of

temporal slice of cd, which is 3-ball. The part of CD above it shifts towards future in SSFRs. In BSFR parts of the boundary of space-time surfaces at the active boundary of CD become unchanging permanent parts of the re-incarnate - kind of log file about the previous life. One can say that the law of Karma is realized.

If CD decreases in size in BSFR the former active boundary keeps its position but its size as distance between its tips is scaled down: $T \to T_1 \leq T$. The re-incarnate would start from childhood at $T - T_1/2$ and would get partially rid of the permanent part of unchanging self-hood corresponding to interval $[T - T_1/2, T/2]$ so that the permanent part of reincarnate would correspond to $[T - T_1/2, T]$. Reincarnate would start almost from scratch, so to say. The part between $T - T_1/2$ and T would be preserved as analog of what was called BIOS in personal computers.

- 3. At the moment of birth CD possibly would thus decrease in size and the former passive boundary now in the range $[T - T_1/2, T - T_1]$ and lower tip of new CD at $T - T_1$ would become active and the seat of sensory experience. Arrow of time would change. Where the analog of biological decay is located? The region of CD in the range $[T/2, T - T_1/2]$ disappearing from "log file" is the natural candidate. This region is also the place, where the events related to birth in opposite time direction should take place.
- 4. The decay of the organism should therefore correspond to the development and birth of re-incarnated organism at the level of MB (it must be also remembered that genuine time reversal takes place at the level of MB and induces only effective time reversal at the level of ordinary bio-matter). The decay of organism dissipates energy in standard time direction: this energy could used by the re-incarnate as metabolic energy. How long lasting biochemical processes have effective time reversals depends on the quantum coherence scale determined by the size scale of corresponding CD.

Could the re-incarnations with opposite arrow of time be seen in bio-chemistry?

The possible occurrence of effective time reversals at the level of bio-chemistry could be perhaps tested experimentally.

- 1. Could the replication of DNA and RNA and build-up of various bio-molecules be effective time-reversals for their decays. Could the same apply to the replication of cells and generation of organs. Replication of DNA is self-organization process in which second DNA strand serves as a template for a new one. The decay of DNA should therefore involve two DNA strands such that the second DNA strand serves as a template for the effectively time reversed replication. The double strand structure indeed makes possible for the other strand to decay first. Cell replication should use another cell as replicate and same would happen in the cell decay.
- 2. An interesting mental exercise is to imagine the time reversals of various basic processes like transcription and translation. In the time reversal of translation of mRNA to aminoacid sequence the amino-acid sequence and mRNA would return to ribosome machinery, and amino-acid and tRNA codon associated with tRNA would return to form tRNA. mRNA strand would shift one step backwards and the process would repeat itself and finally mRNA strand would return to open DNA strand. In the time reversal of transcription of DNA to mRNA, mRNA strand would return to open part of DNA strand, decay to RNA codons and eventually DNA strand would close. It should be easy to check whether these processes really occur in the decay process.
- 3. The formation of stem cells involves de-differentiation. Could it mean time reversal of the entire process leading to a differentiated cell? Also this idea could be tested.

In biology pairs of various structures often occur. Could they correspond in some sense to effective time reversals of each other whereas at the level of magnetic body one would have genuine time reversals

- 1. Could the opposite inherent chiralities of MBs of DNA strands correspond to opposite arrows of time at the level of MB of DNA realizing dark genetic code [L36]? Could this be seen as a kind of explanation for the double strand structure of DNA. Could the passivity of DNA strand with respect to transcription correspond to opposite arrow of time at the level of MB? Could the passive strand become active in time reversal?
- 2. Even brain has this kind of pairing. Right brain hemisphere is passive in the sense that it does not seem to contribute to wake-up intelligence (presumably identified as analytic intelligence). Could either hemisphere serve as a template in the development of brain or could this happen only at the level of MB of brain? Could different time arrows at the level of MB be used to understand the strange passive character of right brain and could one one understand the holism of right brain *viz.* analytic reductionism of left brain as reflection of the fact that dissipation as decay corresponds to time reversal for self-organization generating structures at the level of MB.

What about ordinary re-incarnation?

A couple of comments relating to the notion of re-incarnation in standard sense are in order.

- 1. Eastern philosophies talk about the possibility of liberation from Karma's cycle. Can one imagine something like this? The above picture would suggest that in this kind of process the reduction of the size of CD does not occur at all and therefore there would be no decay process equivalent to the growth of time reversed organism. This would serve as an empirical signature for the liberation if possible at all. CD would continue to increase in size or perhaps keep its size. It would seem that a new kind of non-biological source of metabolic energy would be needed.
- 2. Reincarnation is a basic notion in Eastern philosophies. In ordinary reincarnation person has memories about life of a person, who lived earlier. There is evidence for this. This cannot be understood in terms of time reversed re-incarnation.

Recall that there would be a hierarchy of selves and corresponding CDs within CDs. It has remained an open question whether CDs could also overlap? Could re-incarnation in ordinary sense be explained in terms of this kind of overlap?

Suppose that one has two overlapping CDs: CD_1 and CD_2 and that CD_2 extends farther to the future of CD_1 . The sub-CDs of CD_1 shift to future as the active part of CD_1 shifts to future and increases in size giving rise to a kind of log file defining the personal memories of CD_1 . In this kind of situation the mental images of CD_1 can enter to CD_2 and become mental images of CD_2 . This would be sharing of mental images but in different sense as compared to the fusion of mental images by entanglement, which could also require intersection of sub-CDs of mental images.

Could one imagine that the cosmos is full of selves serving as counterparts of memes wandering around and finding for selves hosting them by providing metabolic energy? Note that ZEO means that CD center of mass degrees of freedom do not carry any conserved quantum numbers so that the motion of these lonely CDs would not be restricted by conservation laws!

- 3. This picture suggests that CD:s form a conscious fractal atlas consisting of charts with various resolutions analogous to the atlas defining a covering of manifold by open sets. The earlier proposal was that in biological death MB redirects its attention to a new system. This picture would be modified: the MB of of CD_1 would still attend the time-reversed system and experience time-reversed life. Some sub-CDs of CD_1 would however belong to a new CD in its geometric future CD_2 . This conforms with the intuitive expectation that space-time surfaces continue outside CD and only the perceptive field of conscious entity is restricted to CD.
- 4. Mental images should correspond to sub-selves and therefore sub-CDs of CD. Contrary to what I have proposed earlier, it seems that after images cannot correspond to BSFR type re-incarnations of mental images nor re-incarnations in standard sense.

Mental images would shift towards the future together with active part of CD and form a kind of log file. Could after images be memories of previous mental images involving a signal time reflect from the the mental image in log file and creating the after image as a sensory memory of the earlier visual mental image? Or could one understand after images in terms of propagation of dark photon signals along closed magnetic loops giving rise to periodically occurring mental images.

In [L132] I discussed how the evolution of self by BSFRs could correspond to a transition to chaos as iteration of the polynomial defining the space-time surface. The proposed picture was that the evolution by SSFRs corresponds to iteration of a polynomial P assignable to the active boundary of CD. This would predict a continual increase of the degree of the polynomial involved. This is however only one possibility to interpret the evolution of self as iteration leading to chaos.

1. One could argue that the polynomial $P_{nk} = P_n \circ \dots \circ P_n$ associated with the active boundary remains the same during SSFRs as long as possible. This because the increase of degree from nk to n(k+1) in $P_{nk} \to P_{nk} \circ P_n$ increases h_{eff} by factor (k+1)/k so that the metabolic feed needed to preserve the value of h_{eff} increases.

Rather, when all roots of the polynomials P assignable to the active boundary of CD are revealed in the gradual increase of CD preserving P_{nk} , the transition $P_{nk} \rightarrow P_{nk} \circ P_n$ could occur provided the metabolic resources allow this. Otherwise BSFR occurs and self dies and re-incarnates. The idea that BSFR occurs when metabolic resources are not available is very natural for this option.

2. Could $P_{nk} \to P_{nk} \circ P_n$ occur only in BSFRs so that the degree *n* of *P* would be preserved during single life cycle of self - that *n* can increase only in BSFRs was indeed the original guess.

While preparing this contribution I learned about a highly interesting claim (https://tinyurl.com/yap8ss4p) made by the research group led by Harold Katcher. The claim is that the epigenetic age (there are several measures for it such as methylation level of DNA) of rats has been reduced up to 50 percent. The theory goes that epigenetic age of molecules would be controllable by hormonal signalling globally.

BSFR would mean death of conscious entity and its reincarnation with opposite arrow of time. The system would rejuvenate in the transition starting a new life in opposite time direction from childhood so to say - rejuvenation would be in question. Doing this twice would lead to life with original arrow of time but starting in rejuvenated state. The claim of the group suggests that living matter could do this systematically using hormonal control.

Tukdam and TGD

This piece of text was inspired by a document (https://rb.gy/abt8za) about a strange phenomenon known as Tukdam. What happens is that in Tukdam the person is physically dead but is believe to be in a continued meditation. There is no EEG, the heart does not beat, and there is no normal metabolism. However, the decomposition processes do not start. The condition can last up to a couple of weeks. Similar longer-lasting ones have been reported: a yogi can be buried underground for months in an oxygen-free state and then wake up.

This challenges neuroscience's view of the brain as the seat of consciousness. According to reports there could be awareness and a sensory experience consisting of different light sensations. The Tibetan Book of the Dead describes these experiences. Near-death experiences have many similar features [L154].

In the body in Tukdam, the area of the heart is reported to feel warmer to the touch than the rest of the body, but the thermometer does not detect this difference. This would indicate that the body receives metabolic energy at the cellular level from some other source than in the normal metabolism, and that living matter can detect what measuring devices based on the recent knowledge provided by modern physics cannot detect. Where could this energy come from? If one wants to answer this, one must also ask what happens in death and what is consciousness and what is life. 1. Dark energy and matter are the two basic puzzles of recent day physics. In the TGD approach, I have identified dark matter as a phase of ordinary matter, for which the effective Planck constant h_{eff} is much larger than normally.

In particular, the gravitational Planck constant $h_{eff} = h_{gr}$ assignable to gravitational flux tubes can be very large and makes quantum coherence possible even on astrophysical scales. Large Planck constants would be associated with the dark matter magnetic body, which would be the TGD counterpart to the magnetic field of Maxwell's theory, but would differ from it in many respects. As a quantum coherent unit, this magnetic body would control the ordinary biological body and induce its coherence. The classical energy of a magnetic body, consisting of volume energy and magnetic energy, would be dark energy.

- 2. In the TGD Universe dominated by zero energy ontology, consciousness is a universal phenomenon and present on all scales, from elementary particles to the level of the cosmos. Even galaxies, stars and planets would be conscious beings. Also life and death would be universal phenomena. Likewise, the biological decomposition process associated with death would correspond to the universal decomposition process, which would essentially correspond to the decomposition of magnetic monopole flux tubes (magnetic catabolism), which would induce the catabolism of the breakdown of biomolecules. Its time-reversed version would be magnetic anabolism and induce the building of bio-structures such as molecules.
- 3. The fundamental metabolic processes would be essentially magnetic anabolism and catabolism induced by "big" state function reductions (BSFRs) changing the arrow of time and inducing the biological anabolism and catabolism. Death would mean reincarnation with the opposite arrow of time.

In Tukdam, the biological body would be dead, but the magnetic body would still be alive and prevent the biological decay from starting. The disintegration of the magnetic body would start in Tukdam much later than normally, and initiate the disintegration of the biological body. The content of the conscious experience in Tukdam, light sensations and deep peace, would come from the magnetic body. The dead biological body would not provide contribution from sensory input, motor activity, and cognition.

By a strange accident, just before seeing the document about Tukdam, I wrote an article [L200, L208] about a seemingly completely unrelated topic, solar flares related to the reversal of the direction of the sun's magnetic field in the solar cycle, which has a period of 11+11 years.

The reversal of the Sun's magnetic field would correspond to magnetic catabolism as the breakdown of long monopole flux tubes into very short parts. It would be followed by magnetic anabolism as their re-fusion into long flux tubes. The solar cycle would correspond to the sleep-wake cycle, or more precisely: a series of lives in different directions of time. Death would only be a change of time's arrow, nothing final.

The model unexpectedly leads to a biological analogy and to understanding what might happen to the magnetic body in biological death.

18.2.4 Conditions on the periods with reversed arrow of time

In zero energy ontology (ZEO) falling asleep (death at"my" level of self the hierarchy) corresponds to ordinary - or "big" - state function reduction (BSFR) and also means a reincarnation with opposite arrow of time. We would be therefore conscious during sleep and wake-up would correspond to falling sleep of that other, time reversed self.

When I fall asleep, I wake-up later tomorrow morning for instance, not yesterday morning. It is interesting to see what kind of conditions this implies and whether it is possible to satisfy this easily and even more interesting is to see whether a time travel to the geometric past - maybe the Golden Youth - could be possible.

The following assumptions are made about what happens in BSFR.

1. Causal diamond (CD) is a correlate for self. CD is obtained by gluing together two identical half-cones along their bottoms. Moment "Now" corresponds to the largest hyperplane $T_{now} = T$ (origin of time coordinate is at either (call it "lower") tip of CD).

- 2. During the sequence of SSFRs defining self, the 3-surfaces at the passive boundary of self are fixed although their 4-D tangent space changes and corresponds to the unchanging part of selfhood soul one might say. The opposite active boundary of CD and 3-surfaces at it change and shift towards geometric future. This gives rise to wake-up consciousness involving sensory input and thoughts, emotions etc. induced by it. Each SSFR is preceded by the analog of unitary time evolution.
- 3. BSFR means a death of self (subself) and its reincarnation with an opposite arrow of time. One can equally well speak about the analog of falling in sleep and waking up after that for some level of hierarchy of selves. The self born in the death of the self with an opposite arrow of time self has no direct memories about the state. Self can however have memories about dreams in which part of say brain is awake. These memories store information about what self experienced during the sleep.

In BSFR the active boundary of the CD becomes passive and is frozen. The size of CD is scaled down so that CD becomes small: this implies that the reincarnated self has a childhood and much of the memories - often not pleasant - stored near the active boundary as subselves living forth and back as conscious entities disappear. The surviving memories of self become "silent wisdom" of the reincarnated self.

4. If CD belongs to a larger CD, call it CD_{super} representing a larger unit of consciousness, the sub-CDs must shift to the same direction as the active boundary of CD_{super} . Otherwise the sub-CDs would drop from the flow of consciousness. This is analogous to co-movement of matter in cosmology.

Note that the mental images of self correspond to sub-CDs around T_{now} and shift towards geometric future as CD increases and new mental images emerges at T_{now} plane: by $M^8 - H$ correspondence these special moments in the life of self correspond to roots of the polynomial defining space-time surface and reside are the upper half-cone of the CD. As CD increases, new roots pop up inside the upper half-cone near the T_{now} hyper-plane for some particular SSFRs. Completely counterintuitively, the mental images about past experiences are therefore in the geometric future of T_{now} hyperplane!

The proposed picture must be consistent with everyday experience. Call the two periods of self sleep wake-up and sleep label the two different BSFRs by "sleep" and "wake-up".

1. In each SSFR CD size increases - at least in statistical sense this implies that T grows. Each SSFR corresponds to a scaling for the CD shifting its active boundary towards the geometric future. During its life cycle CD experiences scaling Λ :

$$T_{now} \rightarrow T_{now,sleep_1} = \Lambda(SSFR)T_{now}$$
, $\Lambda(SSFR) > 1$.

2. When the system falls in sleep the size of CD is scaled down so that also the value of T_{now} is scaled down by $\Lambda_{BSFR} < 1$:

$$T_{now,sleep_2} = (1 - \Lambda(BSFR))2T_{now,sleep_1} = (1 - \Lambda(BSFR))\Lambda(SSFR)2T_{now}, \quad \Lambda(BSFR) < 1$$

After that the CD begins to increase in size by small scalings in SSFRs to opposite time direction and T_{now} begins to decrease from its value $T_{now,sleep}$ begins to decrease.

3. If CD belongs to a bigger CD - call it super-CD - representing a larger unit of consciousness with a longer life cycle, one can argue that the CD must shift to the same direction as the larger CD increases. Otherwise the CD would drop from the flow of consciousness defined by super-CD. This is analogous to co-movement of matter in cosmology. Therefore a given life cycle corresponds also a shift ΔT of sub-CDs towards the growth direction of super-CD takes place and one has for the time coordinate $T_{super,now}$ of the super-CD. Therefore one must perform shift $T \rightarrow T + \Delta T$ for $T_{now,sleep_1}$ and $T_{now,sleep_2}$ to take into account the drifting. This gives for the moments "Now" before ad after the shrinking of CD in BSFR (falling asleep):

$$\begin{split} T_{super,now,sleep_1} &= T_0 + T_{now,sleep_1} + \Delta T ~~, \\ T_{super,now,sleep_2} &= T_0 + (1 - \Lambda(BSFR)) 2 T_{now,sleep_1} + \Delta T \end{split}$$

4. Similar formula holds true for the moment of wake-up. In the previous formula T_{now} is replaced with $T_{now,sleep_2}$ and one has

$$\begin{split} T_{super,now,wakeup_1} &= T_0 + \Lambda^{10}(SSFR)T_{now,sleep_2} + \Delta T^{10} \quad , \\ T_{super,now,wakeup_2} &= T_0 + (1 - \Lambda^{10}(BSFR))\Lambda^{10}(SSFR)2T_{now,sleep_2} + \Delta T^{10} \end{split}$$

The parameter T_0 depends on the choice of the origin of time for super-CD but is irrelevant.

One can deduce a consistency condition for the parameters of the model.

1. During the sleep period the time coordinate $T_{super,now}$ for moment "Now" in the coordinates of larger CD changes in the following manner:

$$\begin{split} T_{super,now,sleep} &= T_0 + T_{now,sleep_1} \to T_{super,now,wakeup} \\ &= T_0 + \Lambda^{1)}(BSFR)T_{super,now,sleep_2} + \Delta T^{1)} ~. \end{split}$$

 T_0 is an irrelevant parameter associated with super-CD. Note that there is breaking of time reversal symmetry since self associated with CD_{super} has fixed arrow of time unlike CD. Hence ΔT has at least in a statistical sense the same sign irrespective of the arrow of time of self.

2. This picture should be consistent with what we observe. When the tired average self fall a sleep at the evening, it wakes wake-up at the morning and is full of energy. Quite generally, wake-up occurs after time $\Delta T(sleep)$ meaning that the value of time T_{super} has increased by

$$T_{super,now,wakeup} = T_{super,now}(sleep_1) + \Delta T(sleep)$$
.

These two expressions for the value of $T_{super,now}(wakeup)$ must be consistent and this gives a conditions on the parameters involved:

$$\begin{split} &(1 - \Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2T_{now,sleep_1} + \Delta T^{1)} \\ &= T_{now,sleep_1} + \Delta T + \Delta T(sleep) \quad . \end{split}$$

 $\Delta T(sleep)$ is given by

$$\Delta T(sleep) = \left[(1 - \Lambda^{1}(BSFR))\Lambda^{1}(SSFR)2 - 1 \right] T_{now,sleep_1} + \Delta T^{1} - \Delta T \quad .$$

Intuitively it seems clear that for a given arrow of time it is not possible to wake-up before one falls asleep, and the condition $\Delta T(sleep) > 0$ for the standard arrow of time gives a constraint on the parameters. One cannot however exclude the possibility of time travel without dying or falling asleep first of the duration of time travel is much longer than that of wave-up period: $\Delta T^{(1)} - \Delta T$.

A special solution corresponds to $\Delta T(sleep) = \Delta T^{1} - \Delta T$ and $(1 - \Lambda^{1}(BSFR)) 2\Lambda^{1}(SSFR) = 1$ giving $T_{now,sleep_2} = T_{now}$.

18.3 Still about quantum measurement theory in ZEO

The relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision could be much clearer. The following considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them.

In the sequel ZEO based theory of consciousness [L69, L118] as quantum measurement theory is discussed first by starting with a criticism of physicalism and after that introducing ZEO based view about consciousness as quantum measurement theory as a solution to the problems of physicalism.

After this the relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision [L66, L67] is discussed. The considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them. One can generalize classical cognitive representations as number theoretical discretizations of space-time surfaces in the extension of rationals considered to their quantum counterparts as wave functions in the Galois group of the extension and introduce also fermions as spinors in the group algebra of Galois group. The strongest option is purely number theoretical representations of spinors as spinors in this group algebra. Presumably however M^8 spinors are required and have interpretation in terms of octonion structure.

An attractive vision is that number theoretical quantum measurements reduce to measurement cascades involving a sequence of state function reductions reducing the entanglement between wave functions in sub-Galois group H and group G/H and ends up to a prime Galois group for group algebra has prime dimension and represents Hilbert space prime not decomposable to tensor product.

Also time measurement is considered from the number theoretic perspective assuming $M^8 - H$ duality [L110]. Clock readings are realized as roots of the rational polynomial determining the space-time surface in M^8 . Time measurement would involve a localization to a definite extension of rationals, whose dimension n must be proportional to the temporal distance T between the tips of causal diamond (CD) to guarantee fixed time and energy resolution.

18.3.1 ZEO based theory of consciousness as quantum measurement theory

Consider first zero energy ontology (ZEO) based quantum measurement theory as a theory of consciousness.

Criticism of physicalism

It is good to start with a criticism of physicalism.

1. In physicalism consciousness would reduce to a physical property, like energy, momentum or charge and one would have the hard problem. There would be absolutely no idea why for instance sensory qualia emerge and how they correspond to sensory input. For instance, the assignment of sensory qualia to brain regions leads to a mystery: auditory, visual, etc. areas look exactly the same. How they can give rise to so different qualia?

Remark: The answer to the question is that this is not possible. I n TGD framework macroscopic quantum coherence and ZEO allow to assume that sensory qualia are seated at sensory organs [L57].

- 2. This is not the only problem: free will is not possible and we must stop talking about ethics and moral as we have indeed done in modern free market economy, which threatens to destroy our civilization.
- 3. The third problem of physicalism and also idealism is that conscious experience is about something: it carries information about something, external world, my body, even about my thoughts. It is associated with a pair of systems- me and the rest of the world - rather than single system as consciousness as a physical property implies. This "aboutness", kills the physicalistis view and actually idealism and under reasonable assumptions also dualism. Standard ontologies of consciousness fail.
Physicalistic approach has also problems with quantum measurement theory. The basic problems are basically due to the fact that observer as a conscious entity remains an outsider: observations affect the measured system but theory cannot say anything about observer as subjective entity. In ZEO the situation is different [L118] (http://tinyurl.com/wd7sszo).

- 1. Quantum jump defines the basic building brick of conscious experience. It is something between two different quantum worlds, not in the world as a physical property of quantum system. Consciousness is a moment of re-creation. This a solves the hard problem and problem of free will.
- 2. Also the paradox of state function reduction can be solved if one can understand the problems related to the notion of time. There are two times: experienced time and geometric time, or the clock time. They are very different. Experienced time irreversible and has preferred moment "Now". Geometric time reversible and without preferred "Now". For some reason these times have been however identified.

ZEO based quantum measurement theory

In ZEO physical states as time= constant snapshots are replaced by pairs of "initial" and "final" states A and B or - by holography - with superpositions of deterministic time evolutions from A to B with respect to geometric time - note the analogy with computer program in computer science, behavior pattern in neuroscience, and function in biology.

- 1. In "small" state function reductions (SFRs) "weak" measurements the superposition of time evolutions from A to B is replaced with a new one such that states A at passive end "initial state" are not changed. Classical determinism is respected although one has quantum jump and generalization of quantum measurement theory. Two times two causalities. The temporal distance T between A and B increases in statistical sense and this gives the correspondence between experienced time as sequence of state function reductions and geometric time is identified as T. These measurements changing B correspond to "weak" measurements analogous to classical measurements and to sensory input. A represents permanent part of selfness, "soul" one might say.
- 2. In "big" (ordinary) state function reductions (BSFRs) the roles of "initial" and "final" states change and the arrow of geometric time changes. Self dies and reincarnates with an opposite arrow of geometric time.
- 3. In more precise view the pairs of time=constant snapshots are replaced with what I call causal diamonds (CDs). The assumption that the size of CD is preserved In BSFR as assumed originally leads to some paradoxical looking implications. For instance, the size of CDs assignable to our sub-selves identifiable as mental images would increase without bound. $M^8 H$ duality suggests strongly that the sizes of CDs can decrease in BSFR: the formerly active boundary would be frozen but the temporal distance of formerly passive boundary would be reduced so that the size of CD would decrease. One could say that self has childhood and starts from scratch with all sins of previous life forgiven.

This picture about state function reduction finds considerable empirical support.

- 1. The paradoxical experimental findings of Minev *et al* in atomic systems challenging standard quantum measurement theory give strong support for the reversal of the arrow of time in BSFR [L104] [L104] (http://tinyurl.com/yj9prkho).
- 2. Also Libet's finding that experience of free will [J4] seems to be preceded caused by neural activity, can be understood. It is not anymore support for the claim that free will is an illusion. State function reduction changing time order happens, and free will causes neural activity in the geometric past.
- 3. There is are lot of support for the new view about time from biology. For instance, selforganization - not only biological - could be understood as involving time reversal meaning that the time reversed reduction of order implied by generalization of second law looks

from standard observer's viewpoint like increase of order. Self-assembly and generation of structures in long scales would involve increase of time order. Evolution is second aspect of self-organization and reduces to the unavoidable increase of h_{eff} as dimension for extension of rationals. Also the need for energy feed - metabolic energy feed in living matter - can be understood because the increase of h_{eff} keeping other parameters constant, increases energy scale. Dark matter would be visible everywhere in sharp contrast with standard prejudices.

4. There is support even from cosmology and astrophysics, where TGD predicts quantum jumps in macroscopic scales. For instance, stars older than Universe can be understood in more detailed picture about ZEO [L105, L106] (http://tinyurl.com/tf38xnx).

One can of course criticize the view about the role of clock time as the distance T between the tips of CD as over-simplified [L118].

1. The state function reductions preceding SSFRs are preceded by unitary processes U. What one can say about "time evolution" U. First of all, U is assumed to produce a zero energy state de-localized in the space of CDs - in particular with respect to the distance T between the tips of CD.

The simplest guess is that in SSFR a complete localization in T - measurement of T - and other moduli of CD (say boost with respect to the lower tip of CD) occurs. Can one reduce the localization in T to a SSFR reducing quantum entanglement or is time measurement something different? What entanglement of CD sizes with different values of T with the measurement apparatus could mean? What the presence of a measurement apparatus for time T - the clock at fundamental level, could mean mathematically? Later also the question whether one could reduce this measurement to pure number theory emerges?

2. The notion of completely localized state is over-idealization and also mathematically poorly defined. Gaussian wave packet over classical states with well-defined classical conserved energy (by Poincare invariance) with respect to T localized around some value T_0 is a more realistic notion and time measurement would mean localization to a wave packet around T_0 .

In [L118] the proposal that the time evolution of self could be seen an analog of cooling process analogous to cosmic cooling is considered. This would correspond to an adiabatic time evolution happening for a particle in box whose size increases slowly. In this process the coefficients in a superposition of states with given classical energy remain unaffected but the classical energies of the states themselves decrease. This would conform with Uncertainty Principle stating that the classical energies scale as 1/T.

A more detailed view about quantum measurement in ZEO

Consider next in more detail what state function as quantum measurement means in TGD.

- 1. In standard quantum measurement theory quantum measurements are often thought to be performed by humans only. In TGD one assumes that state function reduction as analog of quantum measurement is universal and can take place for any pair of mutually entangled systems unentangled from its complement.
- 2. Density matrix for the entangled pair of systems is the fundamental observable. This applies to both BSFRs and SSFRs at active boundary of CD, which correspond to "weak" measurements commuting with the observables diagonalized at the passive boundary of CD and thus leaving the states at it invariant.
- 3. Quantum measurement involves typically measurement of several observables. This is realized as a measurement cascade. First the quantum measurement of density matrix occurs for some pair formed sub-system S_1 and its complement S_2 forming together system S. After the same occurs for S_1 and S_2 . Observables correspond to density matrices in this cascade. One proceeds as along as new decompositions are found. If the final state belongs to a sub-space with prime dimension the cascade stops since there is no further decomposition to tensor product.

4. The density matrix for subsystem in general case decomposes to a sum of projectors t subspaces and the state function reduction takes to one of them. The outcome of the measurement can be sub-space rather than ray.

Number theoretic vision suggests also a second possibility. The SSFR would take place only if the eigenvalue of density matrix having probability interpretation associated with the subspace or ray is in the extension of rationals associated with the matrix elements of the density matrix and space-time surfaces considered (defining the cognitive representation). If one assumes frequency interpretation of probability theory, this probability must be rationals. Entanglement can be number theoretically stable. This would that one can have stable entanglement.

It is natural to assume that BSFR can can increase the extension of rationals associated with the eigenvalues of density matrix in the extension of the extension associated with its matrix elements.

5. Stable entanglement could be crucial for quantum computation as also the possibility of large values of h_{eff} and of time reversal. One can also assign to entanglement with coefficients in an extension of rationals p-adic variant of entanglement entropy by replacing logarithms of probabilities with the logarithms of their p-adic norms. These p-adic entanglement negentropies can be positive so that the entanglement carries information. This negentropy is different from the real negative entropy due to the loss of precise knowledge about entangled states. Quite generally, the sum of p-adic negentropies can be larger than real entropy. This would explain the paradoxical looking fact that highly evolved biological systems are highly entropic [I159] [L26]. england

18.3.2 The relationship between adelic physics and ZEO based quantum theory

The challenge is to formulate quantum measurement theory taking into account the constraints from adelic physics [L66, L67]. One can consider the possibility is that the quantum physics could reduces at the level of cognitive representations to purely number theoretic physics. This would mean huge simplification. I have considered quantum theory at the level of cognitive representations from the point of view of number theory in [L115] and from the perspective of scattering amplitudes in [L114].

Two kinds of cognitive representations

One can consider two kinds of cognitive representations. The cognitive representations considered hitherto correspond to number theoretical discretization of space-time surface determined by an extension of rationals, they are "classical". The bosonic wave functions in Galois group of extension acting on cognitive representations and their fermionic counterparts based on fermionic dynamics in the group algebra of Galois group and its normal subgroups (Galois groups too) would define quantal cognitive representations.

- 1. There are cognitive representations both at the classical level in terms number theoretical discretizations of space-time surfaces defined by the extension of rationals and at the quantum level based on spinorial wave functions in Galois group of the representation. Also the spinorial wave functions in factor sub-groups and normal subgroups of Galois group are involved.
- 2. One can assign preferred primes p_{pref} to the classical space-time dynamics as ramified primes p_{ram} of the extension. For these the polynomial defining extension has double root in O(p) = 0 approximation. This would be the realization of quantum criticality for cognition: criticality is typically in potential models a situation in which two or more extrema of the potential function co-incide catastrophe theory of Thom is classical example.
- 3. At the level of state (spinorial) space wave functions in Galois group acting on cognitive representations are natural candidate for a bosonic state space. Quantum states would be

wave functions in Galois group G with normal subgroup H acting as a Galois group of lower-D extension.

G/H is group itself and one can express wave functions in G as superpositions of products wave functions in G/H and H. The wave functions in G/H and H define naturally a tensor product and an attractive idea is that state function reduction can be regarded as measurement in G/H or equivalently in H. When H has prime order further reduction is not possible since Hilbert spaces with prime dimension are primes of tensor product.

A natural candidate for preferred primes p_{pref} is as orders of smallest possible normal subgroups of Galois group, kind of primitive generating Galois groups.

Remark: One must consider also the possibility that quark and possibly also leptonic degrees of freedom are present as additional spinor indices. The fact that M^8 has octonionic structure could require also M^8 spinor structure.

4. In TGD dark matter is identified as $h_{eff} = n \times h_0$ phases of ordinary manner. *n* is identified as the order of Galois group of Galois extensions and thus of the extension itself. For ordinary value of Planck constant empirical inputs suggests the identification $h = 6h_0$ [L41, L83].

Quite interestingly, one has $6 = 2 \times 3$ so that there is factorization to 2-D and 3-D subspaces assignable to massless particles, and massive gauge bosons. This indeed suggests that number theoretical vision could allows to represent all many-particle states in terms of wave functions (spinor fields) in the group algebra of Galois group.

5. How to construct cognitive representations for fermions? A natural generalization of the bosonic dynamics in *n*-D group algebra of Galois group is introduction of spinor structure in terms of 2^k -dimensional spinors in the group algebra. For k = n both chiralities are present and for k = n - 1 only second chirality. In fact, one could pose even more chirality conditions giving $2^{n/2}$ -D ([n + 1]/2-D) spinors for even (odd) *n*. Indeed, the recent view about SUSY in TGD framework suggests that only quarks - second embedding space chirality - appear as fundamental fermions and that leptons are local composites of 3 quarks - spartners of quarks in well-defined sense [L119] (http://tinyurl.com/y4pdb2xz).

The simplest option is that at the level of cognitive representations the fermionic oscillator operator algebra corresponds to the oscillator operator algebra creating fermions states having at most k = n, k = n - 1, ... n/2 ([n + 1]/2) fermions assignable to these spinors in finite measurement resolution. Entire quantum dynamics at the level of cognitive representations would reduce to the dynamics of fermions in the group algebra of Galois group and its Galois sub-groups.

6. There is also question about the Galois groups of the extensions of various p-adic number fields Q_p induced by the extension of rationals with dimension n. For p-adic numbers in approximation the extension reduces to a finite field G(p,k), $k \leq n$, and one has k-dimensional extension. Galois group G_p is smaller than the Galois group G for rationals. G_p would act naturally in the p-adic counterparts of cognitive representations and the representations of G would reduce to direct sums of representations of G_p . Note that the distinction between sensory and cognitive (real and p-adic) would emerge only at the quantum level.

For p < n+1 the fact that one has $x^{p-1} = 1$ for G(p) implies that the irreducible polynomial P defining the extension Q reduces to a polynomial with degree $nmodp-1 \le p-1$. Information is lost for p < n+1. For $p \ge n+1$ situation is different but also in this case the reduction occurs for ramified primes since polynomial P as in this case multiple roots. This would be the counterpart of quantum criticality at the level of cognitive representations.

7. Could the primes appearing as factors of n be preferred p-adic primes? Since these primes as p-adic primes mean a loss of information, they are distinguished but hardly preferred in p-adic evolution. Ramified primes larger than n are more plausible candidates and can be assigned even with polynomials of order 2. The preferred p-adic primes assignable to elementary particles are indeed large: electron would correspond to $M_{127} = 2^{127} - 1 \sim 10^{38}$ [K68].

Quantum measurement theory for cognitive representations

What can one say about quantum measurement theory for cognitive representations? The basic questions concern the tensor products. How many tensor factorizations there are and can one pose some conditions on them? Assume that fermionic Fock states for second quantized spinor fields in n-D group algebra are enough for quantum physics at the level of cognitive representations.

1. Tensor product decomposition for *n*-D group algebra corresponds to the factorization $n = k \times l$. All factorizations of *n* define a possible quantum measurement situation and state function reduction can take place in bosonic sector to *k* or equivalently *l*-dimensional space. These factorizations would be highly unique since they correspond to pairs of Galois group *G* and its Galois subgroup *H*. They are defined modulo discrete automorphism of *G*. It is not clear whether the choice of this automorphism has physical content: one might consider a discrete variant of gauge invariance.

For the fermionic oscillator algebra analogous statement holds true. Now the decompositions are induced by $n = k \times l$ decompositions.

2. State function reduction cascades would correspond to sequences of Galois subgroups $G \supset G_1 \supset \dots G_k$ such that G_k corresponds to either trivial group of group with prime order. In this case the final state would be reached by a factorization in which the density matrix for G_k does not allow eigenvalues in the extension considered. This extension could be G, G_1 or perhaps rationals (frequency interpretation for probabilities).

$M^8 - H$ duality and measurement cascade

- $M^8 H$ duality [L110] suggests much more concrete picture about the measurement cascade.
 - 1. $M^8 H$ duality predicts that the roots r_n of a rational polynomial defining the space-time surfaces at the level of M^8 correspond "very special moments in the life of self" $t = r_n$ for the M^4 linear time in the rest system of CD, and that once these moments have been experienced, BSFR can take place. This is possible but not the only possible interpretation.
 - 2. $M^8 H$ duality and the view about evolution as analog of genetic evolution in which geness are conserved suggests that the polynomials can be regarded as functional composites of simple polynomials $P = P_{n_1} \circ P_{n_2} \circ \dots P_{n_k}$ satisfying $P_{n_r} = 0$ (n_i refers to the degree of the polynomial). P possesses the roots of P_i and the corresponding Galois groups as normal subgroups as the counterpart for the conservation of genes in evolution.

One can distinguish also primitive polynomials as those defining extensions which do not decompose further. Galois groups with prime number of elements corresponds to such extensions. Note that the same extension can appear at several levels in hierarchy and would correspond to a realization of extension at different hierarchy level defining a kind of abstraction level.

3. Intuitively the measurement cascade should correspond to a cascade proceeding to shorter time and length scales by increasing the resolution and also to a process in which abstraction is gradually concretized.

Could the measurement cascade for a state localized to a given extension of rationals start with the measurement of the root set $X_1 = \{r_{1,1}\}$ of P_{n_1} corresponding to the lowest time resolution. After than P_2 and the root set $X_2 = \{r_{2,i}\}$ would be measured meaning a refined of time resolution replacing $r_{1,i}$ with as subset of X_2 around it.

Here one must be however very cautious: one could also consider a hierarchy of CDs with decreasing size scales as the counterpart of the measurement cascade. I do not understand well enough the scale hierarchy to answer the question whether these two views might relate.

Measurement of time number theoretically

Could the measurement of clock time T as (average) distance between the tips of CD [L118] be understood as number theoretical measurement?

1. What about the measurement of time as the distance T between tips of CD or more generally as the center of mass value T_0 of T in the case that one has Gaussian wave packets localized around varying T_0 ? How could one realize the measurement apparatus - the clock - in terms of entanglement?

Suppose that the superposition over CDs with different values of T corresponds at the level of space-time surfaces in M^8 to that for space-time surfaces determined by polynomials P_n with varying degrees and rational coefficients. The measurement fixing the extension and Galois group would not fix P_n since there is a large number of polynomials with rational coefficients but same Galois group. The measurement fixing the extension leads to a partial (at least) localization in T or T_0 but this is not expected to be enough.

2. A stronger localization in the state function reduction measuring n would require that T or T_0 correlates with the degree n. How could this be achieved in a natural manner? Intuitively the requirement of some fixed time resolution based on the preferred moments $t = r_n$ interpreted as clock readings has fixed resolution as the average time lapse $\Delta T = \langle \Delta T_{i,i+1} = r_{i+1} - r_i \rangle$ would require $n \propto T$ or $n \propto T_0$. How could this be achieved concretely? Could one specify the zero energy states by giving the time resolution as ΔT and being equivalent to energy resolution. This would also dictate the resolution of the cognitive representation as the set of space-time points in the extension.

18.4 Some questions concerning zero energy ontology

Zero energy ontology (ZEO) [L118] gives rise to quantum measurement theory, which naturally extends to a theory of consciousness. In this article also consciousness aspect is central and my sincere hope is that it would not expel those physicist readers for whom consciousness still remains an unscientific notion.

Zero energy ontology (ZEO) briefly

ZEO provides a new ontology solving the key problem of the standard quantum measurement theory and quantum theory itself. It must be emphasized that ZEO is not a new interpretation created to put under the rug the logical paradox due to the conflict between non-determinism of state function reduction (SFR) and the determinism of unitary time evolution. Also the problem about the scale in which quantum world becomes classical disappers: the Universe is quantal im all scales and ZEO view about quantum jump makes the Universe to look like classical.

1. At the level of space-time dynamics, the notion of preferred extremal (PE) as a space-time surface is central: PE is an extremal of an action principle, which by general coordinate invariance must be highly unique once its intersection with either boundary of causal CD $= cd \times CP_2$ (cd is the intersection of future and past directed light-cones of M^4) is given. In the ideal situation this implies holography. Space-time surface is an analog of Bohr orbit and classical theory is an exact part of quantum theory.

There is probably a finite and discrete non-determinism analogous to that associated with soap films spanned by a frame: space-time is indeed a minimal surface as also soap films, and the 3-surfaces at its ends at boundaries of CD are part of the frame. Besides space-time surface is an external for Kähler action analogous to Maxwell action. The challenge is to interpret this finite non-determinism.

2. Quantum states, which I call zero energy states, can be interpreted as pairs of analogs of ordinary 3-D quantum states with positive energy. The members of the pair are at the opposite boundaries of CD. The convenient convention used also in quantum field theories (QFTs) is that the conserved quantum numbers at opposite boundaries sum up to zero classically: this brings in nothing new. At quantum level, 4-momenta are conserved only at the limit when CD has infinite size whereas classically the conservation holds true for all CD sizes: this reflects the Uncertainty Principle [L169]. Also in QFTs exact momentum conservation is obtained only at the limit of infinite quantization volume.

At the space-time level, zero energy states can be regarded also as superpositions of deterministic time evolutions: this is central for the interpretation.

- 3. SFRs are quantum jumps between zero energy states. SFR does not affect any deterministic time evolution but only replaces their superposition with a new one. This solves the paradox that was one of the key motivations for ZEO.
- 4. Zeno effect strongly suggests that there are 2 kinds of quantum measurements assignable to SFRs. For "weak measurements", "small" SFRs (SSFRs), the component of zero energy state at the either boundary of CD, to be called passive boundary (PB), is unaffected. Also the PB is unaffected apart from scaling. At the active boundary (AP) state changes and AP is scaled up (at least in statistical sense) and due to the scaling shifts to the geometric future.

The unitary time evolution preceding each SSFR corresponds to a scaling of CD (or rather, its M^4 projection cd) rather than time translation as its counterpart in string models. In A unitary evolution B between two SSFRs a superposition of CDs with varying sizes is formed and SFR localizes CD to a fixed size, which means the measurement of geometric time identifiable as the distance between the tips of CD. This geometric time correlates with the subjective time defined by the sequences of SSFRs. Subjective and geometric times are not identical as in standard ontology but only correlated.

5. "Big" SFRs (BSFRs) are the counterparts of ordinary quantum measurements. In the BSFR the roles of AB and PB of CD change so that the arrow of time changes since CD increases in the opposite direction of time (at least in statistical sense). For an observer with an opposite arrow of time, BSFR looks like an average deterministic time evolution leading to the final state of BSFR as observed experimentally by Minev *et al* [L104] [L104]. This illusion makes BSFR look classical in all scales although the TGD based dynamics is quantal in all scales due to the hierarchy of Planck constants predicted by TGD.

The possibility of time reversal forces a generalization of thermodynamics to allow both arrows of time: this kind of generalization was proposed long ago by Fantappie [J33] with motivation coming from biology. Quite generally, self-organization processes seem to violate the arrow of time. External energy feed explains this partially but BSFR would be an important additional element of self-organization [L113, L162], especially so in living matter.

The assignment of "free will" to BSFR allows us to understand how free will can be consistent with the classical non-determinism of physics which would be exact.

ZEO based quantum measurement theory and therefore also physics naturally extends to a theory of consciousness, and one cannot avoid using this word, which is still a cursed word in the physicalistic camp.

Problems related to the mathematical realization of ZEO

There are several open questions related to ZEO and TGD inspired theory of consciousness and the existing view involves several working hypothesis which should be reduced to deeper principles or shown to be wrong.

At least the following questions related to physical interpretation of ZEO are still waiting for a detailed answer.

1. Preferred extremal (PE) property of space-time surfaces is central for quantum TGD [L138]. It follows from holography forced by general coordinate invariance (GCI), which however need not be ideal. How uniquely does the PE property of the space-time surface fix the space-time surface inside a given CD? The simplest situation is that the data at the end of the space-time surface at either boundary of the CD, fixes it completely. Space-time surface would be an analog of Bohr orbit.

Full determinism would imply that WCW for CD effectively reduces to the space of 3-surfaces assignable to either end of CD. The dynamics of SSFRs would reduces to that in fermionic degrees of freedom assignable to Boolean cognition since WCW degrees of freedom assignable to sensory perception would be fixed.

However, the dynamics of soap films spanned by frames suggests that this is not the case. The 3-D ends of the space-time surface define a frame and also dynamically generated portions of frame are allowed by the variational principle defined by the sum of a volume term and Kähler action as an analog of Maxwell action. The coefficient of the volume term has an interpretation in terms of a length scale dependent cosmological constant Λ .

Outside the frame space-time surface would be at least for a very large portion of extremals an analog of complex surface and therefore a minimal surface [L174] and also an extremal of Kähler action. At the frames only the equations for the entire action (sum of volume term and Kähler action) would be satisfied. The divergences of the conserved isometry currents for the volume term and Kähler action would have delta function type singularities but they would cancel each other. The portions of the frame could be analogous to singularities of analytic functions such as cuts and poles.

2. Number theoretic universality [L67, L66] in turn suggests that the inherent non-determinism of p-adic differential equations [K80] [L118] proposed to be a correlate of imagination could also relate to this non-determinism. How do the non-determinism of space-time surface, p-adic non-determinism, and non-determinism of the state function reduction relate to each other: could they be even one and the same thing?

ZEO based quantum measurement theory defines a theory of consciousness. How unique is the interpretation of zero energy ontology (ZEO) [L118]? Here 3 options suggest themselves corresponding to "western" and "eastern" world views and their hybrid.

- 1. For the western option, the space-time surface continues outside any CD as external world, in particular sub-CD and sub-CD is a correlate for the perceptive field of self.
- 2. For the eastern option, space-time ends at the boundary of any CD and sub-CD is not a correlate for the perceptive field of self and there is no constraint from the external world at boundaries of CD.
- 3. For the hybrid of these two options, conscious entity corresponds to a hierarchy of CD for which the highest level corresponds to CD for which space-time does not continue outside the CD. The highest level represents a God-like entity.

Problems related to ZEO based theory of consciousness

The new picture about sub-CDs at WCW level raises questions related to the TGD inspired theory of consciousness. This view involves several ad hoc assumptions related to the notions such as attention, mental image, memory, volition and intentions. Do these assumptions follow from more general assumptions or can some of them be simply wrong?

1. CD is a correlate for the perceptive field of self. Sub-CDs of CD define perceptive fields of subselves identified as mental images. What is the precise definition of sub-CD? Can one say that a sub-CD is created when a mental image is created. How does this happen? What determines the position and size of the sub-CD?

The sub-CD is defined by the restriction of zero energy state to sub-CDs so that sub-CDs are induced by CD. This condition is analogous to boundary condition in classical physics and freezes WCW degrees of freedom of sub-CD at the passive boundary (PB) but the failure of determinism leaves discrete degrees of freedom at the active boundary (AB) so that the dynamics of SSFRs is restricted to these sub-WCW degrees of freedom and fermionic degrees of freedom.

2. Where sub-CDs and subselves are located? The natural location for a minimal sub-CD and mental images is around 3-surface at which the classical non-determinism fails: the frames of the soap film in soap film analogy. One can develop a rather detailed picture about frames [L174] based on number theoretic vision realized in terms of $M^8 - H$ duality [L127, L128, L151].

3. How sub-selves (sub-CDs) are created? Can they disappear? The notion of attention as generation of sub-CD achieved by a location of WCW ("world of classical worlds") spinor field at spacetime surfaces having their intersection with the PB of CD in a fixed set of 3-surfaces defining the sub-WCW is highly suggestive. This also affects the WCW spinor field of CD.

The attention can be directed in several ways. Redirection of attention means a movement of the region defining the content of mental images in the interior of a CD. Entanglement and classical communications would be naturally associated with attention defined in this manner. If minimal subselves are associated with the frames as loci of classical non-determinism, the set of targets of attention is discrete and finite.

This view about attention makes it possible to see also memory, anticipation, and intentions as special cases of attention.

4. The time evolution of CD itself would correspond to a scaling of CD (rather than translation), which by the failure of strict determinism brings in new discrete degrees of freedom related to the new frames becoming into the daylight as space-time surfaces increase. In the new picture, the sub-WCW property poses strong restrictions to the earlier picture about the development of sub-CD. The idea about silent wisdom as mental images preserved from the previous life after BSFR is not lost but is considerably modified.

In this picture, the small failure of classical determinism would be an absolutely essential element in that it makes possible a non-trivial theory of consciousness at the level of CD and at space-time level. Otherwise would have only fermionic degrees of freedom forgiven sub-CD. What is intriguing is that everything would be finite. SFRs would involve choices between finitely many alternatives and in this respect the theory would be analogous to the computationalistic approach: in fact, preferred extremals are analogous to computer programs.

18.4.1 Some background

In the sequel, some understanding of the basic ideas and notions of TGD proper [L138] is needed. Also ZEO as the target of critical discussion is briefly summarized.

TGD view briefly

Very concisely, TGD emerges as fusion of special and general relativities and has Poincare invariance of special relativity and General Coordinate Invariance (GCI) and Equivalence Principle (EP) as basic principles. Also the interpretation as a generalization of string models is possible: point-like particles are replaced by 3-surfaces instead of strings and world lines become space-time surfaces.

The notion of induction makes it possible to eliminate classical boson fields as primary dynamical variables and reduce them to the sub-manifold geometry of the space-time surface. For the simplest option, free second quantized quark fields of the embedding space $H = M^4 \times CP_2$ induced to the space-time surface remain as fundamental fermion fields and quarks serve as basic building bricks of both bosons and fermions as elementary particles [L119, L152].

Some understanding of notions such as the "world of classical worlds" (WCW) [K97], preferred extremal (PE) [K14], and various variants of holography [L127, L128] implied by general coordinate invariance (GCI) in TGD framework is assumed. Inclusions of hyperfinite factors of type II₁ (HFFs) [K127, K54] are central elements of quantum TGD proper.

Adelic physics [L66, L67] replacing real number based with number theoretical universal physics based on the hierarchy of adeles defined by extensions of rationals (EQs) and $M^8 - H$ duality (see Appendix 18.4.6) allowing number theoretic and geometric views about physics dual to each other is also assumed as the background.

Hierarchy of Planck constants $h_{eff} = n \times h_0$, with *n* identified as dimension of EQ, is the basic implication of adelic physics and central for quantum TGD. The phases labelled by h_{eff} behave like dark matter [K38, K39, K40, K41]. This hierarchy serves as a correlate for quantum criticality in arbitrarily long length scales.

Cognitive representations identified as points of space-time surface for which preferred coordinates of embedding space are in an extension of rationals are also central for the construction of the theory using M^8-H duality [L127, L128]. Galois group of EQ becomes number theoretical symmetry and is central in the description of quantum variants of cognitive representations [L7, L139].

Zero energy ontology (ZEO) [L118] is a key notion of quantum measurement theory. The basic prediction is that time reversal occurs in the ordinary state function reduction (SFR). This has profound implications for the interpretation of the quantum measurement theory [L104].

TGD inspired theory of consciousness can be seen as an extension of quantum measurement theory and relies on Negentropy Maximization Principle (NMP) as a basic dynamical principle [K73] [L162] implying second law for ordinary entanglement entropy.

$M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix 18.4.6) has changed considerably towards the end 2021 [L169] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \rightarrow m^k = \hbar_{eff} p^k / p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L169] of the $M^8 - H$ duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size L(m) defines the image point. This is not yet quite enough to satisfy UP but the additional details [L169] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M_c^8$ (M^8 is complexified to M_c^8) as a "root" of its octonionic continuation [L127, L128]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$. This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L110]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L169]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L151] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L169]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of the recent view of ZEO [L118] is required. Some aspects of this view will be challenged in the sequel for sub-CDs.

1. The notion of a causal diamond (CD) (see Fig. 20) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms

(3-D balls). The half-cones are mirror images of each other. $CD=cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2 . The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L67])via the $M^8 - H$ duality [L112, L127, L128].

2. In the ZEO, quantum states are not 3-dimensional if the classical determinism does not fail as it actually does, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography forced by general coordinate invariance, time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving the arrow of time that give rise to an analog of the Zeno effect (https://cutt.ly/yl7oIUy) [L118]. The findings of Minev *et al* [L104] provide strong support for ZEO [L104].

To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having opposite signs of energy. That conserved quantities vanish in the 4-D sense, expresses only the content of conservation laws. A weaker form of this condition [L160] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

18.4.2 How uniquely PE property fixes the space-time surface?

How uniquely the PE property fixes the space-time surface if its 3-D intersections with the boundaries of CD are given? This is the key question in this section.

Various variants of holography

General coordinate invariance (GCI) forces holography in the TGD framework. One can however consider several variants of holography [L127, L128, L162].

- 1. Holography in the standard sense would fix the space-time surface from the data of its intersection with either boundary of CD or the data associated with the light-like 3-surfaces at which the signature of the induced metric changes.
- 2. Strong form of holography (SH) states that 2-D data at the intersections of the light-like 3-surfaces and boundary of CD are enough to determine the space-time surface.
- 3. The strongest form of holography inspired by $M^8 H$ duality [L127, L128, L160] states that space-time region is determined by a rational value coefficients of a real polynomial extended to an octonionic polynomials, whose "root" is the space-time surface in M^8 . The *n* roots of a real polynomial would determine a 4-D region in M^8 and its image in $H = M^4 \times CP_2$ would be interpreted as space-time surface.

- 4. There is a variant of holography, which gives up the full determinism of classical field equations and gives rise to what look like classical topological analogs of Feynman diagrams.
 - (a) Consider first the particle level at the level of H. Particle lines generalized to 4-D orbits of 3-D surfaces representing particles. Particles as 4-D orbits of 3-surfaces contain lightline 3- D orbits of partonic 2-surfaces.
 - (b) Partons as building bricks of particles in the information theoretic sense, and correspond to partonic 2-surfaces at which the orbits of partonic 2-surfaces meet. Their orbits are 3-D light-like surfaces at which the signature of the induced metric of the space-time surface changes.

The partonic 2-D surfaces defining topological vertices belong to the 3-D sections of space-time surface with a constant value of M^4 time coordinate t to which one can map the 6-D brane-like entities of M^8 predicted by $M^8 - H$ duality [?]

This picture suggests that, besides the data at the boundaries of CD, also the data at the partonic 2-surfaces in the interior of CD are needed. This failure of classical determinism brings in the failure of the strongest form of holography. There would be a large number of PEs connecting the 3-surfaces at the ends of CD and they would correspond to the analogs of Feynman diagrams.

Zero energy state as a scattering amplitude would be a superposition over these diagrams. This superposition would not be however pre-determined as in the path integral but the zero energy state would define the superposition of paths in question.

Is the failure of classical determinism possible?

The possibility of classical non-determinism is suggested by the interpretation of space-time surfaces as generalized Feynman diagrams. These Feynman diagram entities would not however define an analog of path integral in TGD framework. Classical non-determinis would be a space-time correlate for the non-nondetermism at quantum level.

In this framework partonic 2-surfaces or equivalently the 3-D sections of the space-time surfaces with constant value of M^4 time would act as 3-surfaces at which the deterministic time evolution as a minimal surface would fail.

Another option is that light-like 3-surfaces containing the partonic 2-surfaces at very special moments of M^4 time define frames. These special values $t = t_n$ of M^4 time would be associated with 6-D branes predicted by M^8 picture as universal special solutions and their images in H would define "very special moments in the life of self" defined by the sequences of SSFRs defining the self.

- 1. The first hint comes from the dynamics of soap films. Soap films are minimal surfaces. The soap films spanned by 1-D frames consist of minimal surfaces glued together at the frames and this dynamics is non-deterministic in the sense that it allows several soap film configurations due to the different branchings at frames. At frames the minimal surface equations fail.
- 2. In TGD framework space-time surfaces as PEs are both minimal surfaces and extremals of Kähler action. In this case the 3-surfaces associated with "very special moments of time" $t = t_n$ could define an analog of a dynamically generated frame defining a 4-D soap film. The 3-surfaces at the ends of the CD would be fixed frames like those for soap films.

This realizes quantum criticality in the sense that the field equations outside frame do not involve the parameters of the action which sum of volume term and Kähler action. The interpretation as a non-linear analog of massless free field theory outside the frame conforms with the basic spirit of quantum field theory. These solutions of field equations rely on a a generalization of holomorphy to 4-D situation so that field equations reduce to purely algebraic conditions involving only the first derivatives of embedding space coordinates. The analogy is defined by the solution of 2-D Laplacian equation in terms of real or imaginary part of an analytic function. Field equations consist of two terms, which are divergences for the conserved currents (4momentum currents plus color currents) defined by the induced metric in the case of volume term. In the interior of the space-time surface these divergences vanish separately for the volume term and Kähler action but not at the frame.

3. The field equations must hold true also at the 3-D frame but this need not be true for both volume term and Kähler action separately. The coupling parameters of the theory make themselves visible only via the frame. For the volume action the divergences of the conserved currents are orthogonal to the space-time surface. For K "ahler action, the divergences of the conserved currents contain to terms. The first term is proportional to the energy momentum tensor of Kähler action and orthogonal to the space-time surface.

Second term is not orthogonal to the space-time surface. For twistor lift the Kähler also has an M^4 part with a similar decomposition.

The sums of the parts of divergences orthogonal to the space-time surface and parallel to it must sum up to zero separately. This gives 8 conditions altogether so that the number of field equations is doubled at the frame.

- 4. Could it happen that the divergences of these two isometry currents are singular and proportional to 3-D delta function but that their sum vanishes and conservation laws are respected? The part of the frame in the space-time interior would be dynamically generated whereas the part of the frame at the ends of CD would be fixed.
- 5. The restriction to 3-D frames is not the most general option. The delta function singularities could be located also at 2-D partonic 2-surfaces, at light-like 3-surfaces at which the induced metric changes its signature, and at string world sheets which connect these light-like 3-surfaces and have 1-D light-like boundaries at them. The light-like 3-D surfaces would be analogs of the cuts for analytic functions. Partonic 2-surfaces at the ends of light-like 3-surfaces could be analogs for the ends of the cuts. String world sheets could serve as analogs of poles.
- 6. The non-determinism associated with the soap films and with frames suggests that there is a large number of 4-D "soap films with a given frame", which is fixed at the boundaries of CD but not in the interior of CD.

18.4.3 Questions related to the theory of consciousness

At the level of TGD inspired theory of consciousness theory, causal diamond (CD) defines a correlate of self or of its perceptive field. CD has sub-CDs which correspond to subselves experienced by self as mental images [L118, L162].

Concerning the evolution of self, the basic notions of "small" state function reduction (SSFR) as an analog of "weak measurement" and "big" SFR (BSFR) as an analog of ordinary SFR.

- 1. The first deviation from the standard ontology is that BSFR changes the arrow of time defined by the selection of PB of CD at which 3-D part of zero energy states remains unchaged during SSFRs.
- 2. The second deviation is that either boundary of CD and states at it remain unaffected in SSFRs whose sequence defines self as a conscious entity. This is the TGD counterpart for the Zeno effect of ordinary quantum theory in which repeated measurements of the same observable leave the state unaffected.

The details of the evolution of self are not fully understood and the proposed general view can be criticized.

- 1. How the constraint that sub-CD serves as a correlate for a classical perceptive field can be taken into account?
- 2. What is the precise definition of mental images as subselves? Are they at some special positions inside space-time surface?

- 3. What are the precise definitions of memories and conscious memory recall? The same question applies to the notions of intention, anticipation and attention.
- 4. Can the mental images be destroyed or do they only experience BSFR and continue to live with an opposite arrow of time and become unconscious to self? If a mental image can completely disappear, what could be the physical mechanism leading to its disappearance?
- 5. One can challenge the detailed picture of the notion of time evolution by SSFRs. The assumption about the drift of mental images towards future in the second half-cone of CD is ad hoc. Should it be replaced with a deeper assumption. Could one simply assume that they are stationary.

Three ontological options

The basic problem of ZEO is whether the causal diamond (CD) represents a perceptive field in the sense that the space-time surface continues outside the CD or whether CD is an independent entity in the sense that space-time surfaces do not continue outside CD. Conservation laws do not exclude either option.

ZEO allows 3 ontological options which might be called easter, western, and intermediate views.

Option I: Space-time surfaces are restricted inside CDs. Quantum universe is a collection of CDs containing space-time surfaces, which have ends at the boundaries of CD.

In this framework, space-time in cosmological scales is an idealization and could be perhaps explained in terms of the correlations between CDs. CDs do not form a fractal atlas of something unless one says that the atlas *is* the territory. CD is an independent entity rather than a perceptive field of sub-self.

One can argue that for sub-CDs this picture is problematic since it seems that one loses totally the notion of objective reality as something existing outside CD. There are no sensory perceptions. Could the overlaps with other CDs create the experience about the existence of the external world?

Cosmology would be a mental construct and correspond to a very large CD. One would have a multiverse but only at the level of conscious experience. Option I is consistent with the eastern view that only subjective experience exists but not with the western view.

Option II: Space-time surface continues always outside all CDs and CDs can be interpreted always as perceptive fields. Option II conforms with the westerm option and implies that cosmology is something real.

Option III: Self is a hierarchy of CDs such that for sub-CDs the space-time surfaces continue outside the CD but for the largest CD this would not be the case. Sub-CDs would represent perceptive fields but the largest CD would be a God-like entity experiencing itself as the entire cosmos.

Meditators report altered states of consciousness in which the separation to self and external world ceases and the mind is empty. Also the experience of timelessness is mentioned. Could these states correspond to experiences without mental images (sub-CDs) created by SFRs at this highest level?

Option III is roughly consistent with both western and eastern views about consciousness. If one requires the notion of the external world as objective reality and accepts the proposed explanation of altered states of consciousness, option III remains the only possible option.

A general picture about the dynamics of sub-CDs

The ZEO based view of quantum measurement theory and the theory of consciousness inspired by it have not been precisely formulated for sub-CDs. In particular, the question of how sub-CDs as mental images are created, has remained unanswered.

The following proposal provides such a formulation and is consistent with Options I and III.

1. CDs form a fractal atlas of conscious maps but the map would be the territory since in general the space-time surfaces need not continue outside the CD. There would be no external particles as 4-D lines for generalized Feynman diagrams outside CD.

- 2. Sub-CDs correspond to mental images of CD as a conscious entity. From the point of view of consciousness theory, there are only experiencers (CDs) which can have experiences as mental images (have sub-CDs), be mental images of experiencers (be sub-CDs) and share mental images (intersecting CDs with common sub-CDs).
- 3. Consistency conditions for the quantum dynamics of CDs and sub-CDs and for the overlapping CDs give rise to correlations between the regions of the map. The shared regions are geometrically analogs for the intersections of the intersections of a covering of a manifold by open sets.
- 4. For sub-CD the interpretation of sub-CD as a perceptive field would be natural.

The first question is what does one really mean with sub-CD at the level of space-time surfaces.

- 1. Do the space-time surfaces of sub-CD continue outside sub-CD as space-time surfaces of CD? Does this imply that the quantum dynamics of sub-CDs in ZEO is completely dictated by that of CD? This is certainly not the case. Fermionic zero energy states associated with the sub-CD are possible and are analogous to quantum fluctuations. Note that in the TGD framework all elementary particles can be constructed from fundamental fermions (quarks).
- 2. If the PE (PE) property fixes completely the space-time surface, its intersections with the boundary of CD, this seems to be the case. If the classical dynamics is not completely deterministic, as suggested by the analogy with minimal surfaces spanned by frames, the situation changes.

Sub-CD defines a subsystem of CD with boundary conditions at the boundary of CD which do not completely fix the quantum dynamics of sub-CD. Quantum states as WCW spinor fields inside sub-CD could change in SFRs of sub-CD.

The tensor product of sub-CD with CD would not be ordinary tensor product but much more restricted one and Connes tensor product, related to inclusions of HFFs, would be a possible identification. A sub-system would be like an included hyper-finite factor of type II₁ (HFF).

Suppose that the classical dynamics is indeed non-deterministic and sub-CDs are defined in the proposed manner. How the view about WCW spinor fields changes as one restricts the consideration to sub-WCW.

1. The failure of the classical determinism forces to replace each 3-surface at PB with a discrete tree-like structure consisting of all PEs connecting it to AB. Sub-WCW as the space of PEs is larger than the space of 3-surfaces X^3 at PB. Zero energy states are defined in this sub-WCW and assign to a given X^3 a wave function in this discrete set allowing interpretation as wave function in a set of paths of the tree.

One cannot avoid the association with cognitive representations of adelic physics involving the number theoretic degrees of freedom characterized by Galois group of the extension of rationals associated with the polynomial defining the space-time region [L53, L139].

- 2. The activation of sub-WCW would mean an SFR selecting in WCW of CD such sub-WCW for which the space-time surfaces are such that their ends at sub-CD are fixed. This would correspond to SFR creating a sub-CD and corresponding mental image. This would answer the long standing question whether and how mental images can appear as if from scratch. This SFR would also represent a third kind of SFR having interpretation as a partial localization in WCW associated with CD. This also suggest that mental images could disappear suddenly. This "activation" could be seen as a directed attention.
- 3. WCW degrees of freedom at the boundaries of sub-CD are fixed. Also sub-WCW spinor fields make sense. One can allow the tensor product of Fock spaces of many-fermion states associated with the boundaries of CD. One would have a QFT like picture with sub-WCW degrees of freedom fixed at boundaries of sub-CD.

4. The tensor product of fermionic state spaces at the boundaries of sub-WCW makes sense and one can define zero energy states in the same manner as proposed hitherto. The only difference is that WCW degrees of freedom are frozen at the boundaries of sub-CD. At the level of conscious experience this means that the subself experiences the external world as fixed. This would be by definition the meaning of being subself.

The fermionic Fock state basis has an interpretation as a Boolean algebra so that fermionic zero energy states have an interpretation as Boolean statements of form $A \rightarrow B$. This would mean that consciousness of the subself would be Boolean, cognitive consciousness, thinking. This conforms with the Eastern view that ordinary consciousness is essentially thinking and that the higher level of consciousness as that associated with the highest level of the CD hierarchy of self is pure consciousness. Thinking assignable to the fermionic degrees of freedom would be seen as an endless generation of illusions. "Reality" in this interpretation would correspond to WCW degrees of freedom.

What restrictions must one pose on the quantum dynamics of CDs in the case of sub-CDs? Does the subjective evolution of sub-CD states by SSFRs and BSFRs make sense for sub-CDs?

- 1. The increase of the size of sub-CD makes sense and the proposed subjective evolution by scalings and SSFRs makes sense. The time evolution is also now induced by the increase of the perceptive field of a subself defined by the WCW associated with increasing sub-CD bringing in new 4-surfaces due to the classical non-determinism.
- 2. What about the interaction between CD and sub-CDs. Does this time evolution respect the condition that the space-time surfaces meet the fixed 3-surfaces at boundaries of sub-CD or is it possible that the SSFRs of CD destroy the subself by delocalization so that sub-CD as a mental images must be regenerated by localization in WCW.
- 3. Also the interaction between overlapping CDs and the sharing of mental images can be understood in this framework.

18.4.4 Comparison of the revised view of self with the earlier one

The revised view about TGD inspired theory of consciousness relies on the definition of subself at the level of WCW unlike the older view. In the following the new view is compared with the old view.

The view about SSFRs

Earlier picture

The earlier view about SSFRs was inspired by the M^8 picture.

- 1. The dynamics was assumed to involve both scaling of CD with respect to either tip of CD. The lower half-cone was only scaled whereas the upper half-cone was also shifted as required by the stationarity of the passive boundary. Dynamics at PB was passive in the sense that only a portion of the space-time surface became visible making also new states visible at it (Zeno effect) in the sequence of SSFRs. The idea about scaling leads to a rather concrete proposal for the S-matrix characterizing the scalings of CD.
- 2. The surfaces inside CD (or sub-CD) were assumed to be mirror symmetric with respect to the middle plane of CD. This assumption does not conform with the assumption that these surfaces define a perceptive field in the sense that they are parts of large space-times and continue outside CD.

The old view had several ad hoc features.

1. The creation of mental images was implicitly assumed without specifying what this could mean mathematically. These mental images were assumed to be created in the upper half-cone just above the t = T mid-plane of CD and shift to the geometric future with the upper half-cone of CD. The asymmetry between upper and half-cone could be seen as reflecting geometrically the future-past asymmetry but was ad hoc.

- 2. One can criticize the assumption that the memories about the events of the subjective past are located in the geometric future with respect to the mid-plane of CD.
- 3. Whether mental images can disappear or only die and reincarnate by BSFR, was not specified.

New picture In the new picture the situation is the following.

- 1. Also in the new picture, the time evolution by SSFRs would be a sequence of scalings of CD. The assumption about reflection symmetry of space-time surfaces is given up since it is inconsistent with the identification of sub-CD as a perceptive field. Also now the time evolution is passive in the sense that only a new portion of the space-time surface extending outside sub-CD is revealed at each step.
- 2. As in the previous picture, new discrete WCW degrees of freedom appear during the sequence of SSFRs and complexity increases. For both options only fermionic degrees of freedom remain if full determinism is assumed and if QCC is required also at the level of SFRs.
- 3. In the new view both directed attention, memory, and intention correspond to a generation of sub-CD by a localization in WCW fixing a subset of 3-surfaces at the PB of CD. Redirecting of attention would allow apparent movement of the sub-CD in the interior of CD and as a special case shifting the mental images in the time direction assumed in the earlier picture.
- 4. In the new view the loci of mental images are naturally associated with the loci of classical non-determinism that is 3-surfaces at the 4-D minimal surface branches.
- 5. $M^8 H$ duality suggests that the branchings occur at H image points of the M^8 cognitive representation defined by the quark momenta which are algebraic integers for the extension of rationals defined by the polynomial defining $X^4 \subset M^8$. The non-determinism at $X^4 \subset H$ point set would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8 .

Note that physical states correspond to total quark momenta which are rational integers, one can speak of Galois confinement meaning that physical states are Galois singlets. This gives an infinite hierarchy of bound states formed by a universal, purely number theoretical mechanism. All bound states could be formed in this manner.

The non-determinism at $X^4 \subset H$ point which corresponds to a subset of points as images of quark momenta composing the bound state would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8 . There would be a hierarchy of CDs within CDs and hierarchy of mental images corresponding to the hierarchy of bound states.

The bound state momenta are mapped to $X^4 \subset H$ by $M^8 - H$ duality already described. In particular, the positions of quarks contained in 6-branes X^6 with a constant energy $E = E_n$ are mapped to a sequence of points at the boundary of cd of the system by M^8 -duality and it can be said to represent the positions of these quarks. These point sets define sequences of "very special moments in the life of self".

The targets of attention would therefore form a discrete set assignable to bound states of quarks and antiquarks. Note however that each 3-surface X^3 in the superposition defining the WCW spinor field at the PB of CD has its own discrete set loci of non-determinism. BSFRs can change the superposition of these 3-surfaces. The selection between branches is possible in BSFR but not in SSFRs.

6. An attractive idea motivated by ZEP is that volitional action could be interpreted in the new view as an SFR selecting one path at the node of a tree characterizing the non-determinism. Single deterministic time evolution analogous to a computer program would be selected rather than modifying the deterministic time evolution as in standard ontology. In the M^8 picture, the very special moments $t = r_n$ in the life of self correspond to the roots of a real polynomial. What happens when all roots have been experienced? Does NMP force the BSFR to occur since nothing new can be learned?

Comparison of the views about BSFR

Those aspects of BSFR in which old and new views differ are of special interest.

Earlier view

The fact that the notion of sub-CD and mental image were not properly formulated led to several ad hoc assumptions.

- 1. The possible failure of a strict determinism was realized. The failure of strict determinism was assigned to "very special moments in the life of self" associated with the images $E = E_n$ planes of $M^4 \subset M^8$ at which the partonic vertices as loci of non-determinism were assigned.
- 2. The mental images of previous life near the AB of CD were assumed to be inherited as "silent wisdom". Their contents was from the early period of life with opposite arrow of time and one can of course ask whether they were really "wisdom".
- 3. There were also assumptions about the change of the size scale of CD in BSFR. The idea that the reduction of the size scale guarantees that re-incarnate has childhood was considered. This assumption also prevents unlimited increase of the size scale of sub-CD.

New view The new view makes it possible to develop a more detailed picture of what happens in BSFR.

- 1. The WCW localization at the AB of CD selects one of the branches of the space-time surface beginning at the PB. This selection of the branch happens to each 3-surface in the superposition of 3-surfaces at the PB defined by the WCW spinor field before BSFR.
- 2. The future directed tree becomes a past directed tree beginning from one particular branch at the AB. The initial and final space-time surface share a common space-time surface connecting the roots of the old and new trees. This is essential for having a non-trivial transition amplitude for BSFR at WCW level.

In the earlier view, the mental images interpreted as memory mental images and located near the boundary of CD were assumed to be inherited as "silent wisdom" by the time-reversed reincarnate. What happens now?

The notion of "silent wisdom" as inherited information still makes sense.

- 1. The new space-time surfaces originate from 3-surface which was selected by WCW localization in BSFR. Therefore the new space-time surfaces carry classical information about previous life.
- 2. The space-time surfaces originating from the new root are near to the space-time surface connecting the old and new roots. The WCW spinor field before and after BSFR musthave a strong overlap in order to make the transition amplitude large. This implies that information about previous life is transferred to the new life.
- 3. The nearness property could imply that they are easily re-created as perceptions by directed attention so that they would indeed be "silent" wisdom. These mental images are from the later part of the life cycle rather than from the early life as in the earlier picture. If aging means getting wisdom, then silent wisdom would be in question.

Does the notion of "silent wisdom" as mental images make sense?

1. Mental images - this includes both sensory and memory mental images and intentions) are naturally assignable to the loci of classical non-determinism at the images of the planes $E = E_n$ of the branched space-time surfaces associated with the new root ("very special moments in the life of self").

For the special space-time surface connecting the roots of old and new space-time surface, the surfaces $E = E_n$ in M^8 would not change and the mental images would carry information about previous life. Could one talk about potentially conscious "silent wisdom".

- 2. What happens to the mental images of self in BSFR? Can they be preserved or do they disappear or do they reincarmate by BSFR? The idea about preservation makes sense only for space-time surfaces connecting the roots.
- 3. What can happen to the size scale of CD in BSFR? The extreme option that CD decreases in size by shift of the formerly PB such that the time evolutions are fully determinimistic in the superposition of 3-surfaces. There would be no inherited silent wisdom and the self would start from scratch, live a chilhood. Otherwise these loci would define candidate for inherited silent wistom.

In the earlier picture the mental images corresponding to sub-CD could not disappear although it could die by BSFR and reincarnate with a reversed arrow of time. Can the mental image disappear now? Creation of mental image require metabolic energy feed: this explains 7 ± 2 rule for the number of simultaneous mental images. Could this happen when attention is redirected? Therefore one could argue that mental image must totally disappear when the attention is redirected.

On the other hand, time reversed mental image apparently feeds energy to the environment in the original arrow of time, i.e. apparently dissipates. Could this dissipation be interpreted as an energy feed for its time reversal.

Note that the total disappearance of the mental image means delocalization at the level of WCW and seems possible. The new view clearly challenges the idea about the Karma's cycle of self. This cycle appears in many applications of BSFR.

18.4.5 Conclusions

Also the article Some comments related to Zero Energy Ontology (ZEO)" [L118] written for few years ago challenged the basic assumptions of ZEO. One tends to forget the unpleasant questions but now it was clear that it is better to face the fear that there might be something badly wrong. ZEO however survived and several ad hoc assumptions were eliminated.

Progress at the level of basic TGD

The basic goal is to improve the understanding about quantum-classical correspondence. The dynamics of soap films serves as an intuitive starting point.

- 1. In TGD frame 3-surfaces at the boundaries of CD define the analog of frame for a 4-D soap film as a minimal surface outside frame. This minimal surface would be an analog of a holomorphic minimal surface and simultaneous exremal of Kähler action except at the frame where one would have delta function singularities analogous to sources for massless d'Alembert equation.
- 2. There is also a dynamically generated part of the frame since the action contains also Kähler action. The dynamically generated parts of the frame would mean a failure of minimal surface property at frame and also the failure of complete determinism localized at these frames.
- 3. At the frame only the equations for the entire action containing both volume term and Kähler term would be satisfied. This guarantees conservation laws and gives very strong constraints to what can happen at frames.

The frame portions with various dimensions are analogous to the singularities of analytic functions at which the analyticity fails: cuts and poles are replaced with 3-, 2-, and 1-D singularities acting effectively as sources for volume term or equvavelently Kähler term. The sum of volume and Kähler singularities vanish by field equations. This gives rise to the interaction between volume and Kähler term at the loci of non-determinism.

4. *H*-picture suggests that the frames as singularities correspond to 1-D core for the deformations of CP_2 type extremals with light-like geodesic as M^4 projection, at partonic 2-surfaces and string world sheets, and at 3-D $t = t_n$ balls of CD as "very special moments in the life of self" which integrate to an analog of catastrophe. T Deformations of Euclidean CP_2 type extremals, the light-like 3-surfaces as partonic orbits at which the signature of the induced metric changes, string world sheets, and partonic 2surfaces at $r = t_n$ balls taking the role of vertices give rise to an analog of Feynman (or twistor -) diagram. The external particles arriving the vertex correspond to different roots of the polynomial in M^8 picture co-inciding at the vertex.

The proposed picture at the level of $H = M^4 \times CP_2$ has dual at the level of (complexified) M^8 identifiable as complexified octonions. The parts of frame correspond to loci at which the spacetime as a covering space with sheet defined by the roots of a polynomial becomes degenerate, i.e. touch each other.

Concerning the physical interpretation, a crucial step of progress was the interpretation of M^8 as analog of momentum space allowing to interpret $M^8 - H$ duality as an analog of momentumposition duality and of complementarity principle of wave mechanics [L169]. This forced to modify $M^8 - H$ duality in M^4 degrees of freedom to satify the constraints posed by UP.

There is a nice analogy with the catastrophe theory of Thom [A47, A30]. The catastrophe graph for cusp catastrophe serves as an intuitive guide line. embedding space coordinates serve as behaviour variables and space-time coordinates as control variables. One obtains a decomposition of space-time surface to regions of various dimension characterized by the degeneracy of the root.

Progress in the understanding of TGD inspired theory of consciousness

The improved view about ZEO makes it possible to define the basic notions like self, sub-self, BSFR and SSFR at the level of WCW. Also the WCW correlates for various aspects of consciousness like attention, volition, memory, memory recall, anticipation are proposed. Attention is the basic process: attention creates sub-CD and subself by a localization in WCW and projects WCW spinor field to a subset of WCW. This process is completely analogous to position measurement at the level of H. At the level of M^8 it is analogous to momentum measurement.

One can distinguish between the Boolean aspects of cognition assignable to WCW spinors as fermionic Fock states (WCW spinor field restricted to given 3-surface). Fermionic consciousness is present even in absence of non-determinism. The non-determinism makes possible sensory perceptions and spatial consciousness.

A precise definition of sub-CD as a correlate of perceptive field at WCW level implies that the space-time surfaces associated with sub-CDs continue outside it. This gives powerful boundary conditions on the dynamics. For the largest CD in the hierarchy of CDs of a given self, this constraint is absent, and it is a God-like entity in ZEO. This leads to a connection between the western and eastern views about consciousness.

A connection with the minimal surface dynamics emerges [L174]. The sub-CDs to which mental image as subselves are assigned would be naturally associated with portions of dynamically generated frames as loci of non-determinism. If one identifies partonic 2-surfaces as vertices, one can interpret the collection of possible space-time surfaces for a fixed 3-surface at PB as a tree. All paths along the tree are possible time-evolutions of subself. The dynamics of consciousness for fixed 3-surface at PB becomes discrete and provides discrete correlate for a volitional action as selection of a path or a subset of paths in the tree. The reduction of dynamics of mental imagines to discrete dynamics would mean a huge simplification and conforms with the discreteness of cognitive representations.

Challenges

There are many challenges to be faced. The discrete dynamics of sub-self consciousness certainly correlates with the notion of cognitive representation based on adelic physics [L66, L67] and implying a discretization at both space-time level and WCW level. The Galois group for the extension of rationals acting on the roots of the polynomial plays a key role in this dynamics [L139, L151].

One teaser question remains. Localization requires energy quite generally and this conforms with the fact that mental images demand metabolic energy feed. It is possible to redirect attention and it remains unclear whether the mental image disappears totally or suffers BSFR.

This relates directly to the question whether consciousness continues after the physical death. If mental images (and corresponding sub-CDs) can disappear, the same can happen to us since we are mental images of some higher level self. If this cannot happen, BSFR means death and reincarnation with an opposite arrow of time in a completely universal sense. For instance, sleep period could correspond to a kind of death at some level of the personal self hierarchy generalizing the Id-ego-superego hierarchy of Freud. This would explain why we have no memories of the sleep period.

18.4.6 Appendix: M^8 - and H views about classical non-determinism and particle reactions

M^8 picture and $M^8 - H$ duality

In M^8 picture, space-time surfaces correspond to real projections of 4-D complex "roots" of octonionic polynomials obtained from real polynomials with rational coefficients by algebraic continuation, i.e. by replacing real coordinate by complexified octonion coordinate [L59, L60, L61] [L127, L128]. The interested reader finds a rather detailed summary of $M^8 - H$ duality in Appendix 18.4.6.

 $M^8 - H$ duality maps the point of $M^4 \times E^4$ to a point of $M^4 \times CP_2$ such that the point of $M^4 \subset M^4 \times E^4$ is mapped to some point of $M^4 \subset M^4 \times CP_2$. $M^8 - H$ duality is not a local map. Rather, the normal space of a $x \in X^4 \subset M^8$ goes to a point of CP_2 characterizing its quaternionic normal space.

- 1. To be a 4-D "root" in the complex sense means that the real part of a complexified octonionic polynomial determining the space-time surfaces vanishes. The number theoretic content of this condition is that the normal space of the space-time surface is quaternionic and therefore associative. The second option would be that the tangent space is associative but this gives only M^4 as a solution.
- 2. At a given point there are n roots and some of them can coincide in some regions of the space-time surface. These regions correspond to the branchings of the space-time surface at which particle-like entities identified as space-time surfaces meet and interact.

The quaternionic normal plane at this intersection is not unique so that several CP_2 points of $X^4 \subset H$ correspond to a single point of $X^4 \subset M^8$. The extreme situation is encountered in a point-like singularity when the normal plane at a given point of M^4 is a sub-manifold of CP_2 .

The interpretation is as particle vertices. The intuitive expectation is that they correspond to partonic 2-surfaces and perhaps also string world sheets. These surfaces are mapped to those in $M^4 \times CP_2$ by $M^8 - H$ correspondence.

3. Also 6-D brane like entities are predicted as universal "roots" they correspond to 6-spheres in M^8 with M^4 projection which is a 3-ball with constant value $E = E_n$ of energy as counterpart of the Minkowski time coordinate such that E_n is the root of the real polynomial defining the octonionic polynomial. The momenta $(E_n, p = 0)$ are mapped to points $t_n = (\hbar_{eff}/E_n, 0)$ and define "very special moments of time in the life of self".

The points with $p \neq 0$, in particular the points corresponding to quark momentum, however correspond to $t < t_n$ at the boundary of cd with size $L(p) = \hbar_{ef}/\sqrt{E_n^2 - p^2}$. To these moments the failure of classical determinism giving rise to one particular kind of quantum non-determinism is concentrated. Note that points of double hyperboloid of M^4 with opposite energies are mapped to opposite boundaries of cd.

- 4. The intersections of 4-D "roots" with 6-D brane-like entities are 2-D and it might be possible to interpret them as analogs of either partonic 2-surfaces or string world sheets at which several roots become degenerate of octonionic polynomial co-incide. Outside the singularity, the roots do not coincide and define separate space-time sheets and it is natural to interpret them as external particles of a particle reaction.
- 5. At the light-like orbits of partonic 2-surfaces the induced metric for the *H*-image of the space-time surface becomes degenerate since its signature changes. Could one say that the Minkowskian and Euclidean roots coincide at the partonic orbits?

One can also wonder what the M^8 interpretation of wormhole contacts having two throats could be. Do the two throats correspond to two coincing roots at the level of M^8 having different normal spaces and mapped to separate 2-surfaces in H?

Catastrophe theoretic analogy

Consider the analogy with the catastrophe theory of Thom [A47] in more detail.

- 1. Catastrophe map is the graph of solutions for the vanishing of the gradient of a potential function as a function of control parameters. One considers only real roots as function of variable control parameters and the number of real roots varies as a function of parameters and one obtains lower-dimensional regions at which the number of roots to catastrophe polynomial changes as roots become degenerate [A47, A30]. Cusp catastrophe serves as the school example.
- 2. In the recent case, space-time surfaces correspond to roots of complexified octonionic polynomials and the coefficients of the polynomial appear as control parameters. Also complex roots are allowed and real 4-D space-time surface is obtained as a real projection and mapped to H by $M^8 H$ duality and conjectured to correspond to a preferred extremal of an action determined by the twistor lift of TGD.
- 3. The basic motivations for this assumption are quantum criticality requiring preferred extremal property, which requires at the level of H the independence of the dynamics on coupling parameters of the twistor lift of Kähler action outside the loci of non-determinism demanded by M^8 level.

Connection between singularities and preferred extremals of various types

The above picture suggests the characterization of the space-time surfaces in terms of their singularities as surfaces of M^8 .

At the level of H one can consider 4 kinds of very simple preferred extremals, which give rise to prototype singularities.

- 1. Einsteinian spacetime $X^4 \subset M^8$ with a 4-D M^4 projection and a unique normal space as a point of CP_2 . $X^4 = M^4$ defines a prototype.
- 2. Cosmic string extremal $X^2 \times Y^2$ with Y^2 a complex surface in CP_2 and defining a set of normal spaces assignable to a point of X^2 . $M^2 \times S^2$, S^2 a geodesic sphere defines a proto type. S^2 can be either homological trivial or non-trivial.
- 3. $X^3 \times S^1 \subset M^4 \times CP_2$, where S^1 is a geodesic circle of CP_2 , is a candidate for a preferred extremal and singular surface. Both $M^3 \times S^1$ and $E^3 \times S^1$ are minimal surfaces and vacuum extremals of Kähler action.

For the Euclidean signature, X^3 could be space-like and define a 3-ball compactifying to S^3 as a sub-manifold of the S^6 brane. The very special moments t_n would be singular in the sense that the normal space at a given point of $X^3 \subset M^4 \subset M^8$ would not be unique and would give rise S^1 singularity.

4. CP_2 type extremal with light-like geodesic as $M^4 \subset H$ projection and corresponding to a light-like geodesic in M^8 with normal spaces forming a 3-D surface in CP_2 . Also $M^1 \times Y^3 \subset M^4 \times CP_2$ can be considered but is probably not a preferred extremal.

The intuitive picture is that these 4 types of preferred extremals correspond to singularities of the normal space of $X^4 \subset M^8$ of dimension d = 0, 1, 2, 4 and codimension $d_c = 4 - d$.

Analogy with knot theory

In knot theory a knot in 3-D space is projected to 2-plane where one obtains a diagram containing crossings. Knot invariants can be constructed in terms of this diagram. A knot theory inspired intuition is that space-time surfaces near to these special cases are projected to these special surfaces to get the toy model.

- 1. Canonically embedded $M^4 \subset M^8$ (or $M^4 \subset M^4 \times CP_2$) is an analog of the plane to which the knot is projected. One can project the space-time regions with 4-D M4 projection to M^4 . In particular, those with a Minkowskian signature of the induced metric.
- 2. The M^4 projection of CP_2 type extremal is 1-D light-like geodesic. One must project the deformations of CP_2 type extremals to CP_2 type extremal at the level of H. At the level of H, CP_2 type extremal could correspond to a light-like geodesic of M^8 such that each point of the geodesic is singular point such that the union of quaternionic normal spaces defines a 3-D quaternionic surface in CP_2 .

A puncture in E^3 as an infinitesimal hole serves as an analogy. At the puncture, one can say that all normal spaces labelled by points of S^2 are realized.

At the given point of the light-like geodesic, the quaternionic normal space of point is not unique but a 3-D union of normal spaces and defines a 3-D subset CP_2 .

3. For the $X^2 \times Y^2 \subset M^4 \times CP_2$ type cosmic string extremals and their small deformations, one must project to $M^2 \times S^2 \subset CP_2$. For a point of X^2 the normal spaces define $Y^2 \subset CP_2$ so that the singularity is milder.

For $X^3 \times S^1 \subset M^4 \times CP_2$ the normal spaces at a point of X^3 would define $S^1 \subset CP_2$. If X^3 is Euclidean, these 3-D singularities could correspond to the $t = t_n$ planes associated with the branes. The small deformations of these surfaces would project to $M^3 \times S^1$. This picture would integrate all 3 kinds of singularities and various types of preferred extremals to a single unified picture.

A toy model for the singularities

The following toy model for the singularities in the case of CP_2 type extremals generalizes also to other singularities.

1. A rather general class of CP_2 type extremals can be represented as a map $M^4 \to CP_2$ given by

$$m^k = p^k f(r) \quad ,$$

where p^k is light-like momentum and r is radial U(2) invariant CP_2 coordinate labelling 3-spheres of CP_2 such that $r = \infty$ gives homologically non-trivial geodesic 2-sphere instead of 3-sphere.

If f(r) approaches constant value for $r \to \infty$, one can say that M^4 time stops at this limit, and one obtains a homologically non-trivial geodesic sphere instead of 3-D surface identifiable as an intersection with 6-D brane. Various external particles of the vertex would correspond to $m^k = p_k f_i(r)$ such that their values at $r = \infty$ co-incide.

It is not possible to obtain omologically trivial 2-sphere in this manner.

2. Outside the vertex, the CP_2 type space-time sheets have distinct light-like geodesics as M^4 projections and they can be continued to distinct regions of M^4 in the toy model.

The analog of the knot diagram would be a set of M^4 :s with different constant values of CP_2 coordinates. The CP_2 type extremals would be glued along light-like geodesics to various M^4 s.

The CP_2 points of M^4 :s meeting at the same geodesic sphere must belong to the same geodesic sphere S^2 . The S^2 :s associated with different vertices are different. Note that any two geodesic spheres must have common points.

3. In the toy model for the string world sheets $X^2 \times Y^2$ would be projected to a piece of $M^2 \times S^2$ connecting two partonic vertices with the same S^2 . S^2 :s would be at the ends of the string, whose orbit is a piece of M^2 .

 $B^3 \times S^1$ could be interpreted as a subset of 6-D brane with B^3 identified as the $t = t_n$ cross section of M^4 light-cone.

This picture would suggest that the singularities could be indeed located to $t = t_n$ planes and integrated together to form a rough analog of catastrophe map.

Some examples of minimal surfaces with 1-D CP_2 projection

This subsection is not directly relevant to the basic topic and is added to give ideas about the possible role of volume term.

The original proposal was that preferred extremals are extremals of Kähler action but the twistor lift introduced the volume term as an additional term. This removed the huge vacuum degeneracy of Kähler action meaning that any 4-surface for which CP_2 projection was so called Lagrange manifold with the property that induced Kähler form vanishes, was a solution of field equations. For these surface induced Kähler potential is pure gauge.

The addition of the volume term removes this degeneracy and only minimal surfaces of this kind are possible as extremals. It is however not clear whether they are preferred extremals (are they analogs of complex surfaces?).

These solutions have not been studied previously [K14]. Space-time surfaces representing a warped embedding of M^4 with a flat metric represent the simplest example.

1. Denoting the angle coordinate of the geodesic sphere S^1 by Φ and the metric of S^1 by $ds^2 = -R^2 d\Phi^2$ the ansatz reads in linear Minkowski coordinates as $\Phi = k \cdot m$, where k is analog of four-momentum. The induced metric is flat and the second fundamental form vanishes by the linearity of Φ in m so that the field equations are satisfied.

Boundary conditions require the vanishing of the normal components of momentum currents and give $(\eta^{\alpha\beta} - R^2 p^{\alpha} p^{\beta})n_{\beta} = 0$. This condition cannot be satisfied so that these solutions should have infinite size, which looks unphysical.

The presence of the volume term in the action implies that the induced metric appears in the boundary conditions and this represents a problem quite generally. The only way to overcome the problem is that there are no boundaries. The many-sheetedness indeed makes this possible.

The warped extremals could represent a reasonable approximation of the space-time surface in the regions which are almost empty.

2. The light velocity defined in terms of time taken to get from the M^4 position A to B, is reduced to $c_1 = \sqrt{1 - |k \cdot k|}$. If k is light-like this does not happen.

Although the analog of gravitational force is vanishing in warped metric, the deviation the flat metric from M^4 metric given by $|k \cdot k|$ in flat case could it be interpreted as gravitational potential and the gravitational potential energy of test mass would be given by by $E_{gr} = -m|k \cdot k|$.

Could Nature provide a kind of cognitive representation or toy model of a gravitational field as a piecewise constant function in terms of CDs with which warped vacuum extremals would be associated? The representation would contain length scale dependent Λ as second parameter assigning momentum 4-momentum proportional to Λp^k to the CD. The volume energy would include its gravitational potential energy represented in terms of warping?

For warped solutions the space-time light cone - to be distinguished from its embedding space counterpart - would be defined by $c_1^2 t^2 - r^2 = 0$ and space-time CD would be modified accordingly.

Only single extremal - canonically embedded M^4 - remains from the spectrum of cosmological vacuum extremals for Kähler action having 1-D CP_2 projection and defined by $\Phi = f(a)$, where f is an arbitrary function of light-cone proper time coordinate $a = \sqrt{t^2 - r_M^2}$. At QFT-GRT limit, the many-sheeted space-time is approximated with Einsteinian cosmology with the deviation of the induced metric from M^4 metric defined by the sum of the corresponding deviations for the sheets. Since the value of Λ becomes large in short p-adic length scales, a cosmology resembling GRT type cosmology could emerge and Einstein's equations would be a remnant of Poincare symmetry.

The induced metric for the solutions has very little to do with the metric appearing at the Einsteininian limit. The models of cosmology as space-time surfaces based on Kähler action with vanishing Λ could however make sense in very long scales for which Λ approaches zero.

For string dominated cosmology, the comoving mass is proportional to a [K102, K14, K71]. One has a silent whisper amplified to a Big bang in GRT sense. Also critical cosmology [K14] as an analog of inflationary cosmology for which curvature scalar as dimensional quantity vanishes can be regarded as a silent whisper amplified to a Big Bang and also it becomes Euclidean for a critical value $a = a_0$ of cosmic time.

18.5 What could 2-D minimal surfaces teach about TGD?

In the quantum TGD based on zero energy ontology (ZEO) space-time surfaces within causal diamonds (CDs) are fundamental objects [L118, L165]. $M^8 - H$ duality plays a central role: the earlier views can be found in [L59, L60, L61] and the recent view in [L127, L128, L160] differing in some aspects from the earlier view. $M^8 - H$ duality means that one can interpret the space-time surfaces in two ways: either as an algebraic surfaces in complexified M^8 or as minimal surfaces in $H = M^4 \times CP_2$ [L165]. $M^8 - H$ duality maps these surfaces to each other.

The twistor lift of TGD is another key element [L68, L96]. It replaces space-time surfaces with their 6-D twistor spaces represented as 6-D surfaces in the product of twistor spaces assignable to M^4 and CP_2 and having an induced twistor structure. This implies dimensional reduction of a 6-D Kähler action to a sum of a 4-D Kähler action and volume term having interpretation in terms of cosmological constant Λ . Kähler structure exists only for the twistor spaces of M^4 and CP_2 [A36] so that the theory is unique.

Each extension of rationals (EQ) corresponds to a different value $\Lambda > 0$. For $\Lambda = 0$, the finite-D extension of rationals determined by real polynomials would be replaced with real analytic functions or subset of them.

Whether $\Lambda = 0$ can be accepted physically, will be one of the key topics of this article. At the level of adelic theory of cognition [L66, L65] this question boils down to the question whether cognition is always finite and related to finite-D extensions of rationals of whether also infinite-D extensions and transcendence can be allowed.

18.5.1 Basic notions

 $M^8 - H$ duality and twistor lift of TGD are the basic notions relevant for what follows and its is appropriate to discuss them briefly.

Space-time surfaces at the level of M^8

The recent view of $M^8 - H$ duality [L127, L128, L160] deserves a brief summary.

At M^8 level, space-time surfaces can be regarded as algebraic 4-surfaces in complexified M^8 having interpretation as complexified octonions. The dynamical principle states that the normal space of the space-time surface at each point is associative and therefore quaternionic. The space-time surfaces are determined by the condition that the real part of an octonionic polynomial obtained as an algebraic continuation of a real polynomial with rational coefficients vanishes.

This gives a complex surface which is minimal surface from which one takes a real part by projecting to real part of complexified M^8 : it is not clear whether it is minimal surface of M^8 . Minimal surface property is the geometric analog of a massless d'Alembert equation [L35, L111].

Also real analytic functions can be considered [L127, L128] but this leads to infinite-D extensions of rationals in the adelization requiring that also the p-adic counterparts of the spacetime surfaces exist. Whether this phase which would correspond to $\Lambda = 0$, can be accepted physically, will be one of the key topics in the sequel. The conditions defining the space-time surfaces are exactly solvable and the conjecture is that these surfaces are minimal surfaces by their holomorphy (the induced metric of the spacetime surface does not however play any role and its role is taken by the complexification number theoretic octonion norm which is real valued for the real projections) [L127, L128, L160].

Space-time surfaces at the level of $H = M^4 \times CP_2$

At the level of $H = M^4 \times CP_2$, space-time surfaces are preferred extremals (PEs) of a 6-D Kähler action fixed by the twistor lift of TGD [L96]. The existence of the twistor lift makes TGD unique since only the twistor spaces of $T(M^4)$ and $T(CP_2)$ have the needed Kähler structure [A36]. The 6-D twistor space $T(X^4)$ of the space-time surface X^4 is represented as a 6-surface X^6 in $T(M^4) \times T(CP_2)$. $T(X^4)$ has S^2 as fiber and X^4 as base. The twistor structure of $T(X^4)$ is induced from the product of twistor structures of $T(M^4)$ and $T(CP_2)$. The S^2 bundle structure of X^6 requires dimensional reduction and dimensionally reduced 6-D Kähler action consists of a volume term having an interpretation in terms of length scale dependent cosmological constant Λ and 4-D Kähler action.

Physically "preferred" means holography: to a given 3-surface at the either boundary of CD one can assign a unique space-time surface as an analog of Bohr orbit. This assumption is very probably too strong: the number of Bohr orbits is finite and the dynamically determined frames of the space-time surface would characterize the non-determinism [L165]. "Preferred" has several mathematical meanings, which are conjectured to be equivalent.

One of those meanings is that space-time surfaces simultaneous extremals of both volume term and Kähler action and field equations reduce almost everywhere to the analogs of the conditions satisfied by complex surfaces of complex manifolds. Note that the field equations express local conservation laws for the isometries of $H = M^4 \times CP_2$ and are in this sense hydrodynamic.

The field equations for preferred extremals do not depend on coupling parameters. This expresses quantum criticality and reduces the number of solutions dramatically as required by the fact that at the level the field equations are algebraic rather than differential equations.

Space-time surfaces are therefore minimal surfaces everywhere except at singularities, which are lower-dimensional surfaces. At singularities they are satisfied only for the entire action. The divergences of the isometry currents for the volume term and Kähler action would have delta function singularities, which must cancel each other to guarantee conservation laws.

The singular surfaces can be wormhole throats as boundaries of CP_2 type extremals at which the signature of the induced metric changes, partonic 2-surfaces acting as analogs of vertices at which light-like partonic orbits representing the lines of generalized Feynman (or twistor) diagram meet, and string world sheets having light-like boundaries at partonic orbits.

Also 3-D singularities are predicted and could be associated to time= constant hyperplanes of M^4 , which in M^8 picture are associated with the roots of the polynomials determining spacetime region: I have christened these roots "very special moments in the life of self" [L110]. The roots define 6-spheres as universal special solutions and they intersect future light-cone along $t = r_n$ hyper-plane. It is possible to glue different solutions together along these planes so that they can serve as loci of classical non-determinism.

The singular surfaces are analogous to the frames of soap films [L165]: part of them are fixed and at the boundaries of CD and part of them are dynamically generated. Classical conservation laws for the isometry currents expressing field equations pose strong conditions on what can happen in vertices.

$M^8 - H$ correspondence for the singularities

By $M^8 - H$ correspondence, the singular surfaces of $X^4 \subset H$ correspond to the singularities of the pre-image at the level of M^8 . For the singularities $X^4 \subset M^8$ the quaternionic normal space of X^4 is not unique at points of a d < 4 dimensional surface but is replaced with a union of quaternionic normal spaces labelled by the points of sub-manifold of CP_2 for which the dimension is $d_c = 4 - d$. At the level of H, the singular points blow-up to d_c -dimensional surfaces. What happens for the normal space at a puncture of 3-space serves as a good analog.

In particular, the deformation of a CP_2 type extremal as a singularity corresponds to an image of a 1-D singularity with $(d = 1, d_c = 3)$ and $d_c = 3$ -dimensional blow up. The properties of

 CP_2 type extremals suggest the 1-D curve is light-like curve for mere Kähler action and light-like geodesic for the Kähler action plus volume term.

These situations correspond to $\Lambda = 0$ and $\Lambda > 0$, where Λ is length scale dependent cosmological constant as coefficient of the volume term of action.

Membrane like structures as particularly interesting singularities

Membrane-like structures appear in all length scales from soap bubbles to large cosmic voids and it would be nice if they were fundamental objects in the TGD Universe. The Fermi bubble in the galactic center is an especially interesting membrane-like structure also from the TGD point of view as also the membrane- like structure presumably defining the analog of horizon for the TGD counterpart of a blackhole. Cell membrane is an example of a biological structure of this kind. I have however failed to identify candidates for the membrane-like structures.

An especially interesting singularity would be a static 3-D singularity $M^1 \times X^2$ with a geodesic circle $S^1 \subset CP_2$ as a local blow-up.

- 1. The simplest guess is a bubble-like structure as a product $M^1 \times S^2 \times S^1 \subset M^4 \times CP_2$. The problem is that a soap bubble is not a minimal surface: a pressure difference between interior and exterior of the bubble is required so that the trace of the second fundamental form is constant. Quite generally, closed 2-D surfaces cannot be minimal surfaces in a flat 3-space since the vanishing curvature of the minimal surface forces the local saddle structure.
- 2. A correlation between M^4 and CP_2 degrees of freedom is required. In order to obtain a minimal surface, one must achieve a situation in which the S^2 part of the second fundamental form contains a contribution from a geodesic circle $S^1 \subset CP_2$ so that its trace vanishes. A simple example would correspond to a soap bubble-like minimal surface with M^4 projection $M^1 \times X^2$, which has having geodesic circle S^1 as a local CP_2 projection, which depends on the point of $M^1 \times X^2$.
- 3. The simplest candidate for the minimal surface $M^1 \times S^2 \subset M^4$. One could assign a geodesic circle $S^1 \subset CP_2$ to each point of S^2 in such a way that the orientation of $S^1 \subset CP_2$ depends on the point of S^2 .
- 4. A natural simplifying assumption is that one has $S^1 \subset S_1^2 \subset CP_2$, where S_1^2 is a geodesic sphere of CP_2 which can be either homologically trivial or non-trivial. One would have a map $S^2 \to S_1^2$ such that the image point of point of S^2 defines the position of the North pole of S_1^2 defining the corresponding geodesic circle as the equatorial circle.

The maps $S^2 \to S_1^2$ are characterized by a winding number. The map could also depend on the time coordinate for M^1 so that the circle S^1 associated with a given point of S^1 would rotate in S_1^2 . North pole of S_1^2 defining the corresponding geodesic circle as an equatorial circle. These maps are characterized by a winding number. The map could also depend on the time coordinate for M^1 so that the circle S^1 associated with a given point of S^1 would rotate in S_1^2 .

The minimal surface property might be realized for maximally symmetric maps. Isometric identification using map with winding number $n = \pm 1$ is certainly the simplest imaginable possibility.

Large voids of size scale or order 10^8 light years forming honeycomb like structures are rather mysterious objects, or rather non-objects. The GRT based proposal is that the formation of gravitational bound states leads to these kinds of structures in general relativity but I do now know how convincing these arguments really are.

One should answer two questions: what are these voids and why do they form these latticelike structures?

One explanation of large voids is based on the TGD based view about space-time as a 4-surface in $H = M^4 \times CP_2$.

1. Space-time surfaces have M^4 projection, which is 4-D for what I call Einsteinian space-times. At this limit general relativity is expected to be a good approximation for the field theory limit of TGD.

However, the M^4 projection can be also 3-D, 2-D or 1-D. In these cases one has what looks like a membrane, string, or point-like particle. All these options are realized. The simplest membranes would look like $M^1 \times S^2 \times S^1$, S^1 a geodesic circle of CP_2 , which depends on a point of $M^1 \times S^2$ defining the M^4 projection. Only this assumption allows us to have a minimal surface. Varying S^1 creates the analog of pressure difference making soap films possible. I discovered this quite recently although the existence of membrane like entities was almost obvious from the beginning.

Small perturbations tend to thicken the dimension of M^4 projection to 4 but the deformed objects are in an excellent approximation still 3-D, 2-D or 1-D.

- 2. Large voids could be really voids in a good idealization! Even 4-D space-time would be absent! The void would be the true vacuum. It should be noticed that matter as smaller objects, say cosmic strings thickened to flux tubes, would in turn have galaxies as tangles, which in turn would have stars as tangles. The TGD counterparts of blackholes would be dense flux tube spaghettis filling the entire volume.
- 3. What is remarkable that membranes are everywhere: large voids, blackhole horizons, Fermi bubbles, cell membranes, soap bubbles, bubbles in water, shock wave fronts, etc....

What could then give rise to the lattice like structures formed from voids? Here TGD suggests a rather obvious solution.

1. The lattices could correspond to tessellations of the 3-D hyperbolic space H^3 for which cosmic time coordinate identified as light-cone proper time is constant. H^3 allows an infinite number of tessellations whereas Euclidean 3-space allows a relatively small number of lattices.

There is even empirical evidence for these tessellations. Along the same line of sight there are several sources of light and the redshifts are quantized. One speaks of God's fingers [E4] [K102]. This is what any tessellation of cosmic voids would predict: cosmic redshift would define effective distance. Of course also tessellations in smaller scales can be considered.

- 2. Also ordinary atomic lattices could involve this kind of tessellations with atomic nuclei at the centers of the unit cells as voids. The space between nucleus and atom would literally be empty, even 4-D space-time would be absent!
- 3. Also the TGD inspired model for genetic code [L159] involves a particular tessellation of H^3 realized at the magnetic body (MB) of a biological system and realizing genetic code. This leads to the conjecture that genetic code is universal and does not characterize only living matter. It would be induced to the space-time surface in the sense that part of tessellation would define a tessellation at the space-time surface. At the level of dark matter at MB, 1-D DNA could also have 2-D and even 3-D analogs, even in ordinary living matter!

18.5.2 Key questions

The basic question to be discussed in the following is what the general ideas about 2-D minimal surfaces can teach about minimal surfaces in M^8 and H, and more generally, about quantum TGD.

Uncertainty Principle and $M^8 - H$ duality

The interpretation of M^8 as analog of momentum space [L127, L128] meant a breakthrough in the understanding of $M^8 - H$ duality but created also a problem. How can one guarantee that $M^8 - H$ duality is consistent with Uncertainty Principle (UP)? The surfaces to which one can assign well defined momentum in M^8 should correspond to the analogs of plane waves in H and geometrically to periodic surfaces.

The fact that at the level of M^8 the surfaces are algebraic surfaces defined by polynomials with rational coefficients poses therefore a problem. Periodicity requires trigonometric functions. The introduction of real analytic functions with rational Taylor coefficients would force the introduction of infinite-D extensions of rationals and make this possible. This is however in conflict with the idea about the finiteness of cognition forming the basic principle of adelic physics [L66, L67].

Is the category of polymials enough?

Is it possible to have periodic minimal surfaces at the level of H or at the level of both M^8 and H without leaving the category polynomials?

- 1. Could the non-local character of the $M^8 H$ duality in CP_2 degrees freedom miraculously give rise to periodic functions at the level of H? Or should one perhaps modify $M^8 H$ duality itself to achieve this [L160].
- 2. Periodic frames assignable to light-like curves in M^8 as light-like curves would allow to achieve periodicity in the same manner as for helicoid but this requires the extension of the category of real polynomials to real analytic functions in M^8 . One could even give up the assumption about a Taylor expansion with rational coefficients and assume that the coefficients belong to some possibly transcendental extension of rationals. This option would make sense in $\Lambda = 0$ phase.
- 3. Or could geometry come in rescue of algebra? Could one construct periodic surfaces both at the level of M^8 and H purely geometrically by gluing minimal surfaces together to form repeating patterns as is done for 2-D minimal surfaces? This option could work in $\Lambda > 0$ phases: smoothness at the junctions would be given up but local conservation laws would hold true for the entire action rather than for volume term and Kähler action separately.

If transcendental extensions are allowed, they would naturally contain some maximal root $e^{1/n}$ and its powers. The induced extension of p-adics is finite-D since e^p is an ordinary p-adic number. Logarithms of log(k), $1 \le k \le p$, and their powers are needed to define p-adic logarithm for given p. The outcome is an infinite-D extension. Also π and its powers are expected to belong to the minimal transcendental extension.

It came as a surprise to me that is not known whether e and π are algebraically independent over rationals, that is whether a polynomial equation P(x, y) = 0 with rational coefficients is true for $(x, y) = (\pi, e)$ (https://cutt.ly/xmyL23W.) This would imply that π belongs to the extension defined by the polynomial P(y, e) in an extension of rationals by e. Same would be true in the corresponding finite-D extensions of p-adic numbers. The algebraic independence of π and e would have rather dramatic implications for the TGD view about cognition. That π and e are algebraically independent follows from a more general conjecture by Schanuel and https://cutt.ly/ImyL1YJ).

Is also $\Lambda > 0$ phase physically acceptable?

Can one allow also $\Lambda = 0$ phase for the action. In this case the action reduces to mere Kähler action defined by M^4 and CP_2 Kähler forms analogous to self-dual covariantly constant U(1) gauge fields? Could one see $\Lambda = 0$ phase as an analog of Higgs=0 phase?

In this phase the category of rational functions would expand to a category of real analytic functions and infinite extensions of rationals containing transcendental numbers would be unavoidable and allow light-like curves as frames instead of piecewise light-like geodesics.

One could argue that since the evolution of mathematical consciousness has led to the notion transcendentals and transcendental functions, they must be realized also at the level of space-time surfaces.

One can invent objections against the $\Lambda = 0$ phase for which Kähler action has only CP_2 part and serving at the same time as arguments for the necessity of M^4 part.

1. For a mere CP_2 Kähler action, the CP_2 type extremals representing building bricks of elementary particles become vacuum extremals and are lost from the spectrum. However, also the M^4 part of Kähler action predicted by the twistor lift gives rise to Chern-Simons (C-S) term assignable to the light-like 3-surface X_L^3 as the orbit of partonic 2-surface and one can assign a momentum to X_L^3 . The boundary conditions guaranteeing momentum conservation make possible momentum exchange between interior and X_L^3 . 2. CP_2 Kähler action has a huge vacuum degeneracy since space-time surfaces with 2-D Lagrangian manifold as a CP_2 projection are vacuum extremals. $\Lambda > 0$ eliminates most of these extremals. Also the M^4 part of Kähler action, which vanishes for canonically imbedded M^4 , implies that most vacuum extremals of CP_2 Kähler action cease to be extremals even for $\Lambda = 0$.

While writing the first version of this article I had not realized that what the correct form for the Kähler property in M^4 case is.

- 1. Suppose for definiteness the simplest option that the M^4 Kähler form are associated with the decomposition $M^4 = M^2 \times E^2$. A more general decomposition corresponds to Hamilton-Jacobi structure in which the distributions for $M^2(x)$ and $E^2(x)$ orthogonal to each other are integrable and define slicings of M^4 [L169].
- 2. The naive guess was that $J^2 = -g$ condition must be satisfied. This implies that the M^2 part of Kähler form of $M^4 = M^2 \times E^2$ decomposition has an electric part, which is imaginary so that the energy density is of form $-E^2 + B^2$ (= 0 for M^4). For instance, solutions of $M^2 \times Y^2$, where Y^2 is any Lagrangian manifold of CP_2 would have negative energy for $\Lambda = 0$. Even worse, Kähler gauge potential would be imaginary and the modified Dirac equation would be non-hermitian.
- 3. The problem disappears by noticing that the M^2 by its signature has hypercomplex rather than complex structure, which means that the counterpart of the imaginary unit satisfies $e^2 = 1$ rather than $i^2 = -1$. This allows a real Kähler electric field and the situation is the same as in Maxwell's theory.

18.5.3 About 2-D minimal surfaces

A brief summary about 2-D minimal surfaces and questions raised by them in TGD framework is in order. One can classify minimal surfaces to those without frame and with frame.

Some examples of 2-D minimal surfaces

The following examples about minimal surfaces are collected from the general Wikipedia article about minimal surface https://cutt.ly/Hn673ry) and various other Wikipedia articles. This article gives also references to articles (for instance the article "The classical theory of minimal surfaces" of Meeks and Perez [A54]) and textbooks discussing minimal surfaces, see for instance [A46]. Also links to online sources are given. "Touching Soap Films - An introduction to minimal surfaces" https://cutt.ly/dmwMnJ7) serves as a general introduction to minimal surfaces). There is also a gallery of periodic minimal surfaces (https://cutt.ly/RmwMQ49), which is of special interest from the TGD point of view.

1. Minimal surfaces without frame

In E^3 frameless minimal surfaces have an infinite size and are often glued from pieces, which asymptotically approach a flat plane.

Catenoid (https://cutt.ly/in675Z6) is obtained by a rotation of a catenoid, which is the form of the chain spanned between poles of equal height in the gravitational field of Earth. Catenoid has two planes as asymptotics and is obtained from torus by adding two punctures. Costa's minimal surface (https://cutt.ly/in65wyP) is obtained from torus by adding a single puncture and its second end looks like a catenoid.

Frameless minimal surfaces in E^3 allow also lattice-like structures. Schwarz minimal surface (https://cutt.ly/dn65rJm) is an example about minimal giving rise to 3-D lattice like structure. These surfaces have minimal genus g = 3.

In compact spaces closed minimal surfaces are possible and some quite surprising results hold true, see the popular article "Math Duo Maps the Infinite Terrain of Minimal Surfaces" (http://tinyurl.com/yyetb7c7). These surfaces have area proportional to volume of the embedding space and the explanation is that these surfaces fill the volume densely [A37, A42].

2. Minimal surfaces with lattice like structure

There exists also minimal surfaces with lattice-like structure.

- 1. Riemann described a one parameter of minimal surfaces with a 1-D lattice structure consisting of shelfs connected by catenoids (https://cutt.ly/Pn65y3f).
- 2. Scherk surfaces (https://cutt.ly/3n65oeB) are singly or doubly periodic. Scwartz surfaces (https://cutt.ly/un65pCK) are triply periodic structures defining 3-D lattices and have minimal genus g = 3. This kind of surfaces have been used to model condensed matter lattices. These surfaces have also hyperbolic counterparts.

3. Minimal surfaces spanned by frames

Minimal surfaces with frames allow to models soap films and are obtained as a solution of the Plateau's problem (https://cutt.ly/7n65fgT).

- 1. Helicoid (https://cutt.ly/Wn65jgT) represents a basic example of a simply periodic framed surface. Also helicoid involves transcendental functions. A portion of helicoid is locally isometric to catenoid.
- 2. Arbitrary curves can serve as frames with some mild restrictions. The minimal surface need not be unique. A given 2-D minimal surface is obtained in topological sense from a compact manifold by adding a puncture to represent boundaries defined by frames or the boundaries at infinity.

Some comments on 2-D minimal surfaces in relation to TGD

The study of the general properties of 2-D minimal surfaces from the TGD perspective suggest a generalization to the TGD framework and also makes possible a wider perspective about TGD itself.

1. Frameless minimal surfaces in TGD framework

Frameless minimal surfaces in E^3 have infinite sizes since they are locally saddle like. In TGD framework, the most interesting space-time surface are expected to be framed. Despite this frameless minimal surfaces are of interest.

1. In the TGD framework the minimal surfaces could extend to infinity in time-direction and remain finite in spatial directions. The asymptotically flat 2-plane could in TGD correspond to the simplest extremals of action: M^4 and "massless extremals" (MEs); surfaces $X^2 \times Y^2$ with X^2 a string world sheet and Y^2 complex manifold of CP_2 ; and CP_2 type extremals with 1-D light-like curve as CP_2 projection.

Conservation laws do not allow M^4 even in principle unless the total angular momentum and color charges vanish. Various singularities could deform flat M^4 in close analogy with point and line charges.

2. In curved compact spaces also closed minimal surfaces are possible [A37, A42] (http:// tinyurl.com/yyetb7c7). One can wonder whether CP_2 as a curved space might allow a volume-filling closed 2-D or 3-D minimal surfaces besides complex surfaces and minimal Lagrangian manifolds [L111]. For $\Lambda > 0$, only complex surfaces defined by polynomials in M^8 appear in PEs. It is difficult to see how this kind of exotic structure could define a physically interesting partonic 2-surface although formally one could consider a product of string world sheet and this kind of 2-surface.

2. Minimal surfaces with lattice structure

2-D minimal surfaces in E^3 allow lattice-like structures with dimensions 1, 2 and even 3. They are are interesting also in TGD framework.

1. Scwartz surface (https://cutt.ly/un65pCK), call it S, allows in the TGD framework a variant of form $M^1 \times S \times S^1$, where S^1 is a geodesic sphere. Same applies to all 2-D minimal

surfaces allowing a lattice structure and could be in a central role in condensed matter physics according to TGD. Also hyperbolic variants of a lattice like structure expected to relate to the tessellations of hyperbolic 3-space can be considered and could play important role at the level of magnetic bodies (MBs) as indeed suggested [L159].

2. If $\Lambda = 0$ phase is physically acceptable, it would make possible light-like curves as frames and also lattice-like minimal surfaces with periodicity forced by that of the light-like curve assignable to to CP_2 type extremal as M^8 pre-image.

Note that $\Lambda = 0$ phase relates to $\Lambda > 0$ phase by the breaking of conformal symmetry transforming light-like curves to light-like geodesics. The interpretation of $\Lambda = 0$ phase in terms of the emergence of continuous string world sheet degrees of freedom is attractive.

Another interpretation would be based on the hierarchy of Jones inclusions of hyper-finite factors of type II_1 (HFFs). $\Lambda > 0$ phase would define the reduced configuration space ("world of calassical worlds" (WCW)) in finite measurement resolution defined by the included HFF representing measurement resolution and $\Lambda = 0$ phase as the factor without this reduction. The approximation of real analytic functions by polynomials of a given degree would define the inclusion. This sequence of approximations would be realized as genuine physical systems ,rather than only approximate descriptions of them.

3. For $\Lambda > 0$ allowing only polynomial function, periodic smooth minimal surfaces in M^8 . The construction of Schwartz surface suggests how one can circumvent this difficulty.

Schwartz surface defines a 3-D lattice obtained by gluing together analogs of unit cells. If a region of a minimal surface intersects orthogonally a plane, the gluing of this surface together with its mirror image gives rise to a larger minimal surface and one can construct an entire lattice-like system in this way. These surfaces are not smooth at the junctions.

In the TGD framework, one would construct lattice in time direction and the gluing would occur at edges defined by 3-D $t = r_n$ planes ("very special moments in the life of self" [L110]). Local conservation laws as limits of field equations are enough and derivatives can be discontinuous at $t = r_n$ planes. The expected non-uniqueness of the gluing procedure would mean a partial failure of the strict classical determinism having a crucial role in the understanding of cognition in ZEO. This is discussed in [L165].

 M^8 -picture suggests a very concrete geometric recipe for constructing minimal surfaces periodic in time direction and this would make it possible to realize UP for $M^8 - H$ duality.

The general vision would be that $\Lambda > 0$ phases the periodic minimal surfaces can be constructed as piecewise smooth lattice-like structures in the category of real polynomials by using the gluing procedure whereas in $\Lambda = 0$ phase they correspond to smooth surfaces in the category of real analytic functions.

3. Minimal surfaces spanned by frames

Minimal surfaces spanned by frames are of special interest from TGD point of view.

- 1. In the TGD framework. Minimal surfaces are spanned by fixed frames at the boundary of CD and by dynamically generated frames in the interior of CD. The dynamically generated frames break strict determinism, which means that space-time surfaces as analogs of Bohr orbits becomes non-unique [L165] and holography (for its various forms see [L127, L128]) forced by the General Coordinate Invariance is not completely unique.
- 2. CP_2 type extremal in H would correspond to 1-D singularity in M^8 analogous to a frame assigned 2-D minimal surfaces. The physical picture suggests that this curve is a light-like curve for the Kähler action ($\Lambda = 0$) and a light-like geodesic for action involving also volume term ($\Lambda > 0$). In the first case the periodicity of the light-like curve could give rise to periodic minimal surfaces as generalization of helicoid. In the second case discretized variants could replace these curves.
- 3. For the minimal surfaces discussed above, polynomials are not enough for their construction and the examples involve transcendental functions like trigonometric, exponential and logarithmic functions in their definition.

The same is expected to be true also in TGD. Should one leave the category of polynomials and allow all real analytic functions with rational Taylor coefficients? Or should one assume also the $\Lambda = 0$ phase making possible real analytic functions?

As far as cognitive representations are involved, this would mean that cognition becomes infinite since the extensions of p-adic become infinite. Could $\Lambda = 0$ phase be associated with an expansion of consciousness, kind of enlightment, and relate to mathematical consciousness?

18.5.4 Periodic minimal surfaces with periodicity in time direction

There are several motivations for the periodic minimal surfaces.

Consistency of $M^8 - H$ duality with Uncertainty Principle

Consistency of $M^8 - H$ duality with UP is one motivation.

1. M^8 is interpreted as an analog of momentum space. $M^8 - H$ correspondence must be consistent with UP. If $M^8 - H$ correspondence in M^4 degrees of freedom involves inversion of form $m^k \to \hbar_{eff} m^k/m^2$. [L127, L128, L160]. This solves the problem only partially. $M^8 - H$ correspondence should realize also the idea about plane wave as space-time counterpart of point in momentum space.

The first guess [L160] would be that the $X^4 \subset CD \subset M^8$ is mapped to a union of translates of images of CD by inverse of P^k , where is the total momentum assignable to CD. What I saw as a problem, was that this gives a lattice-like many-particle state rather than a single particle state as a counterpart of a plane wave.

If the momentum is space-like, this is indeed the case. Therefore I proposed that the image is a quantum superposition of translates rather than their union and represents an analog of plane wave. I failed to realize that this is not the case for time-like momentum since periodicity in time direction does not mean lattice as many-particle state.

A geometric correspondence for time-like momenta is possible after all! The problem is a concrete realization of this correspondence and here the geometric construction gluing together the analogs of unit cells to form a periodic structure in time direction suggests itself.

2. Quite concretely, one could take part of $X^4 \subset CD \subset M^8$ defining particle and construct a periodic surface with a period determined by the total time-like momentum assignable to this part of X^4 . X^4 has a slicing by planes $e = e_n$ [L110] assignable to 6-branes with topology of S^6 defining universal special solutions of algebraic equations. Here e_n is a root of the real polynomial defining X^4 .

One could take a piece $[e_1, ..., e_k]$ of $X^4 \subset CD$ and glue it to its time reversal in M^8 to get a basic unit cell and fuse these unit cells together to obtain a periodic structure.

The differences $e_i - e_j$, which for M^8 correspond to energy differences, are mapped by inversion to time differences $t_i - t_j$ in H. The order of magnitude for the p-adic length scale assignable to CD in question is the same as for the largest difference for the roots as conjectured on basis of the conjecture that the p-adic length scale correspond to a ramified prime of the extension dividing $|t_i - t_j|^2$ for some pair (i, j). The p-adic prime for CD need not however be a ramified prime and one can develop an argument for how it emerges [L165].

3. Rather remarkably, one can glue together portions $[t_1, ..t_r]$ and the mirror image of $[t_k, t_r]$, for any k. All possible sequences of this kind are possible! This suggests an analogy to logical reasoning: $[t_n, t_{n+1}]$ would represent a basic step $t_n \to t_{n+1}$ in the reasoning and one could combine these steps. Could this process serve as the geometric correlate for logical thought or as engineering at the level of fundamenta interactions?

The physicalists refusing to accept non-determinism at the fundamental level fail to realize that our technology relies on a fusion of deterministic processes and is therefore not consistent with strict determinism. Also computer programs consist of deterministic pieces. 4. There is still one open question. Does the construction of the time lattices occur only at the level of H or both at the level of M^8 and H? One can argue that the realization of the analog of inverse Fourier transform forces the construction at both sides.

Bohr orbitology for particles in terms of minimal surfaces

In TGD, space-time surfaces correspond to analogs of Bohr orbits. One should also have classical space-time analogs for ordinary bound states as Bohr orbits for particles. Atoms represent the basic example. In TGD Universe, Bohr model should be much more than mere semiclassical model. Also the geodesic orbits of particles in gravitational fields should have minimal surface analogs.

The Bohr orbits should be representable as parts of minimal surfaces identifiable as deformed CP_2 type extremals. There are two options to consider corresponding to $\Lambda = 0$ phase and to $\Lambda > 0$ phases.

1. $\Lambda = 0$ phase

 $\Lambda = 0$ phase corresponds to a long length scale limit but general consideratons encourage its inclusion as a genuine phase. Its relation to $\Lambda > 0$ phases would be like the relation of real numbers to extensions of rationals and transcendental functions to polynomials.

1. For $\Lambda = 0$, CP_2 type extremals are vacuum extremals and correspond to 1-D singularities, which are light-like curves in M^8 blown up to orbits of wormhole contacts in H.

Light-like curve as an M^4 projection of Bohr orbit of this kind can give rise to "zitterbewegung" as a helical motion with average cm velocity v < c. The proposal for the TGD based geometric description of Higgs mechanism realizes this zitterbewegung of CP_2 type extremals for Kähler action. This makes it possible to assign to any particle orbit - be it Bohr orbit in an atom or a geodesic path in a gravitational field, an average of a light-like curve.

2. Light-likeness gives rise to Virasoro conditions emerging in the bosonic string theories. This served as a stimulus leading to the assignment of extended Kac-Moody symmetries to the light-like partonic orbits X^3 . The isometries of H define the extended Kac-Moody group. The generators of the Kac-Moody algebra depend on the complex coordinate z of the partonic 2-surface and on the light-like radial coordinate of X^3 . Super-symplectic symmetries assigned to the light-like $\delta M^4_{\pm} \times CP_2$ and identified as isometries of WCW have an analogous structure [K97] [L138].

The light-like orbits of the partonic 2-surfaces in H are connected by string world sheets. The interpretation could be that in $\Lambda = 0$ phase strings emerge as additional degrees of freedom.

3. For CP_2 part of Kähler action $\Lambda = 0$ CP_2 type extremals are vacua (this need not be the case for the deformations). The C-S term for CP_2 Kähler action carries no momentum and cannot contribute to momentum and cannot realize momentum conservation for deformed CP_2 type extremals.

However, the C-S term for the M^4 part of Kähler action defines the partonic orbits as dynamical entities. If the projection of the deformation of CP_2 type extremal at the wormhole throat has M^4 projection with dimension D = 3, M^4 C-S term gives rise to non-vanishing momentum currents and the smooth light-orbit is consistent with the momentum conservation if boundary conditions are realized. What is remarkable that M^4 C-S term also gives rise to small CP breaking, whose origin is not understood in the standard model. The tiny C-S breaking term would be paramount for the existence of elementary particles!

The implications of this picture are rather profound. It could be possible to assign to any physical system rather detailed view about the minimal surfaces involved both at the level of H and M^8 .

Could tachyonic states appear as parts of non-tachyonic states somewhat like tachyonic virtual particles appear in Feynman graphs?

1. The possibly existing periodic minimal surfaces with tachyonic total momenta would have an interpretation as lattice-like many-particle states. This excludes them as unphysical. In fact, one cannot construct tachyonic periodic minimal surfaces in the proposed way since the planes $t = t_n$ have time-like normal. 2. M^8 picture allows to interpret tachyonicity as a trick. In the M^8 picture the choice of $M^4 \subset M^8$ is in principle free. The mass squared of the particle depends on this choice since M^4 momentum is a projection of M^8 momentum to $M^4 \subset M^8$. For eigenstates of M^4 mass, one can rotate $M^4 \subset M^8$ in such a way that the mass squared vanishes. For a superposition of states with different mass squared possible in ZEO this is not possible but one can choose M^4 so that mass squared is minimized. This gives rise to p-adic thermodynamics as a description for the mixing with heavier states.

One could understand the tachyonic ground state as an effective description for the choice of M^4 in this manner.

2. $\Lambda > 0$ phase

For $\Lambda > 0$ only light-like geodesics are possible and this forces a modification of the above picture by replacing light-like curves with piece-wise light-like geodesics.

- 1. A discrete variant of zitterbewegung consisting of pieces of light-like geodesics is suggestive. The dynamics in stringy degrees of freedom would be almost frozen and completely dictated by the ends of the string. Discretized version of smooth dynamics would be in question. This kind of phenomenological model for hadronic strings has been proposed.
- 2. The change of the direction of the partonic orbit takes place in a vertex. In M^8 picture it is associated with a partonic 2-surface associated with a $t = r_n$ hyperplane at which several CP_2 type extremals meet at the level of H. These reactions could be seen as ordinary particle reactions.
- 3. Another way to change the direction would be based on the interaction of parton with the interior degrees of freedom so that conservation laws are not lost. The interaction between the 3-D orbit of wormhole throat and interior is defined by the condition that normal components of the isometry currents of the total Kähler action are equal to the divergences of C-S currents the partonic orbit. For the M^4 part of C-S action only momentum currents are non-vanishing whereas for CP_2 only color currents are non-vanishing.

At the turning points the normal current of the entire Kähler action - and the divergence of the isometry current for C-S part CP_2 type extremal must become non-vanishing and divergent but cancel each other. Local conservation laws hold true and one can speak of a momentum exchange between interior and wormhole throat. This picture applies also to color currents.

3. A connection with Higgs mechanism

The fact that zitterbewegung makes the particle effectively massive in long enough scales, suggests an analogy with the massivation by the Higgs mechanism.

- 1. The interactions between partonic orbits and the interior of the space-time surface are analogous to the interactions of particles with a Higgs field leading to the massivation as the Higgs field develops a vacuum expectation value.
- 2. M^4 Kähler form represents a constant self-dual Abelian gauge field. Although this field is not a scalar field, it is analogous to the vacuum expectation value of the Higgs field as far as its effects are considered.

4. A connection twistor diagrams and generalization of cognitive representations

Also a connection with twistor diagrams is suggestive. The light-like geodesic lines appearing as 1-D singularities in M^8 would correspond to light-like differences of the time-like momenta assignable to vertices. In H they are assignable with partonic 2-surfaces identifiable as boundaries of 3-D blow ups of 1-D singularities in M^8 . In M^8 , the graphs containing time-like momenta connected by singular lines would define analogs of twistor diagrams. Also at the level of H the lines connecting partonic 2-surfaces would be light-like as also the distances between them since the inversion map preserves light-likeness of the tangent curves.

This would pose additional conditions on cognitive representations.

1. The original proposal [?] as that cognitive representation consists of points of X^4 for which M^8 coordinates belong to the EQ associated with the polynomial considered. The expectation was that one has a generic situation so that this set is automatically finite.

The explicit solution of the polynomial equations however led to a surprising finding was that the number of these points was a dense set for the space-time surfaces satisfying co-associativity conditions [L127, L128]. The second surprise was that co-associativity (associativity of normal space) is the only possible option.

2. The additional conditions guaranteeing that the cognitive representation consists of a finite number of objects, generalize it from a discrete set of points to a union of singularities with co-dimension $d_c = 4 - d$, d = 1, 2, 3.

The vertices would be connected by d = 1 light-like singularities and belong to 2-D partonic 2-surfaces as d = 2 singularities at $t = r_n$ surfaces in turn defining d = 3 singularities. Also 2-D string world sheets having d = 1 singularities as boundaries would be included.

3. This would also generalize twistor diagrams as a frame holographically coding for the spacetime surface as an analog of Bohr orbit. At the M^8 level, the definition of the parts of this structure would involve only parameters with values in EQ (say the end points of a light-like geodesic defining it).

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 surface would induce corresponding biological patterns.

The notion of time crystal [B16] (https://cutt.ly/2n65x0k) as a temporal analog of ordinary crystals in the sense that there is temporal periodicity, was proposed by Frank Wilczeck in 2012. Experimental realization was demonstrated in 2016-2017 [D9] but not in the way theorized by Wilczek. Soon also a no-go theorem against the original form of the time crystal emerged [B28] and motivated generalizations of the Wilzeck's proposal.

Temporal lattice-like structures defined by minimal surfaces would be obvious candidates for the space-time correlates of time crystals.

1. One must first specify what one means with time crystals. If the time crystal is a system in thermo-dynamic equilibrium, the basic thermodynamics denies periodic thermal equilibrium. A thermodynamical non-equilibrium state must be in question and for the experimentally realized time crystals periodic energy feed is necessary.

Electrons constrained on a ring in an external magnetic field with fractional flux posed to an energy feed form a time crystal in the sense that due to the repulsive Coulomb interaction electrons form a crystal-like structure which rotates. This example serves as an illustration of what time crystal is.

- 2. Breaking of a discrete time translation symmetry of the energy feed takes place and the period of the time crystal is a multiple of the period of the energy feed. The periodic energy feed guarantees that the system never reaches thermal equilibrium. According to the Wikipedia article, there is no energy associated with the oscillation of the system. In rotating coordinates the state becomes time-independent as is clear from the example. What comes to mind is a dynamical generation of Galilean invariance applied to an angle variable instead of linear spatial coordinate.
- 3. Also the existence of isolated time crystals has been proposed assuming unusual long range interactions but have not been realized in laboratory.

Time crystals are highly interesting from the TGD perspective.
- 1. The periodic minimal surfaces constructed by gluing together unit cells would be time crystals in geometric sense (no thermodynamics) and would provide geometric correlates for plane waves as momentum eigenstates and for periodic self-organization patterns induced by the periodic minimal surfaces realized at the level of the magnetic body. It is difficult to avoid the idea that geometric analogs of time crystals are in question.
- 2. The hierarchy of effective Planck constants $h_{eff} = nh_0$ is realized at the level of MB. To preserve the values of h_{eff} energy feed is needed since h_{eff} tends to be reduced spontaneously. Therefore energy feed would be necessary for this kind of time crystals. In living systems, the energy feed has an interpretation as a metabolic energy feed.

The breaking of the discrete time translation symmetry could mean that the period at MB becomes a multiple of the period of the energy feed. The periodic minimal surfaces related to ordinary matter and dark matter interact and this requires con-measurability of the periods to achieve resonance.

- 3. Zero energy ontology (ZEO) predicts that ordinary ("big") state function reduction (BSFR) involves time reversal [L118, L165]. The experiments of Minev *et al* [L104] [L104] give impressive experimental support for the notion in atomic scales, and that SFR looks completely classical deterministic smooth time evolution for the observer with opposite arrow of time. Macroscopic quantum jump can occur in all scales but ZEO together with h_{eff} hierarchy takes care that the world looks classical! The endless debate about the scale in which quantum world becomes classical would be solely due to complete misunderstanding of the notion of time.
- 4. Time reversed dissipation looks like self-organization from the point of view of the external observer. A sub-system with non-standard arrow of time apparently extracts energy from the environment [L113]. Could this mechanism make possible systems in which periodic oscillations take place almost without external energy feed?

Could periodic minimal surfaces provide a model for this kind of system?

1. Suppose that one has a basic unit consisting of the piece $[t_1, .., t_k]$ and its time reversal glued together. One can form a sequence of these units.

Could the members of these pairs be in states, which are time reversals of each other? The first unit would be in a self-organizing phase and the second unit in a dissipative phase. During the self-organizing period the system would extract part of the dissipated energy from the environment. This kind of state would be "breathing" [L225].

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.

18.6 The dynamics of SSFRs as quantum measurement cascades in the group algebra of Galois group

Adelic physics [L65, L66] is a proposal for the physics of both sensory experience having real physics as correlate and cognition having various p-adic physics as correlates. Adele is a book-like structure formed by real numbers and the extensions of p-adic number fields induced by a given extension of rationals with the pages of the book glued together along its back consisting of numbers belonging to the extension of rationals. This picture generalizes to space-time level. Adelic physics relies on the notion of cognitive representation as unique number theoretic discretization of the space-time surface. This discretization has also fermionic analog in terms of spinor structure associated with the group algebra of the Galois group of extension.

Adelic physics, $M^8 - H$ duality, and zero energy ontology lead (ZEO) to a proposal that the dynamics involved with "small" state function reductions (SSFRs) as counterparts of weak measurements could be basically number theoretical dynamics with SSFRs identified as reduction cascades leading to completely un-entangled state in the space of wave functions in Galois group of extension of rationals identifiable as wave functions in the space of cognitive representations. As a side product a prime factorization of the order of Galois group is obtained.

The result looks even more fascinating if the cognitive dynamics is a representation for the dynamics in real degrees of freedom in finite resolution characterized by the extension of rationals. If cognitive representations represent reality approximately, this indeed looks very natural and would provide an analog for adele formula expressing the norm of a rational as the inverse of the product of is p-adic norms.

18.6.1 Adelic physics very briefly

Number theoretic vision leading to adelic physics [L65] provides a general formulation of TGD complementary to the vision [K97] (http://tinyurl.com/sh42dc2) about physics as geometry of "world of classical words" (WCW).

- 1. p-Adic number fields and p-adic space-time sheets serve as correlates of cognition. Adele is a Cartesian product of reals and extensions of all p-adic number fields induced by given extension of rationals. Adeles are thus labelled by extensions of rationals, and one has an evolutionary hierarchy labelled by these extensions. The large the extension, the more complex the extension which can be regarded as n-D space in K sense, that is with K-valued coordinates.
- 2. Evolution is assigned with the increase of algebraic complexity occurring in statistical sense in BSFRs, and possibly also during the time evolution by unitary evolutions and SSFRs following them. Indeed, in [L132] (http://tinyurl.com/quofttl) I considered the possibility that the time evolution of self in this manner could be induced by an iteration of polynomials at least in approximate sense. Iteration is a universal manner to produce fractals as Julia sets and this would lead to the emergence of Mandelbrot and Julia fractals and their 4-D generalizations. In the sequel will represent and argument that the evolution as iterations could hold true in exact sense.

Cognitive representations are identified as intersection of reality and various p-adicities (cognition). At space-time level they consist of points of embedding space $H = M^4 \times CP_2$ or M^8 ($M^8 - H$ duality [L59, L60, L61] allows to consider both as embedding space) having preferred coordinates - M^8 indeed has almost unique linear M^8 coordinates for a given octonion structure.

3. Given extension of given number field K (rationals or extension of rationals) is characterized by its Galois group leaving K - say rationals - invariant and mapping products to products and sums to sums. Given extension E of rationals decomposes to extension E_N of extension E_{N-1} of ... of extension E_1 - denote it by $E \equiv H_N = E_N \circ E_{N-1} \dots \circ E_1$. It is represented at the level of classical space-time dynamics in M^8 (http://tinyurl.com/quofttl) by a polynomial P which is functional composite $P = P_N \circ P_{N-1} \circ \dots \circ P_1$. with $P_i(0) = 0$. The Galois group of G(E) has the Galois group $H_{N-1} = G(E_{N-1} \circ \dots \circ E_1)$ as a normal subgroup so that $G(E)/H_{N-1}$ is group.

The elements of G(E) allow a decomposition to a product $g = h_{N-1} \times h_{N-1} \times ...$ and the order of G(E) is given as the product of orders of H_k : $n = n_0 \times .. \times n_{N-1}$. This factorization of prime importance also from quantum point of view. Galois groups with prime order do not allow this decomposition and the maximal decomposition and are actually cyclic groups Z_p of prime order so that primes appear also in this manner.

Second manner for primes to appear is as ramified primes p_{ram} of extension for which the padic dynamics is critical in a well-defined sense since the irreducible polynomial with rational coefficients defining the extension becomes reducible (decomposes into a product) in order O(p) = 0. The p-adic primes assigned to elementary particles in p-adic calculation have been identified as ramified primes but also the primes labelling prime extensions possess properties making them candidates for p-adic primes. Iterations correspond to the sequence $H_k = G_0^{\circ k}$ of powers of generating Galois groups for the extension of K serving as a starting point. The order of H_k is the power n_0^k of integer $n_0 = \prod p_{0i}^{k_i}$. Now new primes emerges in the decomposition of n_0 . Evolution by iteration is analogous to a unitary evolution as ex^{iHt} power of Hamiltonian, where t parameter takes the role of k.

- 4. The complexity of extension is characterized by the orders n and the orders n_k as also the number N of the factors. In the case of iterations of extension the limit of large N gives fractal.
- 5. Galois group acts in the space of cognitive representations and for Galois extensions for which Galois group has same order as extensions, it is natural do consider quantum states as wave functions in G(E) forming *n*-D group algebra. One can assign to the group algebra also spinor structure giving rise to $D = 2^{M/2}$ fermionic states where one has N = 2M or N = 2M + 1). One can also consider chirality constraints reducing D by a power of 2. An attractive idea is that this spinor structure represents many-fermion states consisting of M/2 fermion modes and providing representation of the fermionic Fock space in finite measurement resolution.

18.6.2 Number theoretical state function reductions as symmetry breaking cascades and prime factorizations

The proposed picture has very important quantal implications and allows to interpret number theoretic quantum measurement as a number theoretic analog for symmetric breaking cascade and also as a factorization of an integer into primes.

- 1. The wave functions in G(E) elements of group algebra of G(E) can be decomposed to tensor products of wave functions in $G(E)/H_{N-1}$ and H_{N-1} : these wave functions in general represent entangled states. One can decompose the wave functions in H_{N-1} in similar manner and the process can be continued so that one obtains a maximal decomposition allowing no further decomposition for any factor. These non-decomposable Galois groups have prime order since its group algebra as Hilbert space of prime dimension has no decomposition into tensor product.
- 2. In state function reduction of wave function G(E) the density matrices associated with pairs $G(E)/H_{N-1}$ and H_{N-1} are measured. The outcome is an eigenstate or eigen-space and gives rise to symmetry breaking from $G(E) \equiv H_N$ to $E_N \times H_{N-1}$. The sequence of state function reductions should lead to a maximal symmetry breaking corresponding to a wave function as a produce of those associated with Galois groups of prime order. This define a prime factorization of the dimension n of Galois group/extension to $n = \prod_{i=1}^{N} p_i^k$! The moments of consciousness for self would correspond to prime factorizations! Self would be number theoretician quite universally!

Also also the fermionic cognitive representation based on finite-D Fock states defined by spinor components of G(E) is involved. The interpretation of Fock state basis as a basis of Boolean algebra in TGD: the spinor structure of WCW could be representation for Boolean logic as a "square root" of Kähler geometry of WCW. Cognition indeed involves also Boolean logic.

18.6.3 SSFR as number theoretic state function reduction cascade and factorization of integer

A highly interesting unanswered question is following. "Small" state function reductions (SSFRs) define the life cycle of self as their sequence. What are the degrees of freedom where SSFRs occur?

- 1. SSFRs take place at the active boundary of CD which shifts in statistical sense towards future in the sequence of state function reductions. State at the passive boundary is not changed.
- 2. The idea that quantum randomness could correspond to classical chaos (or complexity) associated with the iteration of polynomials (Mandelbrot and Julia fractals) [L132] led to reconsider the hypothesis that the polynomial representing space-time decomposes to a product

 $P = P_2(T - r) \times P_1(r)$. T corresponds to the distance between the tips of CD and r = t to the radial coordinate of M^4 assignable to the passive boundary of CD and equal to time coordinate t. $P_i(0) = 0$ is assumed to hold true.

 P_2 would change in SSFRs whereas P_1 and state at passive boundary would not. SSFRs (analogous to so called weak measurements) at active boundary would give rise to sensory input and various associations - Maya in Eastern terminology. P_1 would correspond to the unchanging part of self - "soul" or real self as one might say.

I was also led to consider a simplified hypothesis that P_2 is obtained as iteration $P_2 = Q_1^{\circ n}$ in *n*:th *n* unitary evolution preceding SSFR. One would start from some iterate $Q_1^{\circ k}$. This would reduce quantum dynamics to iteration of polynomials and to a deep connection with Mandelbrot and Julia fractals but it was quite clear why this would be true.

3. The mere factorization $P = P_2 \times P_1$ implies that the Galois groups associated with active and passive boundary of CD commute and number theoretic state function reduction cascade for the wave functions in G(E) for the extension determined by P_2 at active boundary could correspond to SSFR. Or course, also other commuting degrees of freedom are possible but number theoretic degrees of freedom could be the most important degrees of freedom involved with SSFRs.

18.6.4 The quantum dynamics of dark genes as factorization of primes

Gene level provides a fascinating application of this picture.

Thiscontribution was inspired by discussion with Bruno Marchal about his with title "Do the laws of physics apply to the mind?" (https://tinyurl.com/ycls2bpt). Bruno Marchal is a representative of computationalism, which might be called idealistic and Bruno believes that physics follows from computationalism. The somewhat mystical notion of self-reference is believed to lead to consciousness. I do not share this view. The gist of the posting comes towards end where I describe how computationalism generalizes to quantum computationalism in TGD generalizing also the notion of quantum computation. What conscious problem solving is? This is the question to be discussed.

- 1. As found, dark photons and dark protons forming DNA codons as triplets could correspond to triplet representations for prime factor Z_3 of Galois group of Z_6 . Codon and conjugate codon could in turn correspond to the prime factor Z_2 of Galois group Z_6 so that double strand would correspond to Z_6 suggested by findings of Mills [L41] and TGD inspired model color vision [L83].
- 2. DNA codons could correspond to extension with Galois group Z_3 , and one can consider an entire hierarchy of extensions of extensions of ... extensions with dimensions n_i satisfying thus $n = \prod_{i=1}^{N} n_i$ and having Z_6 as subgroup at the lowest level of the hierarchy. The number N of factors would be the number of polynomials in the functional composition and thus define a kind of abstraction levels (abstractions are thoughts about thoughts about..., maps of maps of ...). N is expected to increase in evolution.
- 3. Could this abstraction hierarchy be realized at gene level? Genes decompose into transcribed regions exons and introns. Could different decomposition of genes to exons and introns correspond to different values of N and n_i and to different Galois groups. Could genes themselves form larger composites?

Could genomes form even large structures such as chromosomes with larger Galois groups. Years ago I considered the possibility of a collective gene expression based on the collective MB of organelle, organ, or even population: could this correspond to an extension associated with several genomes?

4. Could SSFR correspond to a sequence of symmetry breakings for the Galois groups of these structures decomposing them to sub-groups? Number theoretic interpretation would in terms of decompositions of integers to primes! Genome would be a quantum computer performing number theory!

5. Metabolic energy feed would increasing h_{eff} would also increase the orders $n_i = h_{eff}/h_0$ of the extensions appearing in the composition of extensions and thus the orders of polynomial factors P_i in the functional composite defining the extensions. Therefore the decompositions would be dynamical.

Metabolic energy feed requires BSFR changing the arrow of time if metabolic energy feed is actually feed of negative energy to environment. The emergence of a new prime factorization would require BSFR. That the time evolution by iterations would not require BSFR would support the proposal that time evolution by BSFRs could be induced by iteration dynamics for the polynomial P_2 assignable to the active boundary of CD.

18.6.5 The relationship of TGD view about consciousness to computationalism

This text was inspired by discussion with Bruno Marchal about his with title "Do the laws of physics apply to the mind?" (https://tinyurl.com/ycls2bpt). Bruno Marchal is a representative of computationalism, which might be called idealistic and Bruno believes that physics follows from computationalism. The somewhat mystical notion of self-reference is believed to lead to consciousness.

I do not share this view. The gist of the posting comes towards end where I describe how computationalism generalizes to quantum computationalism in TGD generalizing also the notion of quantum computation. What conscious problem solving is? This is the question to be discussed.

To my view computationalism is one of the failed approaches to consciousness - it cannot cope with free will for instance. It however contains an essential aspect which is correct: the idea of deterministic program leading from A to B. Problem solving be can regarded as attempt to find this program. You fix A as initial data and try to find a program leading from A to a final state characterized by data B. The program has duration T and can be very long and it is not clear whether it exists at all. You try again and again and eventually you might find it. In the real conscious problem solving this process means making guesses so that the process cannot be deterministic.

What does this view about problem solving correspond to in ZEO? We have states A and B represented as quantum states and we try to find quantum analog of classical program leading from A to B in some time T which can be varied.

1. A and B are realized as superpositions of 3-surfaces and fermionic states at them - located at time values t=0 and t=T. T can vary. Can we find by varying T a (superposition of) deterministic time evolution(s) - preferred extremal(s) (PE) - connecting A and B?

In ZEO and for fixed A and T PE in general does not exist. In ideal situation (infinite measurement resolution) and for given A and T, B is unique if it exists at all. One has analog of Bohr orbit and the quantum analog of classical program as the superposition of Bohr orbits starting from A and hopefully leading to B as a solution of the problem.

Remark: These superpositions can be regarded as counterparts of functions in biology and behaviors in neuroscience. The big difference to standard physics is that time=constant snapshot in time evolution of say bio-system is replaced with quantum superposition of very special time evolutions - PEs. Darwinian selection of also behaviors in biology correlates strongly with this.

2. So: given A and B, we try to find a value of T for which superposition of PEs from A to B exists. This would be the quantum program leading from A to B, and solving our problem.

Actually, not only ours, universe is full of conscious entities solving problems at various levels of self hierarchy. This takes place by a sequences of "small" SFRs (SSFRs, weak measurements) increasing T in statistical sense and replacing the state at B with a new one determined by state A for given value of T. At the level of conscious experience this is sensory perception and all that which is associated with it.

Finding the solution is analogous to the halting of quantum Turing machine by ordinary state function reduction, which corresponds in ZEO to a "big" (ordinary) SFR (BSFR). This

would mean death in universal sense and reincarnation with reversed arrow of time in ZEO? Or is BSFR and death failure to solve the problem? I cannot answer.

Remark: The notion of self-reference is replaced with much more concrete notion of becoming conscious of what one was conscious of before SSFR. SSFR indeed gives rise to conscious eperience and one avoids the infinite regress associated with genuine self-reference. As an additional bonus one obtains evolution since the extension of rationals characterizing space-time surfaces can increase meaning higher level of consciousness. At the limit algebraic numbers the cognitive representation is dense subset of space-time surface.

3. Also finite measurement resolution and discreteness characterizing computation emerge from number theory.

To be a solution classically means that the 3-surface(s) representing B to have fixed discrete cognitive representation given by finite number of embedding space points in the extension of rationals defining the adele. Quantally, quantum superpositions of these points with fixed quantum numbers represent the desired final state.

Also Boolean logic emerges at fundamental level as square root of Kähler geometry one might say. Many-fermion state basis defines a Boolean algebra and time evolution for induced spinors is analogous to truth preserving Boolean map in which truths code for infinite number of conservation laws associated with symmetries of WCW.

4. How to find the possibly existing solution at given step (unitary evolution plus SSFR) with t=T? One performs cognitive quantum measurements at each step represented by SSFR. They reduce to cascades of quantum measurements for the states in the group algebra of Galois group - call it Gal - of Galois extension considered.

Gal has hierarchical decomposition to inclusion hierarchy of normal subgroups implying the representation of states in group algebra of Gal as entangled states in the tensor product of the group algebras of normal sub-groups of Gal. The hope is that this Galois cascade of SFRs produces desired state as an outcome and one can shout "Eureka!".

18.7 DNA and Time Reversal

This section is devoted to the view about DNA inspired by (zero energy ontology) ZEO [L148, L123] forming the basis of the quantum measurement theory of Topological Geometrodynamics (TGD) [K9, K6] and by the notion of dark DNA [L97] inspired by the TGD view about dark matter as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ [L66, L34, L75] at (magnetic body) MB [L2, L98, L52, L219] - the third key notion distinguishing TGD from standard model.

18.7.1 Basic picture

The basic prediction of ZEO is that "big" (ordinary) state function reduction (BSFR) changes the arrow of time meaning "death" and "reincarnation" with opposite arrow of time. For dark matter at the MB the periods with a given arrow of time would be long and induce the long-lasting effective change of the arrow of time for the ordinary matter.

This leads to a new view about self-organization [L125] involving in an essential manner time reversed dissipation looking like energy feed in the standard direction and quantum coherent MB as a master quantum controlling the ordinary matter. The energy feed is necessary since the increase of h_{eff} requires energy.

Time reversal and the dynamics of DNA

The time reversals of the basic processes like transcription and replication turn out to be possible only for the conjugate strand - this is basically due to the chiral selection and CPT theorem in TGD context. CPT C denotes harge conjugation, P spatial reflection, and T geometric time reflection to be distinguished from thermo-dynamical time reversal and time reversal occurring in BSFR. The triviality of C (matter-antimatter asymmetry) implies that T acts like P mapping molecules to their mirror images. By chiral selection enzymes can catalyze processes but not their time reversals. For instance, conjugate strand polymerizes in reverse time direction - this looks like depolymerization in standard time direction. Polymerization of the conjugate strand however occurs in standard time direction but in reverse direction along strand.

The recombination of DNA strands during meiosis is poorly understood. This could correspond to reconnections for the magnetic flux tubes associated with the active DNA strands. Time reversal would occur in BSFR and formerly passive conjugate DNA strands would depolymerize to "loose" codons [L142] (not independent letters) by the time reversed polymerization, the flux tubes associated with the formerly active strands would suffer reconnections inducing recombination without assistance of enzymes, second BSFR would occur, and be followed by the replication of recombined active strands.

Does DNA have longitudinal electric field with direction correlating with the arrow of time?

According to the findings of Becker [J5, J44], the direction of the electric along the body axis field determines whether the system is awake or asleep. By the properties of electric field under time reflection, the arrow of time correlates also with the direction of the electric field. TGD predicts that consciousness is possible even at the level of DNA. Could also DNA have a longitudinal electric field with direction correlating with the arrow of time of DNA at the MB of DNA? Could there be a switch changing the direction of this electric field?

There is an inspiring analogy with microtubules, which are highly dynamical and carry a longitudinal electric field, whose strength correlates with the microtubule length [I160, I161]. Could sticky ends generate a longitudinal field along DNA double strand with strength determined by the lengths of the sticky ends?

In the standard picture the flux of the longitudinal electric field would be proportional to the difference of the negative charges associated with the sticky ends. In TGD framework DNA strands are accompanied by the dark analog of DNA with codons realized as 3-proton units neutralizing the negative charge of the ordinary DNA except at sticky ends.

A simple proposal for the time switch based on the analog of Becker's DC currents emerges: proton flow of the dark protons between sticky ends would change the arrow of time. The model could generalize also to proteins known to be ferro-electrets and accompanied also by their dark analogs.

18.7.2 DNA and time reversal

TGD inspired theory of consciousness based on ZEO [L148] predicts that also DNA is a conscious system: actually TGD Universe is in a well-defined sense panpsychic. In a "big" (ordinary) state function (BSFR) system "dies" and "reincarnates" with a reversed arrow of time. The hierarchy of effective Planck constants $h_{eff} = nh_0$ [L34] having a number theoretical interpretation [L66] labels the phases of the ordinary matter behaving like dark matter and will be referred to as "dark matter" in the sequel. Large values of h_{eff} make quantum coherence possible in arbitrarily long length and time scales.

The dark matter at the layers of the MB of the system (MB means a deviation from Maxwell's electrodynamics) controls the ordinary bio-matter. Dark matter resides at the flux tubes carrying monopole flux not possible in the Maxwellian world. The TGD based model [L25] identiies the negatively charged exclusion zones (EZs) generated in Pollack effect [L20, ?] as regions from which part of protons transferred to flux tubes as dark protons. Applied to the water environment of DNA this leads to the notion of dark DNA as flux tubes carrying dark proton triplets representing genetic codons [L97]. Also mRNA, aminoacids, and tRNA would have these representations. Dark DNA strands would accompany the ordinary DNA strands. The positive charge of the dark DNA and mRNA would screen the negative charge of ordinary DNA and stabilize it.

The attention is in the recent article in the dynamical processes associated with DNA. Could time reversal play a key role in various processes related to DNA. The basic process considered are DNA transcription and replication and meiosis and it is interesting to view them in ZEO. Could one imagine a switch inducing time reversal of DNA as a "big" (ordinary) state function (BSFR) in the scale of entire DNA double strand + dark DNA double strand accompanying it?

Deassembly as a time reversal of assembly and time reversal switch for DNA?

In ZEO one must seriously consider the possibility of reverse translation, reverse transcription and reverse polymerization. The recombination of DNA strands, which is the least well-understood part of meiosis, might involve time reversal of the polymerization of the passive strand and also DNA repair might involve time reversal. Time reversal might allow the healing of genetic defects.

Time reversed processes might occur at least in DNA scale but it is an open question whether they occur in long time scales. As already found, matter-antimatter asymmetry and chiral selection pose strong constraints on the allowed time reversals: they can occur only for the conjugate DNA strand as catalyzed processes. The time reversal of translation is not possible but time reversal of transcription using the conjugate strand is.

1. Few natural scientists like the branch of philosophy called deconstructionism (in particular, "anything goes" irritates any TOE builder) but it would seem that deconstruction is an excellent characterization of assembly and de-assembly as time reversals of each other.

Deconstruction would not be actually a new idea. Sustainable development means that nowadays wastes are treated systematically. Various mechanical and electric devices are de-constructed into their basic building bricks to be used again.

Why not the same in biology? For instance, could protens be deconstructed to tRNA and mRNA, which in turn would be deconstructed to mRNA codon? It turns out that chiral selection prevents time reverse translation.

2. Deconstruction at the level of DNA would naturally involve time reversed DNA + dark DNA and very naturally the passive strand related by a conjugation to active strand would be now active. Deconstruction would be a construction in a reversed time direction. Could this give a reason why for the presence of the passive DNA strand?

One must clarify how the strands are related? What does time reversal do to the strands?

- (a) Since charge conjugation replacing protons with antiprotons does not occur, C must act trivially. CPT = 1 which is identity in quantum field theories but in TGD states that the states at the boundaries of CD are permuted the corresponding fermionic vacua are analogous to Dirac sea and its conjugate. This implies that PT acts trivially and T acts as a reflection P changing the chiralities and direction of the strands.
- (b) Time reversal would transform left-handed strand to right-handed vice versa and the 3' and 5' ends would be permuted. The effect would be a permutation of the strands geometrically. DNA strands would become their mirror images geometrically and for the $3' \rightarrow 5'$ orientation the order codons would be the same.
- (c) The strands of DNA have opposite chiralities. Chiral selection can explain why only the second DNA strand is active: there are no ezymes catalyzing it transcription. In the time reversal the passive strand would become active and the time reversed DNA transcription would begin from 3' end so that the resulting mRNA would conjugate of the mRNA associated with the active strand. For standard time direction the process would look like conjugate mRNA sequence approaching the usually passive strand and decaying to the "loose" mRNA codons [L142] (nucleotides in standard picture).
- (d) If the processes proceed from $3' \rightarrow 5$ direction determined by chemistry, the time reversed transcription would produce the same mRNA. In standard time direction mRNA consistent with conjugate DNA strand would attach to conjugate DNA strand and split to RNA codons (in TGD and to RNA nucleotides in standard picture).
- 3. How could one achieve the deconstruction of say mRNA as a time reversal at the level of DNA? Could there exist a simple time reversal switch in DNA reversing the electric field of DNA+dark DNA? Could there be an enzyme changing the position of this switch?

What could be this switch? In next secton it will be proposed that switch would just move the part of the dark proton sequence associated with sticky end nucleotides to the opposite end of the DNA strand! There would be a proton current flowing along the ordinary DNA strand.

These switching currents could be the counterparts for the direct currents of Becker [J5, J44] and would change the direction of DNA's electric field! This mechanism would change the arrow of time and direction of the electric also at the level of the entire body as it falls in sleep or wakes up! Same applies to the electric field from the frontal lobes to hindbrain.

DNA transcription and replication and their time reversals

Could the time reversals of DNA replication and transcription occur? Is the depolymerization of the DNA strand equivalent to the time reversal or polymerization or are these separate processes? Does the time reversal of the replication make sense?

The basic constraint comes from the discrete symmetries. By matter-antimatter asymmetry charge conjugation is trivial - otherwise also antiprotons would define representation of the dark code. Since the generalization of quantum field theoretic identity CPT = 1 holds true one must have that a generalization of PT = 1 holds true. Time reversal would change the chirality of DNA strands.

Chirality selection for enzymes in turn poses a second powerful constraint meaning that time reversed processes can occur for the passive conjugate DNA strand only (having opposite chirality as compared to active DNA strand). The implication is that enzyme, which have a fixed chirality, can catalyze in standard time direction only processes for the active DNA strand but not for the passive strand. Enzymes can however catalyze time reversed processes for the conjugate strand. In particular, the degradation of active DNA strand cannot be equivalent with time reversal of polymerization since the latter cannot be catalyzed by enzymes.

Consider first the discrete symmetries in more detail.

- 1. The key constraints emerge from the ZEO based generalization of the CPT = 1 identity of quantum field theories generalized to ZEO. Here C is charge conjugation, P is reflection and T time reflection. In ZEO "1" is replaced by permutation of states at the opposite boundaries of CD defining the zero energy state and the replacement of Dirac vacuum with its conjugate. Call this permutation operation P_{ZEO} so that one has $CPT = P_{ZEO}$.
- 2. Since antiprotons are not involved in biology by matter-antimatter asymmetry, C = 1 is true and one obtains $PT = P_{ZEO}$. Therefore T must act as reflection and map DNA strand to its mirror image. Chirality is changed and the order of codons becomes opposite and 3' and 5' ends are permuted. The DNA strand looks like the original one as far as codons are considered but is its geometric mirror image so it is not expected to be active - unless P permutes 3' and 5'. From Wikipedia [115] one learns that this is not the case. Hence the conjugate strand would become active in the time reversal.

In particular, the time reversed catalyzed processes can use only the conjugate strand as a template since only in this case the enzymes satisfy the chirality constraint. In particular, this applies to polymerization and depolymerization, which are not time reversed process as was the first guess. Furthermore, the polymerization for conjugate trand is depolymerization in reversed time direction.

Matter-antimatter asymmetry and chiral selection therefore imply that catalyzed processes for the active DNA strands are in the standard time direction and for the passive DNA strands in the opposite time direction.

Some examples help to understand what would be involved.

1. Consider first the time reversal of the transcription. If the time reversal occurs it must attach mRNA strand to the time reversed conjugate strand and the time reversed transcription would mean splitting of mRNA to "loose" codons [L142]: this process can be catalyzed by enzymes with standard chirality. If the conjugate of the gene coding for mRNA does not exist as a gene, this process is not possible. Therefore mRNA must allow also the ordinary depolymerization catalyzed by enzymes. Same is expected to apply to the depolymerization of DNA and proteins. Loose codons would be analogous to tRNAs.

This raises a question about how symmetric the spectrum of genes is. How often does the conjugate of gene exist? If there is strong symmetry breaking the reverse transcription rarely occurs.

2. An interesting challenge is to understand the details of DNA replication and its possible time reversal. What constraints does the chiral selection for enzymes pose? The replication of both strands is catalyzed by the same enzyme: DNA polymerase and the processes occur simultaneously. Since enzymes have single chirality only, this leaves only one possibility: the replication of the conjugate strand involves time reversal and is depolymerization in the reversed arrow of time.

Indeed, the replication of the conjugate strand occurs in a direction opposite to the ordinary $(3' \rightarrow 5')$. The replication of the conjugates strand would be the decay to codons but in reversed time direction. Note that the splitting of the DNA double strand to separate strands (unentangled quantum systems) is necessary to change the arrow of time only for the conjugate strand.

Meiosis and time reversal

Meiosis is an especially interesting application since the reshuffling of DNA strands in meiosis is not well-understood in biology-as-nothing-but-chemistry approach. The crucial step is the shuffling of the corresponding pieces of homologous DNA strands. Could the reshuffling involve de-assembly regarded as a time reversal of the assembly followed by re-assembly meaning a return to the original arrow of time: this would be completely analogous to what mechanic does when repairing a machine. Also the DNA repair could rely on this mechanism.

1. The first observation made already earlier is that the formation of several reconnections between - say - active DNA strand involving touching at several points with subsequent reconnection at the level of magnetic flux tubes would give an elegant description for the reconnection at the level of say active strands. Here magnetic flux tubes would demonstrate their explanatory power.

The problem is that if this occurs for pairs of both active and passive strands, there is no guarantee that the reconnection patterns determining the re-shuffling are consistent. How can one guarantee this?

- 2. Here time reversal of polymerization for the passive DNA strand comes in rescue. Two BSFRs changing the arrow of time would take place.
 - (a) The arrow of time changes for both strands of DNA. At the de-assebly step the passive strand decays to codons. This is just time reversal for polymerization and by the chirality selection for enzymes only the passive strand can de-assemble in this manner. This happens for the conjugate strands of both double DNA strands involved.
 - (b) At the shuffling step the two formerly active time reversed DNA strands pair with each other and the repeated reconnections about as a sequence of SSFRs inducing shuffling of the pieces of DNA. This process cannot be catalyzed by enzymes since the required chirality would be wrong. Since the outcome is non-deterministic the situation must be quantum critical in the sense that the classical time evolutions defining the zero energy state are initial value sensitive and state function reduction selects superposition of evolutions corresponding to the same outcome.
 - (c) At the re-assembly step the arrow of time changes back to the original for the resulting shuffled active DNA strands replicate.

Whether the translation of mRNA to proteins could have a time reversal was asked in the earlier article [L137]? This does not seem to be possible. Due to the chiral selection proteins do not have double strand structure with strands possessing opposite chiralities. Also mRNA has only one chirality. Therefore the time reversal of translation proceeding from mirror proteins and mirror tRNA to mirror mRNA is not possible.

18.7.3 Could the sticky ends make DNA double strand a conscious ferroelectret?

The basic motivation for this section could be Becker's finding [J5, J44]; its direction determines whether the system is awake or asleep. In ZEO [L148] these states could correspond to opposite arrows of time at some level of the fractal hierarchy of the layers of MB labelled by the values of h_{eff} . The arrow of time would change in BSFR. The sign of the longitudinal electric field correlates with the arrow of time on basic of the basic properties of electromagnetic field tensor so that BSFR should change the direction of electric field: this suggests some kind of switch changing the arrow of time and in standard ontology turning consciousness on/off.

Could the same be true for DNA + dark DNA system as well? In the sequel the idea that sticky ends make the DNA double strand + its dark counterpart with $h_{eff} > h$ a ferro-electret carrying longitudinal electric field is considered. The longitudinal electric field is non-vanishing also in standard framework without dark DNA if the lengths at the ends of the DNA double strand are different. This field would be analogous to the electric field along the body axis.

This model is discussed also in a related article [L222]. As far as contents are considered, the recent discussion is more or less identical except that the main emphasis is on consciousness.

Different ends of DNA double strand

There is a variety of different ends of DNA double strand and of telomere.

1. Blunt ends contain two paired bases so that they do not define a full codon.

5' - CTGATCTGACTGATGCGTATGCTAGT - 3'3' - GACTAGACTGACTACGCATACGATCA - 5'

Straight cut by exonuclease enzyme produce blunt ends.

2. Overhangs are short, mimally just one nucleotide A in 3' end: one could have for instance following configuration

$$\begin{array}{l} 5' - ATCTGACTA - 3'\\ 3' - TAGACTGA - 5' \end{array}$$

Overhangs are most often palindromic.

3. An example of longer sticky end is following:

$$5' - ATCTGACT3' - TAGACTGACTACG$$

The length of the unpaired portion of sticky end can be hundreds of nucleotides.

4. Frayed ends correspond to sequence of basic pairs breaking the A-T, C-G pairing rules.

$$5' - ATCTGACTAGGCA - 3'$$

 $3' - TAGACTGACTACG - 5'$

Empirical evidence for the ferroelectret property of DNA

To the best of our knowledge, there is no reported evidence for longitudinal static electric fields in DNA in an extensive Web search. This might be simply because of inability to measure them in past. Indeed, a model for DNA nucleotides A,T,C,G as ferroelectrets based solely on standard chemistry is discussed [I196] and would imply that also DNA can be ferroelectret. This could in a special case give rise to a longitudinal electric field, and if there is an electric field in the absence of external electric field (spontaneous ferroelectricity), it could be also in the direction of DNA strand.

The reported existence of electric currents along DNA perhaps analogous to Becker's DC currents is one indirect evidence for the longitudinal electric field. A very interesting test would be so called DNA crystals [I154, I46] (see also the popular artcle at https://cutt.ly/Hd3fvMW)) in electric field, heated, or put under mechanical stress.

DNA is analogous like cell interior being negatively charged with one negative charge per nucleotide assignable to the phosphate. The stability of DNA against Coulomb force is however not well-understood and TGD would solve the problem with a pairing of DNA strand with a parallel helical flux tube carrying 3 dark protons per codon with dark proton triplet realizing genetic codon. Ordinary chemical codons would be a secondary representation of the code. Could this make possible ferroelectret property of DNA?

Could the sticky ends of the telomeres give rise to a longitudinal electric field along DNA?

In the standard picture about DNA different negative charges at the sticky ends could give a longitudinal electric field proportional to the difference of the charges. DNA double strand would however have a net charge now. Second possibility is that the nucleotides behave as dipoles even in the absence of the external electric field. If these dipoles are forced to be parallel to DNA by an external electric field they give rise to a longitudinal electric field.

TGD based view is that DNA is paired with dark analog of DNA. This view leads to the suggestion that sticky ends/overhangs give rise to positive or negative charges at the end of DNA and that opposites at the ends of DNA generate strong longitudinal electric field along DNA. For DNA with blunt ends there would be no electric field.

What would be needed for chromosome as dipole like entity is that the ends of the chromosome carrying the telomeres have charges of opposite sign: in the simplest case they would have the same magnitude so that one would have a dipole.

1. Could telomeres be analogous to microtubules?

Microtubules are highly dynamical having a varying length. They also have a longitudinal electric field [I160, I161]. Likewise, the the ends of chromosomes are dynamical and their length is changing and controlled by the telomerase enzyme [I189, I198]. Could telomeres or entire chromosomes be analogous to microtubules? Could chromosomes (https://cutt.ly/Ud21bjd) carry longitudinal electric fields? That would not be surprising since living matters are populated by ferroelectrets [I117].

Remark: The option that only telomeres could carry these fields would require that the joint between the coding portion of DNA and telomere is charged. This does not look natural.

Due to the properties of the electric field under time reversal, the direction of the bio-electric field would in TGD Universe correlate with the arrow of time [L148] changing in "big" (ordinary) state function reductions (BSFRs) meaning "death" or "falling asleep" and re-incarnation with an opposite arrow of time. In particular, sleep could correspond to conscious experience but with a different arrow of time at some level of the hierarchy of layers of MB) [L101] serving as master controlling the biological body (BB).

Remark: The hierarchy of Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter behaving like ark matter predicts [L66, L101] macroscopic quantum coherence explaining the coherence of biomatter. This allow BSFRs in arbitrarily long length and time scales, for instance, the scales of chromosomes.

The first guess motivated by the findings of Becker about bio-electric fields [J5, J44] is that when the telomere shortens, the electric field associated with DNA weakens, and eventually the organism dies [I54]. Telomere length is controlled by telomerase enzyme and for stem cells, germ cells and cancer cells the shortening does not occur [I121].

Telomeres are dynamical and could somehow provide DNA with a longitudinal electric field closely related to this dynamics. The strength of the electric field associated with the DNA double strand could correlate with the properties of telomeres and in particlar the lengths of their negatively charged sticky ends at the ends of the chromosome.

2. The TGD based model for DNA as ferroelectret

Although most of the telomere has a normal base-pairing, there is an additional unpaired nucleotide sequence - overhang - associated with either strand. In the minimal case it is just one nucleotide A. What could this mean in TGD framework: could it give the desired constant electric field along DNA strand. Is its strength proportional to the length of the overhang determined by the number of its nucleotides? There would be 1 negative charge per nucleotide.

- 1. Suppose that both strands are accompanied by dark DNA strands parallel to them and having opposite charge neutralizing the DNA in the scale of this pairing. Dark codon would be identified as a 3-proton unit. Dark RNA, tRNA and amino-acids are predicted. Vertebrate genetic code is predicted correctly in the sense that the number of DNA codons corresponding to given dark amino-acid is the same as for vertebrate genetic code [L97, L124].
- 2. What could be the counterpart of the sticky end for dark DNA sequence? Suppose that the dark DNA strands be equally long so that there would be no symmetry breaking. This leaves two natural options for a given sticky end.
 - (a) Both dark DNA strands have portions associated with the sticky end. Since the sticky end/overhang would be neutralized, this would give for the end of the double strand a positive charge Q = ne, n the number of nucleotides in the sticky end.
 - (b) Both dark DNA strand portions are missing at the sticky end. Now the charge would be negative and equal to the charge Q = -ne of the sticky end.
- 3. The magnitude of the electric field along DNA flux tube created by a single sticky end would be

$$E = \frac{Q}{S} = \frac{en}{S}$$

where S is the thickness of the system DNA + dark DNA. The fields of the sticky ends sum up and there would be a net electric field along DNA double strand +dark DNA given by

$$E = \frac{Q_1 - Q_2}{S} = \frac{e(n_1 - n_2)}{S} \; .$$

One can consider two options.

Option I: There is dark DNA present (TGD option) and the situation is a) at the first end of the chromosome and b) at the opposite end. One obtains opposite signs of charges $Q_1 = n_1 e$ and $Q_2 = -n_2 e$ and electric field is $E = (n_1 + n_2)e/S$.

Option II: There is no dark DNA (standard physics option). The charges at the sticky ends are negative and one has $E = e(n_1 - n_2)/S$.

4. The video about telomeres [I163] (https://cutt.ly/MfiOCc1) suggests that the sticky ends are associated with different DNA strands and are of the same length. For the standard physics option (no dark DNA) charges at the sticky ends have the same sign and one has $E = e(n_1 - n_2)/S$. The field vanishes for Option II and equals to E = 2n/S for Option I.

This field would be quite strong. The electric fields at opposite ends of the chromosome sum up and cancel each other along DNA if the charges are of the same sign : there is however positive interaction energy causing a repulsive force. For the TGD option the Coulomb energy is negative. For the standard physics option it would be positive and would not favor the stability of DNA.

Quantitative estimates

In the sequel some simple quantitative estimates are performed.

1. Minimization of electrostatic energy taking into account only the nearest neighbor interactions

The system must minimize its electrostatic energy to be stable. Assume that the charges of the overhangs are opposite: $n_1 = -n_2 = n$. For the more general situation with $n_1 \neq n_2$. For the same sign for n_1 and n_2 there would be a repulsion between the ends of DNA.

1. In this case overhangs would give a negative contribution to the electrostatic energy of the system.

$$E_{ends} = -\frac{n^2 e^2 L}{S}$$

where L is the length of DNA double strand without overhangs and S is it transversal area. Otherwise the contribution is positive.

2. The negative electrostatic energies between dark strand and ordinary strand with opposite charges. There are two pairs of this kind. In the first approximation one has

$$E_{OD} = -2N \frac{e^2}{R_{OD}}$$

N is the total number of nucleotides in DNA without overhangs and R_{OD} is the distance between dark and ordinary DNA strands. One has N = (dn/dl)L, where dn/dl is the number of codons per unit length. One has approximately dn/dl = 10 nucleotides per nanometer.

This gives

$$E_{OD} = -2\frac{(dn/dl)e^2L}{R_{OD}}$$

The ratio of the two negative contributions tending to stabilize the system is

$$r = \frac{E_{OD}}{E_{ends}} = 2\frac{(dn/dl)S}{R_{OD}} \simeq \frac{20S}{nm \times R_{OD}}$$

3. There are positive electrostatic interaction energies between dark strands with distance R = R_{DD} and ordinary strands with distance $R = R_{OO}$. The energy is given by

$$E = \frac{Ne^2}{R} = \frac{(dn/dl)e^2L}{R}$$

The total contribution to the electrostatic energy is positive and given by

$$E_{OO} + E_{DD} = (dn/dl)e^2 L \times (\frac{1}{R_{OO}} + \frac{1}{R_{DD}})$$
.

The total electrostatic energy in this approximation is

$$E = e^{2}L\left[-\frac{n^{2}}{S} - 2(dn/dl)\left(\frac{1}{R_{OD}} - \frac{1}{R_{OO}} - \frac{1}{R_{DD}}\right)\right]$$

4. The generalized electrostatic force in the longitudinal direction is given by

$$F = -\frac{dE}{dL} = -e^2 \left[-\frac{n^2}{S} - 2(dn/dl)\left(\frac{1}{R_{OD}} - \frac{1}{R_{OO}} - \frac{1}{R_{DD}}\right)\right]$$

For $n > n_{min}$ DNA tends to get longer and for $n < n_{min}$ it tends to get shorter.

5. In equilibrium this force must vanish. F = 0 condition fixes the number n of nucleotides in the sticky end:

$$n^2 = n_0^2 = (dn/dl) \times S[-\frac{2}{R_{OD}} + \frac{1}{R_{OO}} + \frac{1}{R_{DD}}]$$
,

This gives

$$n = n_{min} = \sqrt{(dn/dl)\frac{S}{R_{DD}}} \times \sqrt{-2\frac{R_{DD}}{R_{OD}} + \frac{R_{DD}}{R_{OO}} + 1} = \sqrt{\frac{10S}{R_{DD}nm}}\sqrt{-2\frac{R_{DD}}{R_{OD}} + \frac{R_{DD}}{R_{OO}} + 1}$$

Note that the condition $n_{min} > 0$ requires that without the overhangs at the end the configuration would be unstable.

$$2\frac{R_{DD}}{R_{OD}} \geq \frac{R_{DD}}{R_{OO}} + 1 \ .$$

must hold true. Since the right-hand side is larger than unity one must have $2R_{DD} > R_{OO}$. As a special case one could have a maximally symmetric DODO type configuration with $R_{OO} = R_{DD} = R_{OD}$ for which the above inequality becomes equality and one has n = 0. n = 1 is realized rather generally and is maximally near to this situation

- 6. *n* would not depend on the length *L* of the chromosome in the approximation taking into account only the nearest neighbor interactions between various DNA codons. Taking them into account implies that the electrostatic energy is a nonlinear function of *L* and n_{min} is predicted to depend on *L* probably the dependence is weak suggesting that the dependence of L = L(coding) + L(telomere) or actually the telomere length L(telomere) on n_{min} is strong so that it would be an ideal control variable.
- 7. The increase of the length n of the overhang creates a force increasing the length of DNA and its reduction does the opposite. One can say the situation is critical and that $n = n_{min}$ stabilizes the situation. The reduction of the length of overhang below critical value would have disastrous effects.

This model is certainly not the only one that one can imagine and involves drastic approximations since only the nearest neighbour Coulomb interactions has been taken into account. Also the sticky ends of the chromosome could have different lengths and thus charges so that the chromosome would have a net charge and the stable length for DNA would depend on this charge.

Also the distances between various DNA strands serve as parameters and the stable length depends on these parameters: these parameters could depend on chemical parameters like pH and thermo-dynamical parameters. The length of the sticky end is expected to vary also during the life span of the chromosome and also depend on how many DNA replications preceded the generation of the chromosome. The length of the sticky end has spectrum and implies a spectrum for the telomere length since the length L(coding) of the coding part of the chromosome cannot be changed. In the linear approximation all lengths L = L(coding) + L(telomere) are allowed and if the corrections are small, L(telomere) is very sensitive to L(stickyend).

The length of the sticky end rather than the length of the telomere would be the primary controller. The quite high strength of the longitudinal electric field is a surprise. An interesting prediction is that prokaryotes with circular DNA strands would have no wake-up-sleep cycle like eukaryotes. Viruses however have both circular and open strands.

2. Minimization of the electrostatic energy taking into account interaction between nonnearest neighbors

What kind of corrections the inclusion of the Coulomb interactions of charges which are not nearest neighbors couldhave?

1. Nearest neighbors have been identified as neighbors in transversal direction and it has been assumed that only DNA-DNA and DDNA-DDNA, and DNA-DDNA interactions matter. A better approximation takes into account also the repulsive nearest- neighbor interactions of phosphates and those of dark protons along dark DNA. The same story applies to DNA-DDNA interactions.

All these terms give a contribution proportional to L and mean only a scaling of the parameter n_0 , whose order of magnitude remains the same and by the presence of the longitudinal dipole electric field can be positive.

2. Consider the contribution of the interactions of given DNA codon and DDNA codon with the non-nearest neighbors along DNA and dark DNA. These interactions can be regarded as dipole and higher multipole interactions since the total charges of the codon pair DNA + DDNA vanish. In the lowest order approximation dipole-dipole interactions depending on the distance r between dipoles like $1/r^3$.

3. Simple dimensional arguments give the general form of the dipole contributions. By dimensional considerations alone, the sum over dipole interaction energies for a given codon or nucleotide gives a contribution proportional to $1/L^2$. Summing over these contributions gives a total contribution proportional to 1/L.

The dipole contribution is proportional to $(dn/dl)^2$, to the square of the dipole moments of a given nucleotide (codon). Since dipole moments are of the order eR, R the transversal scale of DNA+DDNA system, individual dipole-dipole interaction energy is proportional to e^2S

Therefore the Coulomb interaction energy would be of the general form

$$E = \frac{e^2 L}{S} [-n^2 + n_0^2] + k e^2 (dn/dl)^2 \frac{S}{L}] \quad .$$

where k is a numerical factor determined by the details of the model. Note that dark protons forming a dark variant of ordinary nucleus are expected to have also counterparts of strong interactions expected to be short ranged.

4. The minimization of energy would give

$$F = -\frac{dE}{DL} = \frac{e^2 L}{S} [-n^2 + n_0^2] + k e^2 (dn/dl)^2 \frac{S}{L}] = 0$$

This gives for L(n)

$$L(n) = \frac{dn}{dl} S \sqrt{\frac{k}{-n^2 + n_0^2}}$$

The condition that the argument of square root in non-negative, implies that one must have either $(k > 0, n < n_0)$ or $(k < 0, n > n_0)$. $n < n_0$ option seems to be the physical one.

5. $n < n_0$ requires k > 0 so that the dipole interaction energy is positive. For $n \to 0 \ L$ approaches to

$$L(0) = \frac{dn}{dl} S \sqrt{\frac{k}{n_0^2}}$$

L(0) could correspond to the length for the coding part of DNA (no telomere is allowed). At the limit $n \to \infty L(n)$ approaches infinite value and the length of the telomere becomes extremely sensitive to the value of n and n becomes an ideal control variable.

For $n > n_0$ one must have k < 0 meaning that the contribution of the dipole-dipole interactions to the total energy is negative. The stable DNA length shortens roughly like $L \propto 1/n$ as *n* increases: this does not conform with the intuitive picture.

Relation to TGD inspired theory of consciousness

Two remarks from the point of view of TGD inspired theory of consciousness based on ZEO are in order.

1. The proposal motivated by the properties of electromagnetic field tensor under time reflectin T is that the direction of electric field flux should correlate with the arrow of time. One would expect that the change of the arrow of time requires the change of the direction of the electric field. Somehow the length of dark DNA should be reduced at the first end and increased at the opposite end.

Could the dark protons be added to or removed from the flux tube defining dark DNA to achieve this. Pollack effect [L20, I162] is in TGD framework indeed explained in terms of the transfer of ordinary protons to dark protons (with $h_{eff} = nh_0 > h$) at the dark magnetic flux tubes [L25] and has become basic element of the TGD inspired quantum biology.

The roles of DNA strands are expected to change in time reversal so that the active strand (the transcribed one) would become passive and *vice versa*. The gene expression would come however its time reversal: mRNA would be un-transcribed to mRNA codons by the formerly passive strand.

2. If one could change the roles of active and passive strands by changing the arrow of time - that is the direction of the longitudinal electric field of DNA - by changing the numbers of dark protons at the ends of DNA, one could have a dramatic demonstration for the key idea. An external electric field with direction opposite to that of DNA might allow achieving this. This would be like changing the direction of spontaneous magnetization by using an external magnetic field.

18.7.4 Tests for the TGD based model of DNA as ferroelectret

The standard physics view is that the possible ferroelectricity for DNA is due to the instantaneous polarization of codons A,T,C,G in external field which is proportional to electric field E if the polarization vanishes for E = 0. Ferroelectric is analogous to spontaneous magnetism that there is electric field also for E = 0: this requires permanent electric dipole moments generated by small external field an left when the field is taken to zero.

In [I104] a model for the polarizability of nucleotides A,T,C, G is developed based on standard physics so that the external electric field would generate dipole moment for given nucleotide. What one hopes is model producing ferro-electric behavior. The model calculations give ferroelectric behavior and a square shaped hysteresis curve. In case of entire DNA each nucleotide would behave independently in inhomogenous electric field with varying direction.

Also in [I196] the dipole moments are estimated for both bases and nucleotides, and the esimated dipole moments are in the range of 2-6 Debyes (D = .02 enm) that is .04 - .12 enm. TGD estimate for the electric field is about ne/S, $S = \pi R^2$ the effective area of the flux tube assignable to DNA + dark DNA.

The first thing to notice is that the flux would be along entire DNA, not only the telomere and the overhangs portions carry the charges creating the electric field along DNA. Electric flux flows along DNA. Telomere would be a kind of buffer against the evil world. Overhang/sticky ends could play a key role in control of the arrow of time for DNA. Similar mechanism would be at work at the level of entire body changing the direction of endogenous electric field and leading to wake-up to sleep or vice versa [J5, J44].

Suppose that the charges at the opposite ends of DNA are of opposite sign. An un-necessary strong assumption is that they are of the same magnitude. The dipole moment would be roughly given by the difference $Q_1 - Q_2$ of the charges multiplied by the distance L between ends of the chromosome along the DNA strand. Note that the channeling of electric flux along DNA would be rely on TGD view about space allowing monopole flux tubes whose deformations carry also electric field.

The static electric field would be realized as a conserved electric flux flux along the entire DNA, not only telomere. The order of magnitude is 10 GV/m for R = 1 nm so that it would be rather strong. The strength of electric field is proportional to $1/R^2$ and R is expected to vary in the range 1 - 10 nm. Note that L(151) = 10 nm corresponds to the p-adic length scaled the thickness of the DNA coil and chromosome thickness.

The effective dipole moment per nucleotide would be $p \simeq ned \simeq n \times .3$ enm and quantized as multiples of n. The estimate is at most by a factor 2.2 - 7.5 larger than the estimates from the atomic contributions and would allow to select between the standard model and TGD based model.

Nanoscopic implications

What could be possible experimental consequences of the proposed electric field? Consider first the situation at the level of single DNA double strand.

1. The accelerated motion of a test charge along DNA could serve as a test for this option. One can consider both quantum motion without dissipation - perhaps along the dark DNA - and

Ohmic current along the ordinary DNA. They would runs also in absence of external electric field unlike ordinary Ohmic currents.

These currents could be nanoscopic analogs of the DC currents observed by Becker in body scale and brain scale. If they are steady currents the current is conserved and must return so that a closed current loop is formed. The currents could be also pulselike taking surplus dark protons between ends of the chromosomes and changing the their roles. This would be quantum event associated with BSFR and could mean time reversal.

Electronic (not protonic) currents along DNA [I60] have been observed for single DNA strands in an external electric and it is found that the conductivity is surprisingly high. In the recent case conduction double strand property and sticky ends would be essential.

2. How could the current return in steady situation? This question must be answered also for Becker's current. Does the current flow as ohmic current along ordinary DNA and return back along the dark DNA as non-dissipative current? The proton current along DNA along electric field to negatively charged and dark protons would be accelerating: the quantum description would correspond to a particle in linear potential, which is standard quantum mechanical problem.

The larger the charge (the length of the sticky end), the stronger the current. Its magnitude would be quantized being proportional to the length and charge *ne* of the sticky end. The variation of sticky end length would vary the strength of the current.

The is evidence for proton AC current conduction in the DNA double strand-imidazole composite material under anhydrous conditions (no water) in the frequency range 4 Hz - 1 MHz [I144]. If the mechanism is the proposed one - probably not - the oscillatory current could correspond to occurrence of BSFRs changing the arrow of time with 2 BSFRs *per* each period of T = 1/f. This would predict the current to be I = 2nef, where $\pm ne$ are the charges at the ends of the double DNA strand.

How to test whether DNA double strand is ferroelectret?

Possible tests of the model are considered in the sequel.

- 1. How to test whether DNA double strand is ferroelectret?
- 1. The measurement of the possible longitudinal electric field of DNA and its correlation with the length of the telomer or of the sticky end would be an interesting experimental project. DNA exconuclease restriction enzyme allowing to cut pieces from the end of either DNA strand could allow creation of desired length of unpaired portion of DNA. Also blunt ends could be created and the prediction is that there is no electric field in this case.
- 2. The telomere or the entire DNA would be like a dipole and would interact with external electric fields. One should be able to prepare a DNA sample as an electret so that DNAs would have the same dipole direction and this structure could be put in an electric field allowing to measure the dipole moment of DNA as a macroscopic motion in the field.

The external electric field would give rise to a torque acting on the entire DNA double strand. If nucleotides behave as independent dipoles as the standard physics based model suggests, this would not be the case and the dipole moments of the nucleotides would only turn in the direction of the external field.

3. One could also study whether and how the possible DNA dipole moment making sense for short enough DNA double strands is affected by the telomerase affecting the length of telomere. The first guess would be that is the length of the sticky end which is affected and that the length of the telomere correlates with this by stability conditions. Pyroelectricity and piezoelectricity and the use of external electric field produce ferroelectrets from various biological tissues [I117]. These methods applied to DNA crystals [I154, I46] could allow to test the hypothesis. The measurement of the possible longitudinal electric field of chromosome or DNA double strand and its correlation with its length could serve as a futuristic bioelectric marker: this could be an experimental project. Currently, the measurement of telomere length by quantitative PCR is quite common and for a summary of critical factors and recommendations for assay design, interested readers may see [I134]. Also, a full description and protocol for examination of the telomere G-overhang structure in different plant, human and vertebrate models are available [I59, I120, I166, I175].

Could pyroelectricity, piezoelectricity, or the behavior in external electric fields be used to demonstrate that DNA has a longitudinal internal electric field

One can consider also the consequences at condensed matter level. Athensteadt has found [I117] that it is possible to make various tissues of vertebrates piezoelectric or pyroelectric.

Pyroelectric materials (see https://cutt.ly/5d3gT8r) are crystals in which the change of the temperature involving thermal energy flow induces a macroscopic electric polarization and therefore electric field making the material ferroelectric. In piezo-electric materials (https:// cutt.ly/cd3gJ4v) mechanical stress induces a generation of polarization and macroscopic electric field. Also an external electric field can induce polarization producing a ferroelectret.

One can visualize the situation using a triangle having kinetic, electric, and thermal energies as corners. For piezoelectric materials the motion occurs along the edge connecting electric and mechanical energy. For pyroelectric materials the motion occurs along the edge connecting electric and thermal energy.

The proposal is that DNA double strand + dark DNA strand carries internal electric field is 1-D ferroelectric aperiodic crystal due to its inherent polarization. One cannot exclude the possibility that also single DNA strand + dark strand has this property. DNA should be *n vivo* state. DNA crystals [I154, I46] might allow to test the phenomenon. For instance, it is known that DNA suspended in liquid which is evaporated forms crystal (https://cutt.ly/Hd3fvMW). Could DNA crystals become ferroelectrets by heating or cooling or by applying a mechanical stress or an external electric field?

If this would occur, the interpretation would be that DNA strands become parallel and have parallel electric fields giving rise to ferroelectricity. In the positive case, one could test the hypothesis by using DNA preparations with different values of n for the number of overhang nucleotides: electric field in the ideal situation would be proportional to n if the area density of the parallel DNA strands is the same.

18.8 Mysteries related to gene expression and meiosis

The selection of the allele in gene expression and meiosis still involves mysteries.

- 1. In mitosis (https://cutt.ly/3HZfSps) the chromosome pair of DNA consisting of the chromosomes of parents of cell replicates. Each cell has both mother's and father's genes, which are homologous but not identical. Allele dominance means that in a given cell only either allele tends to be expressed (https://cutt.ly/ZHJicsQ). Whether mother's or father's allele dominates, depends on the cell. The origin of this dominance is not understood.
- 2. In meiosis (https://cutt.ly/zHZfJVl) occurring in the formation of gametes the chromosome pair is replaced with a single chromosome and the DNA strands effectively reconnect so that the new strand contains alleles from either parent, which seems to be selected randomly. If the random recombination occurs for both strand pairs, it is difficult to understand how the combination processes can be identical. The recombination process however take in a similar way for both DNA strands. Most naturally, the reconnection would occur only for the other pair of strands from parents. These strands could be the strands which are active in transcription. After this, this strand could serve as a template in DNA replication to form a DNA double strand.

Condensed matter physicists are discovering that the world of electrons at atomic level is govering by knotting and linking (https://cutt.ly/mHVCrPC). This picture is just what TGD

predicts but applies to all systems, not only electrons, and in all scales from hadron physics to cosmology. Besides particle like entities there would be magnetic flux tubes connecting them to networks. This is completely new from the perspective of quantum field theory based description based on point-like particles.

Since 3-space is a surface in $M^4 \times CP_2$ is 3-D, flux tubes and string world sheets accompanying them are necessarily linked and knotted: this distinguishes TGD from string models. This implies braiding and makes possible topological quantum computation (TQC) like activities at fundamental level, in particular in living matter and especially at the DNA level.

Furthermore, since spacetime is a 4-D, string world sheets and flux tubes can reconnect in a topologically stable manner (in superstring models this is not possible). Reconnection becomes a fundamental aspect of the TGD inspired quantum biology. For instance, reconnection plays a central role in the TGD inspired view of a living system as a topological quantum computer [L189].

Reconnection also plays a key role in the recombination of DNA strands of father and mother chromosomes leading to the formation of gametes. In TGD it would be preceded by a reconnection at the level of dark DNA associated with magnetic flux tubes and occurring in cell divisions. The reconnected flux tubes representing gametes would serve as templates for the recombination of the ordinary DNA strands. This picture leads to surprisingly strong predictions concerning natural selection at cell level and the notion of sex.

18.8.1 Are DNA expression and the formation of gametes induced by dark gametes?

TGD suggests that the recombination of DNA is induced by a reconnection process at the level of dark DNA [L222]. The reconnection process for dark DNA strands of father and mother at the level of MB would induce the recombination process at the level of ordinary DNA strands. Second suggestion is that dark gametes formed in the replication of cells control the gene expression and induce allele dominance depending on cells. Further implication would be that cells have a well-defined sex. Perhaps even organelles and organs could have such.

- The recombination process for DNA would be guided by a reconnection process for dark DNA at the magnetic flux tubes. Suppose that the pairs of dark DNA strands at the magnetic flux tubes reconnect to form a pair of strands in which the pieces of strands are mixed just like they are thought to do for ordinary DNA. One obtains for a given strand two outcomes with father ↔ mother symmetry realized for the corresponding pieces of the strands. The symmetry related pairs correspond to different sexes and if only the other strand is selected, the sex of the descendant is fixed.
- 2. Dark meiosis as a reconnection process at the level of dark DNA would occur before meiosis, naturally in the previous DNA replication since otherwise the cells would MBs with both sexes. This dark DNA would select from the paternal and material ordinary DNA strands ordinary codons and fuse them to the ordinary DNA strand of the gamete. The process would rely on resonance mechanism [L103, L136, L159, L194]. This process could occur for both DNA strands or a single strand. It might be possible to test, which option is realized. The ordinary model has problems in understanding why the both strands suffer the same recombination: now this problem would not be encountered.

TGD view about genes involves the notion of dark DNA realized at the level of magnetic body (MB) and suggests a solution to the mystery of allele dominance.

- 1. The process leading to the DNA of gamete occurs at the level of dark DNA as reconnection. Two strands are formed by reconnection and yield two different gametes with opposite sex and related by father father \leftrightarrow mother symmetry.
- 2. Could dark gametes at the level of MB form already in fertilization or considerably before the generation of gametes, say in previous cell replication? If dark gametes form in the fertilization, the ordinary gametes would be copies of these two dark gametes and there would be only two kinds of gametes and only two kinds of children, males and females. This is not certainly true.

If the dark gametes are formed later in the daughter cell, most naturally in cell replication, daughter cells can have different dark DNA producing different gametes as their copies. The members of dark gamete pair related by father \leftrightarrow mother symmetry would produce male and female kind gene expressions.

3. Only single gamete DNA can appear in a given gamete, which could be understood if only the second dark gamete DNA can be associated with a given cell. A pair of gametes could form in the cell replication and the members of the pair go to different daughter cells. Allele dominance would emerge after the first replication in which dark meiosis would occur for the first time.

One could say that ordinary mitosis involves dark meiosis leading to allele dominance in a given cell and ordinary meiosis takes place only later. There would male and female cells and one could say that fertilization occurs repeatedly in dark meiosis.

- 4. The resonance mechanism [L194] allows us to understand the allele dominance quantum mechanically. The dark DNA controls gene expression and is in energy resonance with ordinary DNA. Depending on the dark gene, the resonance selects either the allele of mother or of father.
- 5. If new dark gametes emerge at each cell division, there is a large number of descendants at the cell level. The survival of a cell with a given dark gamete implies that the ordinary gametes associated with it have a higher chance to participate in sexual reproduction. Only those dark gametes, for which the cells controlled by them survive and have produced ordinary gametes as their images, have a change to participate in sexual production, which is like the finals in Olympics. Evolution would be survival of the fittest already at the level of cells and selection would occur already at the level of cells.
- 6. The two dark gametes produced in the dark meiosis in cell replication and going to different cells in cell division are related by father ↔ mother symmetry and since XX chromosome pair characterizes female and XY chromosome pair male, sister and brother cells, which are mirror images of each other emerge and are associated with different cells. Therefore cells would have a well-defined sex!

This raises interesting questions. Could organelles and even organs tend to have same cellular sex so that also these could be said to have a well-defined sex? Could the battle between sexes start already at the cell level and possibly lead to extinction of the other sex? Could cells have sexual relationships like us and tend to pair? Could possible multi-cellular structures with a well-defined sex have this kind of relationships? What comes into mind are epithelial layers consisting of two cell layers and various binary structures in the body and brain.

18.8.2 Summary of the TGD based view of mitosis and meiosis

The above considerations boil down to the following overall view of mitosis and meiosis in the TGD framework.

Consider first ordinary mitosis and meiosis.

- 1. In the ordinary mitosis two copies of chromosomes are formed. After this cell divides. The same could happen for the dark chromosomes. But this would leave allele dominance a mystery.
- 2. Ordinary meiosis involves replication of chromosomes of soma cells with chromosomes of father and mother. This is followed by recombination of the chromosomes followed by cell division so that two germ cells are obtained. After that both daughter cells with recombinant genomes split to germ cells giving four germ cells.

The TGD view of meiosis would be different. Dark meiosis and ordinary meiosis need not occur simultaneously and dark meiosis could occur before the ordinary one in some earlier mitosis.

1. Dark DNA can suffer at some cell replication dark meiosis involving recombination of dark DNAs for both chromosomes. The resulting dark DNA strands go to separate cells. The dark parts of the DNA would be analogous to that of gametes which would be different for the two daughter cells.

Since dark DNA controls ordinary DNA, the dark gamete would by resonance mechanism select which allele dominates. One would have two kinds of cells with different allele dominances. One could say that the cells have different sex. This is a testable prediction.

- 2. If this replication occurs after some replication after the first replication, the dark gametes formed in the dark meiosis of different cells are different, and one can obtain a large number of different dark gametes. This number is not so large as for the ordinary meiosis since dark gametes do not change in the cell replications.
- 3. The dark gametes, which have formed by dark meiosis already in an earlier cell replication preceding meiosis, would determine the outcome of the recombination of ordinary DNA in the ordinary meiosis following dark meiosis after some cell replications. After this the dark gametes pair with ordinary DNA and give rise to an ordinary gamete.

18.8.3 Bioharmony, resonance mechanism, and emotions

TGD assigns to the genetic code a bioharmony [L103, L136, L159, L194] bas a correlate for emotional states of moods.

- 1. The working hypothesis is that bioharmony dictates the frequency ratios of genes represent as triplets of dadrk photons exactly and that the sfrequency cale does not matter. Codons and genes would play the role of addresses in communications using dark 3N-photons as analogs of Bose-Einstein condensates. One would have 3N-resonance instead of ordinary (1-)resonance. For instance, gene expression would be guided by dark gametes and the dark gene would select by resonance mechanism the allele of either mother or father.
- 2. Just as the chords code for musical harmony and emotions, dark codons would code for bioharmony and serve as correlates for emotions at the molecular level. This gene expression would be responsible for emotional intelligence.
- 3. The 3-chords associated with the genetic code would correspond to a combination of a unique tetrahedral harmony and icosahedral harmony realized as Hamiltonian cycles.

There is a considerable number of icosahedral harmonies, which appear in 3 basic classes. Bioharmony is a fusion of tetrahedral harmony with 3 icosahedral harmonies of type Z_6 , Z_4 and Z_2 . The icosahedral harmony with Z_6 symmetry is unique and corresponds to 3 amino acids (AAs) coded by 6 codons and one AA coded by 2 codons. The two harmonies with Z_4 symmetry correspond to 5 AAs coded by 4 codons. Z_2 can correspond to π rotation or reflection and are coded by 10 codons in absence of symmetry breaking. The number of harmonies with Z_2 symmetry is considerably higher.

There are many open questions.

- 1. Could the possibly stable molecular bioharmonies correlate or even characterize the dark gametes and correlate with the sex of the cell. Could the molecular bioharmonies characterize genes or cells? Could the two Z_4 harmonies distinguish between the two sexes?
- 2. If bioharmonies correlate with emotions, one would expect that they can change. I have proposed a model [L84] explaining the strange finding that the RNA from conditioned neurons of a snail induce conditioning in the unconditioned neurons of second snail (http://tinyurl. com/y92w39gs). The molecular emotions crucial for the conditions would correlate with the bioharmony assignable to RNA.
- 3. How stable are the bioharmonies? How long lasting bioharmonies could be? Could they define cellular moods lasting for the entire life and basically determine the personality?
- 4. Could the change of bioharmony correlate with epigenetic change as suggested by resonance mechanism. A correlation between bioharmony and gene expression controlled by mechanisms like methylation is suggestive.

18.8.4 About the notion of sex?

Sex is determined by X and Y chromosomes. The females gametes have two X chromosomes and male gametes have both X and Y chromosome. The mixing of sex chromosomes would give two XX and two YX chromosomes and the selection would be determined the sex.

The ordinary cells have both mother and father chromosomes and allele dominance decides about the gene expression. If the proposed picture holds true, each cell division would generate new kinds of dark gametes dictating the gene expression. As far as gene expression is considered there would be a large collection of different descendants, which can have both sexes.

If only the second variant of the dark gamete appears in a given cell, each cell would have a well-defined sex. If organelle or even organ consist dominantly of cells of either kind, it could be said to have a well defined sex. The notion of sex would not boil down to a single bit. We would be composites of cell structures with different sexes and a collective of a large number of descendants. This would force us to give up the naive genetic determinism.

Chapter 19

About the Number Theoretic Aspects of ZEO

19.1 Introduction

The interaction between number theoretic vision, ZEO, and the TGD view DNA enriches all of them. In this article the recent view about quantum measurements is discussed in light of the recent progress in the understanding of the number theoretic aspects of TGD [L127, L128].

19.1.1 $M^8 - H$ duality and classical non-determinism

The progress in the understanding of $M^8 - H$ duality serves as a strong motivation for looking ZEO from the number theoretic perspective.

 $M^8 - H$ duality [L127, L128] is a central piece of the number theoretic picture. $M^8 - H$ duality involves the map of a 4-D surface of M^8 to H determiniming holography in terms of the associativity of the normal space of the space-time surface. The realization of holography determine the 4-surface of M^8 by using the 3-D mass shells of $H^3 \subset M_c^4 \subset M_c^8$ determined as roots of a polynomial serve as holographic data.

 $M^8 - H$ duality is not a mere geometric map. Uncertainty Principle requires that the counterpart of CD in M^8 is mapped to a superposition of CDs as a plane wave for which the role of position coordinate is taken by the center of CD in M^4 .

1. The CDs involved have the same center and the roots correspond to mass shells and their H-images to proper time a = constant hyperboloids of M^4 such that proper time coordinate is essentially $a = h_{eff}/m$ for a Galois singlet with integer value momentum and integer value mass squared using as unit the p-adic length scale defined by the largest ramified prime.

Octonionic associativity condition leads to a selection of a unique origin for the pair of positive and negative energy light-cones in M^8 mapped to pairs of half-cones of CD.

2. The intuitive picture is that also the Poincare transforms of CDs should be allowed. Is this physically acceptable and how could one realize this?

 M^8 corresponds to momentum space so that origin is a special point and coordinates are naturally unique. In M^8 Lorentz transformations are rotations and translations do not act on momenta but multiply Fourier components by phases.

The $M^8 - H$ duality could map the half-light cones of M^8 with opposite sign of energy to the half-cones of CD. $M^8 - H$ duality is essentially an inversion thye level of momentum space. The value of $h_{eff} = nh_0$ in the inversion would be determined by the polynomial P in question as the order of its Galois group.

Any point of $M^4 \subset H$ conserve as the origin defining the point of inversion. All choices are possible. The solution of the problem is a quantum superposition of all possible choices that is a plane wave in M^4 for the center of CD. The momentum would be defined by the total momentum assignable to either half-cone of the CD. $M^8 - H$ duality would be between states rather than being purely geometric.

Holography applies also to string worlds sheets, which intersect the mass shells at 1-D curves. The reconnections of string world sheets correspond to self-intersections of the space-time surface and occur at discrete points deterministically for space-time surfaces as preferred extremals (PEs). At the intersection points there is nondeterminism since AC+BD can go to AC+BD or AD+BC. The reconnection gives rise to the basic braiding operation of strings as space-like braid strands.

If $M^8 - H$ duality holds true, polynomials determine space-time regions and the Galois groups define fundamental symmetries of physics. The key questions relate to the interpretation of the functional composition of polynomials. Second question is whether one can allow product polynomials.

- 1. Product polynomials are allowed and give a direct connection to particle physics and an intuitive picture about free many-particle states. Fundamental particles would correspond to irreducible monic polynomials with a simple Galois group.
- 2. The idea that functional decomposition gives many particle states in the usual sense is given up. The functional composition of polynomials would give rise to many-sheeted space-time as a hierarchical structure and connect the number theoretic view concretely with the view involving MBs. Also a connection with the notion of infinite prime emerges.

19.1.2 ZEO based quantum measurement theory from number theoretic perspective

The view about TGD based quantum measurement theory relies on zero energy ontology (ZEO) and its interpretation as consciousness theory involves several ad hoc elements. The notion of state function reduction (SFR) is the key notion. One can distinguish between "big" SFR (BSFR) as counterpart of ordinary SFR and "small" SFR (SSFR) as counterpart of weak measurement. What happens in SSFR and BSFR from a number theoretic point of view, is the key question.

The view about SSFRs is simplified.

1. SSFR is assumed to occur after BSFR, which leads to a complete localization of the WCW spinor field to a space-time surface represented by fixed polynomial P at the level of M^8 : localization would be in the resolution defined by the resolution defined by the cognitive representation defined by the polynomial.

The localization to single P has operational interpretation. One says that the localization occurs to single $P = P_1 \circ ... \circ P$ if the $P = ... \circ P_1 \circ ... \circ P$ if only the mass shells correspond to the roots of polynomials P_1 contain quarks. The higher mass shells are not activated.

Note that the states of quarks considered are associated with either half-cone. In other halfcone there is delocalization forced by the fact that the observables associated with the two half-cones do not commute.

- 2. SSFR(s?) occurs for a fixed polynomial *P*. SSFR involves cognitive measurement cascade decomposing an irreducible representation of Galois group to a tensor product of irreps of relative Galous groups. There are also measurements in quark spin degrees of freedom for representations of relative Galois groups as well as measurements in the degrees of freedom related to the failure of strict classical determinism for the dynamic of the space-time surface.
- 3. Hitherto it has been assumed that there is a sequence of SSFRs followed by the counterpart of unitary time evolution. The TGD counterparts for the unitary evolutions would correspond quite generally to scalings and scalings could represent approximately time translations of the second tip of CD.

The situation could be however considerably simpler: there could be only a single SSFR so that the question of when BSFR does occur would become obsolete. The time evolution by the scalings could be assigned to the fermionic degrees of freedom and to the mass shells defined by the roots of P.

One can also consider BSFR from a number theoretic point of view.

- 1. Suppose that the state is described by a polynomial P and that the many-quark state corresponding to, say, the lower half-cone of the CD is known. The state in the upper half-cone is not known. The state after BSFR corresponds to the state defined by $Q \circ P$ assignable to the upper half-cone of CD. This state must contain the mass shells assignable to P but with an opposite sign of energy for the Galois singlet states so that a lot of information is preserved. P would represent kinds of Akashic records and each BSFR would add to these records new records and the information content of the Universe would increase.
- 2. BSFR must be preceded by the analog of a unitary time evolution in which a superposition of space-time surfaces involving polynomials $Q \circ P$ are present. Note that the information related to P would be conserved. Since Q represents a higher abstraction level in the hierarchy of polynomials the process would mean emergence of larger space-time sheets modelled in terms of magnetic body (MB). Operationally this means that quarks must be transferred to the space-time sheet assignable to the roots of Q. One could also say that the entire state is a superposition of states associated with $Q \cdot P$, for arbitrary choices of Q but that quarks in the lower half-cone are associated with the mass shells of P only.
- 3. Here we have considered only the entire state. The intuitive picture has been that BSFRs can occur rather independently: the BSFRs at higher level however induce BSFRs at lower levels: somewhat like the decision of the boss induces decisions at the lower levels of the hierarchy.

When SSFR has taken place and Galois degrees of freedom in the product of relative Galois groups are unentangled, also BSFRs replacing individual polynomials P_i in $P = P_1 \dots \circ \dots P_n$ with $Q_i \circ P_i$ can occur: without this assumption the highest level would act like a dictator.

4. When does BSFR occur? If only a single SSFR occurs, there is no problem. If single SSFR involves a sequence of SFRs as measurements for the quark quantum numbers associated with the mass shells characterized by p-adic length scales, one obtains a sequence of scalings giving rise to a subjective time evolution having the increasing CD size as a correlate of geometric time.

If several SSFRs take place, the situation changes. Could NMP force BSFR in the case that there is a sequence of SFRs? Could the CD in the beginning of the SSFR sequence correspond to a sub-CD assignable to P. The spotlight of consciousness would not be large enough. As the size of the CD increases, additional particles become visible and eventually the CD as a perceptive field reaches the size of the entire CD. After this BSFR occurs. As a matter of fact, single SFR in the proposed sense is also consistent with this interpretation.

19.1.3 The notion of time from number theoretic perspective

There are also questions related to the notion of time.

- 1. The model for various time related aspects of conscious experience involves ad hoc elements and here an attempt is made to get rid of these elements. How the SSFR involving besides cognitive cascade also other measurements or a sequence of SSFR could correspond to a steady increase of geometric time determined in terms of CD size is the basic question.
- 2. Does the position of CD shift to the direction of future in the sequence of BSFRs and if it does so, what could be the natural mechanism causing this? This is one of the key questions.

The existence of stars older than the Universe suggests that the center of mass of CD need not shift to the future. The system would evolve forth and back in time.

On the other hand, the phenomenon of after images and the sleep-awake cycle could be understood also in terms of the shifting of CD to which mental images is assigned. Time crystal like phenomenon at the level of conscious experience implied by the existence of spacetime surfaces, which are approximately periodic minimal surfaces, suggests an alternative explanation. Understanding what happens in memory recall is one of the key challenges and one both classical and quantal aspects of memory recall must be considered. The recent model is considerably simpler than the earlier one and the earlier picture follows without ad hoc assumptions.

19.2 State function reduction from number theoretic point of view

The only way to make progress is to challenge the existing views. The view about how ZEO [L118, L165] [K132] gives rise to a theory of consciousness as a generalization of quantum measurement theory involves several assumptions, which might be challenged as un-necessary and possibly wrong at the level of details. Occam's razor might be needed.

Consider the basic assumptions involved.

- 1. The recent picture is based on the general TGD view about physics, which involves the dual views about physics as geometry and physics as generalized number theory. This part of theory seems rather stable.
- 2. In the number theoretic vision [L127, L128] functional composition of polynomials plays a key role. A tentative interpretation has been that it corresponds to the formation of many particle states in the case that polynomials appearing as factors of composition are prime polynomials with simple Galois groups. One must challenge this assumption.

Functional composition could also correspond to topological condensation, whose number theoretic interpretation has remained hitherto open. As a matter of fact, free many-particle states could correspond to a products $P = \prod P_i$ of irreducible polynomials with simple Galois groups and the functional composition $Q \circ P$ could correspond to a formation of interacting state formed by a topological condensation to a larger space-time sheets. P could also represent the magnetic body of the system as a many-sheeted structure.

ZEO is a crucially important piece of the theory.

- 1. The notion of BSFR as a counterpart of ordinary state function reduction (SFR) changing the arrow of time, and SSFR as a counterpart of weak measurement preserving the arrow, are central but there are still considerable uncertainties concerning the details of the picture.
- 2. The basic notions such as hierarchy of CDs, zero energy states, and the necessity of both BSFR and SSFR seem to be well-motivated. Also the cascade of cognitive measurements decomposing wave functions for the representations of the Galois group to entangled products of wave functions in relative Galois groups looks convincing. The special feature of Galois entanglement is its directedness which brings in mind attention. The localization of the nondeterminism as failure of strict determinism at space-time level to the frames of space-time surface as analog of soap film (minimal surface) seems also well-motivated. The reconnections indeed involve a failure of determinism naturally as a choice between two options.

19.2.1 What could happen in SSFRs?

Concerning the details of SSFR the situation is less clear.

1. The assumption has been that each SSFR as a counterpart of weak measurement is preceded and followed by a unitary time evolution increasing the size of the CD in statistical sense. These unitary evolutions could correspond to scalings of CD with the passive boundary fixed. In spin glass systems they would be realized [L166]. The exponential law for the relaxation of magnetization in spin glass would be replaced with a power law so that time would be a logarithm of the linear M^4 time. The scaling operator defining the unitary scaling would be determined by the super-symplectic symmetry in the same way as the conformal scaling operator in string models. 2. Each SSFR would correspond to an SFR selecting a unique space-time surface among possible holographic alternatives (perhaps selection of braiding distinguished by reconnections) plus a cascade of cognitive SFRs in the Galois group of the space-time surface reducing the wave function to a product of wave functions in its decomposition to relative Galois groups in question. The consciousness theoretic interpretation would be as an analysis. In the opposite time direction it would correspond to a generation of an idea, to a kind of heureka moment as BSFR.

The sequence of SSFRs has been interpreted as a sequence of moments of consciousness defined by the life cycle of self as a conscious entity. BSFR would be a universal counterpart for death followed by a reincarnation with an opposite arrow of time.

3. Does one really need a sequence of unitary evolutions followed by SSFRs?Could single SSFR as a cascade of cognitive SFRs be enough? This would solve the problem of when BSFR occurs.

For single SSFR, the life cycle of self would be essentially a cascade of cognitive SFRs, a process of cognitive analysis leading to a reduction of quantum coherence. One might argue that this is indeed what aging is at the highest level [L229], and would also conform with the second law of thermodynamics [L162]. The occurrence of SSFRs implies the reduction of the number of choices and this is what seems to take place in aging.

On the other hand, we also have eureka moments and our mental images are born and die, which suggests a hierarchy of subselves realized in terms of function composition for which the cognitive cascades take place. We sleep and this could mean BSFR at some level of our personal self hierarchy. It would seem that the sub-CDs should be able to make several BSFRs during a single SSFR at the higher level. As found, this is possible.

4. The cognitive measurement cascade as such leads only to an unentangled tensor product of irreducible representations of the relative Galois groups. After this, the observables associated with the Galois representations, with spins of quarks, and non-deterministic classical degrees of freedom must be measured.

Does the sequence of SSFRS correspond to a sequence of scalings of a CD?

The increase of CD in the sequence of SSFRs would give a correlation between the flow of the subjective time as the sequence of SSFRs and geometric time as the size of CD. Is the sequence of SSFRs is really required or whether SSFR naturally decomposes into a sequence of scalings.

The following argument suggests that it is possible to obtain a sequence of scalings of a CD in a natural way in SSFR.

1. The light-cone proper time a constant hyperboloids correspond to cognitive representations consisting of all algebraic integers in the extension of rationals defined by P. Therefore they correspond to "very special moments in the life of self" as cognitive explosions. The presence of a quark at the point with momentum satisfying this condition is needed to activate it so that cognitive representations are finite. M^8 picture predicts also preferred moments t_n with respect to Minkoski time and also these correspond to the roots of P and define infinite cognitive representations which reduce to finite ones, when quark is required to activate the points of the representation. These preferred moments are naturally associated with massless particles.

As a matter offact, if one requires super-Virasoro symmetry and identifies mass squared with a scaling generator, one can argue that only massless states are possible since the scaling generator must annihilate these states. This leads to a concrete interpretation of the massivation in p-adic thermodynamics. It would be due to an entangling interaction of the massless sub-system with the environment exciting states of sub-system with non-vanishing mass squared: the excited states of the entire system would be massless [L189].

2. The earlier intuitive picture was that the sequence of SSFRs as a cognitive cascade plus SFRs implied by the failure of the classical determinism increases the size of CD by scalings and makes gradually the roots of the polynomial P visible. This assumption does not look

plausible if the size of the CD is determined from the beginning by the largest ramified prime for P.

One can however argue that the perceptive field of the waking up self expands gradually and this correspond to the increase of CD from a size, which is determined by a ramified prime smaller than the maximal, presumably the smallest one so that the increase of the size CD would occur as emergence of increasing p-adic length scales.

Note that the ramified primes appear as divisors for the discriminant which is product for the roots of P. An open question is whether the p-adic primes associated with the masses of Galois singlets can correspond to ramified primes.

3. Intuitively, the p-adic length scales would naturally correspond to the emergence of mass shells with decreasing mass, and therefore an increasing momentum resolution. Masses are defined by the roots of P or by emergence of Galois confined states at a = constant hyperboloid, which satisfy Galois confinement. Each mass value would correspond to a p-adic mass scale and if the large mass scales emerge first with respect to experienced time, the size of the CD indeed increases.

Note that the cognitive measurement cascade would proceed in the reverse order if the polynomial if Q in $Q \circ P$ corresponds to a larger space-time sheet. Cascades would proceed in opposite orders. This brings in mind the development of sensory perception followed by a motor reaction.

- 4. When all mass scales have emerged, the size of the CD is maximal and the BSFR can naturally occur since no information can be gained and NMP [K73] [L162] cannot be satisfied.
- 5. In this picture the cognitive state function reduction in the Galois group would occur first. This would give an unentangled tensor product of representations of relative Galois groups. After that measurement of the quantum numbers in the representations of relative Galois groups for the corresponding mass shells would take place in the proposed order.

Could the space-time surface determined by $P_1 \circ ... \circ P_n$ be replaced with that determined by $P_1 \times ... \times P_n$ in the cognitive cascade?

One of the fleeting ideas encountered during the development of the ideas about cognitive measurements was that it could also affect the space-time surface itself rather than only the wave functions in Galois degrees of freedom.

- 1. The simplest assumption is that it is just a sequence of SFRs in the group algebra of the Galois group which has decomposition to a a product of relative Galois groups. The wave function in Galois group would be reduced to a product of wave functions in the relative Galois groups. Nothing would happen to the space-time surface itself.
- 2. Could the cognitive reduction sequence proceed as $P_1 \circ P_2 \circ ... \circ P_n \rightarrow P_1 \times P_2 \circ ... \circ P_n ... \rightarrow P_1 \times ... \times P_n$? If so, the space-time surface would be replaced with a union of space-time surfaces associated with P_i . Note that multiple roots can occur reducing the dimension of extension and order of Galois group so that it is a sum of orders rather than product.

I have considered this possibility but it seems artificial and ad hoc. I have also considered the possibility that P_i could be replaced with the composite of characteristic polynomial of the density matrix characterizing the entanglement between P_i and $P_{i-1} \circ ... P_n$ so that the measured eigenvalues would be stored in the space-time geometry [L169, L167].

The simplest elegant option is that nothing happens for the space-time surface in the cognitive measurement cascade. Only the Galois entanglement in quark degrees of freedom assignable to quark momenta as points at the mass shells defined by the roots of P and to quark spins would be reduced.

This idea however led to the realization that the surfaces defined by the product polynomials are natural correlates for free many particle states. This will be discussed later.

What kind of polynomials are allowed?

Mathematician's answer to the question of what kind of polynomials should be allowed, could be "irreducible ones". This was also my own first guess.

1. The original assumption was that only irreducible polynomials are physically acceptable. Irreducible polynomials P with simple Galois groups, and therefore having no product decomposition to polynomials with a lower degree polynomials P_i , are analogous to elementary particles and could define space-time regions assignable to elementary particles.

Irreducible polynomials have reducible polynomials as a limiting case. It is difficult to think of throwing them away and one can wonder what physical interpretation they could have.

2. The product polynomial $P_1 \times ... P_n$ would naturally represent a non-interacting many-particle state consisting of disjoint 4-surfaces. A concrete number theoretic and geometric counterpart for the absence of entanglement could also be in question. A weaker assumption is that this kind of state cannot generate entanglement by interactions.

The surface defined by the product $\prod P_i$ would be singular in the sense that it would not be irreducible polynomial and would be localized at "boundary" of discretized WCW as a union of 3-surfaces in half-cones of CDs associated with P_i defining union of 4-surfaces and correspond to a superposition of space-time surfaces restricting to these 3-D surfaces at lower half-cones.

Therefore the intuition of particle physicists suggests that one should allow product polynomials.

The idea that unentangled free many-particle states have product polynomials as correlates is attractive. One can indeed consider a hierarchy of functional composisites involving also product polynomials.

1. The lowest level in the functional hierarchy could correspond as a free many-particle state to a product of irreducible polynomials with a simple Galois group as counterparts of elementary particles. For P(0) = 0 in $P \circ (\prod P_i)$ the roots of P_i would be roots of P giving rise to the analog of conserved genes. Functional composition with a polynomial would give an interacting many-particle state. P would characterize the interaction with particles and represent a space-time sheet at which the particles represented by P_i have topologically condensed.

It should be noticed that the assumption $h_{eff} = n_0 h_0$, $n_0 = (7!)^2$, is satisfied if there is a ground state polynomial with Galois group corresponding to a product or to functional composite of two polynomials with simple Galois group A_7 and two simple Galois groups Z_2 .

- 2. Arbitrarily high function composites are possible. The products of polynomials $Q_j \circ (\prod P_i)$ for these interacting states would in turn define higher level many-particle states and one would have a hierarchy analogous to abstraction hierarchy defined by a repeated function composition giving rise to increasingly complex functions. The hierarchy of space-time sheets of many-sheeted space-time would serve as a geometric counterpart. Also more general states can be constructed by allowing products of polynomials belonging to different levels in the hierarchy.
- 3. What could be the interpretation of the emerging geometric structures? The roots of Q_j correspond to n mass-shells and their inverse images define $m \times n$ mass shells, where $m = \sum m_i$ holds true. The space-time regions associated with P_i has been replaced with its n-fold covering. The n sheets would define the magnetic body.

If $Q_j(0) = 0$ is true the roots of P_i are roots of the composite: this serves as the analog of conserved genes. If P_i corresponds to an irreducible monic polynomial and has a simple Galois group, one can talk about the analog of an elementary particle. The conservation of genes is approximate if Q_j has a root very small root. If a gene corresponds to a Galois group rather than roots, conservation does not require even this. 4. An interesting situation is obtained when the ground state consists of a single irreducible polynomial P. For $Q_j(0) = 0$ in the hierarchy, one would obtain MBs associated with P with arbitrary many levels. Could one say that also elementary particles evolve and these MBs correspond to different evolutionary levels of the particle with increasingly complex cognition. Lenin would have been right about elementary particles after all! p-Adic prime characterizing the mass of the particle in p-adic thermodynamics would correspond to the largest ramified prime for the extension considered.

Second interesting situation corresponds to iteration of a single polynomial as $Q \circ P \rightarrow Q \circ Q \circ P \rightarrow \dots$ with Q(0) = 0. These roots would correspond to a situation familiar from chaos theory and the inverse roots would approach the boundary of the full Julia set.

- 5. The hierarchy of infinite primes [K106] is one of the speculative mathematical ideas inspired by TGD. A geometric interpretation could be in terms of many-sheeted space-time. Number theoretic interpretationin terms of functional composites of polynomials of of polynomials suggests that the hierarchy described above gives a connection with the realization as manysheeted space-time. The primes in the hierarchy of infinite primes could be generalized and correspond to simple Galois groups as analogs of primes.
- 6. Whether the phenomenology of the many-sheeted space-time is consistent with this proposal, is an open question. For instance, does the $M^8 H$ duality predict at the level of H wormhole contacts connecting space-time sheets at different levels of hierarchy. Wormhole contacts have an Euclidean signature of induced metric and could correspond to the roots of P for which the real part is negative and could correspond as Galois confinened states to negative values of mass squared. Also tachyons can appear in the decomposition of Galois singlets to virtual quarks having momenta, which are algebraic integers of the extension of rationals at mass shells determined by the roots of P.

19.2.2 What could happen in BSFRs?

BSFRs correspond to the ordinary SFRs and the new element is that the arrow of time changes. The findings of Minev et al [L104], discussed in [L104], provide empirical support for this. The proposal also solves the question about how the world which can be quantum coherent in arbitrarily long scales can look classical in long scales. The findings of Libet about active aspects of conscious experience [J4] provide an additional support for the notion of BSFR.

Some facts about BSFRs

What do observations say about BSFRs?

- 1. The findings of Libet about active aspects of consciousness [J4] find a nice explanation in terms of BSFR as also the findings of Minev et al [L104] in atomic physics scales [L104].
- 2. On can argue that if time reversed systems exist they would have been observed a long time ago. This is not the true. According to the standard physics view, time reversed systems send classical signals only to the direction of the geometric past with respect to us. The classical signals from the time reversed systems in the geometric past do not reach us. The time reversed signals from the geometric future do this only if we can detect them and our claimed ability to anticipate future events and precognize suggests that this is possible [L221]. TGD suggests a classical mechanism of memory and anticipations involving time reflection of a signal in BSFR for a subsystem [K94]. Earthquakes are one and candidate for a macroscopic BSFRd discussed in [L106]
- 3. There exist stars older than the Universe [E2] discussed from TGD pointmofview in [L105]. This could be understood if the stars evolve by a sequence of BSFRs and the cm time coordinate for the star remains stationary.

The WCW state before BSFR

To understand what could happen in BSFR [L118, L165] [K132] one must first consider the state before the BSFR.

- 1. In ZEO the 3-surfaces (mass shells) associated with P_i would define the parts of 4-surfaces in a lower half of the corresponding CD. The proposal has been that they form a Russian doll structure with a common center as origin. Each CD has either of its tips as natural origins but the non-associativity of octonions forced them to select either tip and thus either halfcone of the CD. This means the selection of the arrow of time. The states at the passive tip, the selected one, are passive and correspond to the initial, prepared state of particle reaction. Galois reduction and selection of branches of minimal surface at frames corresponds to a preparation.
- 2. The 4-surfaces associated with P_i in $P = P_1 \circ ... \circ P_i ... \circ P_n$ would be topologically condensed on the portion of the larger space-time surface by wormhole contacts in the lower half of its CD. The wormhole contacts would correspond to tachyon-like mass shells predicted as roots. Galois confinement for physical states would allow only non-negative mass squared. This would give content to the nebulous idea of many-sheeted space-time. In the QFT picture, tachyonic mass squared values would correspond to virtual particle exchanges. One can say that in TGD virtual particle momentum spectrum is discrete and even finite so that one gets rid of divergences.
- 3. The state before BSFR would be a state of WCW spinor field localized to, say, the lower half-cone CD_{-} of CD. All polynomials in the superposition would effectively reduce in CD_{-} to that associated with P since for $Q \circ P$ there would be no quarks at the mass shells of Q in CD_{-} . The state in the lower half-cone, determined by P alone, does not provide the information to deduce it. In the operational sense, only a single state determined by P exists.

The proposal is that the analogs of Kac-Moody and Super Virasoro conditions for the supersymplectic algebra [L114] determine the entire superposition over $Q \circ P$:s. The holography at the level of WCW [L127, L128] could fix the state as a WCW spinor field from the holographic data provided by the roots of P. The superposition of ver $Q \circ P$ would correspond to a discretization of a WCW spinor field satisfying the super symplectic gauge conditions [L114].

- 4. If the condition Q(0) = 0 is satisfied, the roots of $Q \circ P$ consist of the roots of P and the inverse images of the roots of Q by P^{-1} . After BSFR the WCW state is localized to the space-time surface determined holographically by the mass shells for single $Q \circ P$. BSFR can be said to occur in the space of polynomials and conserve the existing roots so that information is not lost.
- 5. The space-time surface inside CD_{-} is fixed by holography determined by mass shells H^{3} with positive or negative energy depending on which half-cone is in question. Only one of choice for the sign is possible since otherwise the PE does not exist since the holography is overdetermined.

What could happen in BSFR?

What could happen in BSFR?

- 1. In BSFR the state in CD_+ is localized in the same way but becomes physically undetermined in CD_- . The roles of future and past are changed and BSFR would therefore reverse the arrow of time.
- 2. BSFR would correspond to a localization to a single polynomial defining proper time a = constant hyperboloids in the positive/negative half cone of the CD, whose size would correspond to the largest ramified prime of the polynomial. The arrow of time changes. The time evolution by BSFRs would be a kind of flip-flop sequence between opposite arrows of time and half-cones of CD.

In TGD inspired theory of consciousness, BSFR would be interpreted as the counterpart of death followed by a reincarnation (these terms are of course understood in a universal sense).

- 3. Since the polynomial surface gives rise to a unique discretization defined by the extension of rationals determined by *P* interpreted as cognitive representation [K18] [L151, L139, L131], one can argue that the localization to a single polynomial in BSFR should be interpreted as a localization only modulo finite measurement resolution. One can ask whether the localization could occur first to a single Galois group and only after that to a single polynomial. The state after the Galois localization would involve a large number of polynomials with the same Galois group and different ramified primes.
- 4. Is the opposite process $Q \circ P \to P$ in which some levels disappear and information is lost, possible. Number theoretic evolution inevitably leads to an increasing cognitive complexity as polynomials with an increasing degree emerge. One cannot however exclude these transitions.

What can one say about the state associated with the polynomial $Q \circ P$ defining the final state. The mass shells of P but with opposite energies can contain quarks besides the mass shells of Q. The Galois confined groups with integer valued momenta are in general different and BSFR could be interpreted as SFR occurring in particle reactions. The conservation of momentum which is true at the limit of infinitely large CD poses constraints on the momenta and masses. Some quarks at lower mass shells must be moved to the mass shells associated with Q. Kind of ionization transferring quarks from the lower levels of the hierarchy to the new level should take place.

Can different levels in polynomial hierarchy make BSFRs independently?

The proposed first guess about BSFRs is not general enough. The point is that the BSFR would occur for all factors P_i defining levels of the hierarchy of MBs simultaneously. The existing picture is that BSFRs are not simultaneous but can occur separately but not completely independently. A BSFR at higher level induces BSFRs at lower levels just like the decision of "boss" at higher level induces decisions at the lower levels. A more general picture would look as follows.

1. BSFR for $P = P_1 \circ ... \circ P_n$ involves a localization in the space of polynomials which are extensions of type $P \to Q \circ P$. After this a cognitive cascade occurs unentangling relative Galois groups associated with P_i . This process need of course not be complete.

Cognitive cascade is followed by SFRs in quark degrees of freedom and in the degrees of freedom related to classical non-determinism.

2. After this a particular unentangled P_i could be replaced with $P_i \rightarrow Q_i \circ P_i$ in BSFR. This would mean that a CD associated with P_i increases in size. Sub-selves would correspond to P_i s and this particular sub-self would thus die and reincarnate. At the level of P this would mean the replacement $P = P_1 \dots \circ P_i \circ \dots P_n \rightarrow P = P_1 \dots \circ (Q_i \circ P_i) \circ \dots \circ P_n$. In this picture the CD:s associated with P_i could have different arrows of time.

This raises however the question whether Galois groups of P_i :s with different arrows of time entangle in the next BSFR. This could make sense for the same arrow of time only.

19.3 Questions related to the TGD inspired theory of consciousness

TGD inspired theory of consciousness could be seen as an interpretation of the ZEO based quantum measurement theory [L118] [K132]. The physical correlates for the phenomena of consciousness should have a simple description in the proposed framework.

19.3.1 About the notion of time

The basic motivation behind ZEO is that it could provide a solution to the problems related to the difference between experienced time and geometric time, which are usually identified although this is in a striking conflict with basic empirical facts. 1. One should understand the arrow of time and why the time increases in one direction, at least in a statistical sense. There are two natural geometric times: light-cone proper time a, which is naturally associated with CD and the linear time coordinate t associated with the $M^4 \subset H$.

These two times would correspond to two different views about time evolution already briefly discussed [L189]. Light-cone proper time would be assignable to particles with thermal mass determined by p-adic thermodynamics [K68] and linear Minkowski time to massless particles for which translations must replace scalings. The first one is with respect to scalings and the second one with respect to time translations. Note that scalings and translations do not commute.

Number theoretically both times are very special. For a given extension of rationals all points with algebraic Minkowski coordinates for M^8 can belong to the cognitive representations. A kind of cognitive explosion takes place. Quark momenta are naturally algebraic integers and the actual cognitive representation is determined by the momenta of quarks present in the state and is finite.

2. The analog of the unitary evolution associated with *a* should correspond to scaling rather than time translation. If the pairs of unitary processes followed by SSFRs, the unitary process could correspond to the scaling as in super string models.

Super symplectic transformations, acting as symmetries of the "world of classical worlds" (WCW), involve a scaling generator, which would have a representation in terms of supersymplectic algebra and scale the size of the CD. If the p-adic scale corresponds to the largest ramified prime for P, this should mean the increase of the largest ramified prime during time evolution by scalings.

3. This leads to ask whether the increase of experienced time in SFR, or in the cascade of SFRs associated with it, the polynomial P should be replaced with $Q \circ P$ such that Q has maximal ramified prime larger than that for P. Here one must be however cautious. For a fixed sub-CD, the flow of the experienced time could correspond to the increase of a as a characterizer of the size of the CD

How the possibility of two times might reflect itself as a character of conscious experience? For instance, could everyday experience and some altered states of consciousness such as DMT experiences correspond to different geometric times for the perceptive field. DMT experiences could correspond to experience in which hyperbolic geometry of a = constant surface is projected to t = constant the hyper-plane [L179].

For large values of a, the local curvature of H^3 decreases and at the limit of large values of a H^3 becomes t in a good approximation. The everyday experience could therefore correspond to large a and therefore in a good approximation to t whereas the DMT induced states of consciousness would correspond to small a [L179].

Momentum eigenstates and time translations can be considered at 3 levels: corresponding to space-time level, embedding space level and WCW level.

1. Could ZEO make it possible to talk about wave packets for sub-CDs, or rather, for the state associated with either half-cone of sub-CD. Could one assume that the wave packets of sub-CDs are localized within the largest CD involved? This is the view proposed in [L127, L128].

Sub-CD would correspond to a sector of WCW and define the decomposition of WCW. WCW would also have decompositions according to Galoism group of the polynomial, the degree of the polynomial P, and the number of levels its its functional composition.

2. Could one define M^4 time evolution at the space-time level as a flow in which the flow lines of time translation as isometry in M^4 are projected to the space-time surface and define a "subjective" space-time view about time translation? H view would be the second view, in which the 3-surface would be a particle-like entity rather than the arena of physics. The notion of the quantum group [A23, A52] could catch this notion. Gravitational and inertial charges could correspond to space-time and embedding space views about conservation laws [L150]. Gravitational time translation could have a representation as a quantum group transformation at the level of X^4 .

S-matrix is a fundamental notion in the standard QFT.

1. The TGD counterpart of S-matrix relating the states assignable to the half-cones of CD identified as Galois singlets made of quarks at fundamental level would correspond to the S-matrix as the particle physicist understands it. This transition would be associated with BSFR. The size of the largest CD would characterize the duration of transition [L150].

TGD suggests that the unitary matrix of QFTs could be replaced with the fermionic counterpart of Kähler metric and therefore as a property fermionic states space [L141] and highly uniquely determined by the infinite-D character of the fermionic state space as also the Kähler metric of WCW [K64, K34, K97].

- 2. One has two times, linear time t and light-cone proper time a. For both of them the roots of P correspond to very special moments of time. The time evolutions with respect to t and a would naturally correspond to translations and scalings respectively. I already proposed that these two times could correspond to perceptive fields defined by t = constant hyperplane appropriate for massless states and a = constant hyperboloid appropriate for massive states. Should one speak about separate time evolutions for a and t. p-Adic particle massivation suggests that a is the correct time. For large values of a when the curvature of H^3 approaches zero, $a \simeq t$ is a good approximation. Therefore the counterparts of the unitary evolutions could always correspond to scalings.
- 3. Typically, the number of unstable particles decreases exponentially on M^4 time t. As already noticed, this kind of time evolution should correspond to a sequence of BSFRs and to perceptive fields which correspond to $t = t_n$ hyperplanes. For the relaxation of magnetization in spin glass the exponential law is replaced with a power law [L166] so that time would be a logarithm of the linear M^4 time. This would naturally correspond to a and scalings. For small values of a, the large curvature of H^3 would imply a strong deviation from the behavior with respect to linear time t. Spin glass systems would therefore correspond to small value of a.
- 4. For large values of a the time evolution by scalings associated with BSFRs or SSFRs should have an approximate interpretation as time translations for short enough times Δt . The earlier view has been that the shift of the active boundary of CD takes place in time evolution by SSFRs forcing the scaling of the CD.

Could approximate counterparts of the time translations be induced as scalings of CD leaving the state at the passive boundary invariant and only increasing its size? If so, the time translations by Δt for the other tip of CD would reduce to scalings for which Δt corresponds to the scaling $\Lambda = 1 + \Delta t/T(CD)$ for CD having T(CD) as the temporal distance between its tips? Note that the scalings would be different for the sub-CDs of the hierarchy rather than affecting all sub-CDs in the same way.

For small values of $\Delta t/T(CD)$ this assumption would indeed transform the power law $\Lambda^k = exp(kln(+\Delta T/T(CD)))$ with the rate k to and exponential decay $\Lambda^k \simeq exp(-k\Delta T/T(CD))$ with rate k/T_CD .

19.3.2 The notion of memory mental image

The notion of memory mental image [K2, K94, K132] [L118, L121, L154] is one particular test for the ZEO based theory of consciousness. One can criticize the recent ZEO based view for having several ad hoc elements.

- 1. Mental images of self correspond to sub-selves of self having sub-CDs as correlates [K70].
- 2. Mental image wakes up when SSFR changes its state. The quantal non-determinism, which does not change CD, should correspond to the failure of the classical determinism assignable to the lower-D frames defining the space-time surface as a minimal surface analogous to soap

film. At frames the field equations for the full action, which includes besides the volume term also Kähler action, are satisfied so that conservation laws hold true. In other regions the field equations for volume term and Kähler action hold true separately.

Also the reconnections of flux tubes and string world sheets associated with the flux tube involve non-determinism since the strands AC and BD can transform to AC+BD or AD+BC in reconnection.

These transitions could wake up mental images scattered around the space-time surface so that memory mental images would be where the original non-deterministic event occured. The formation of copies of mental images is also expected in the memory recall.

- 3. A possible interpretation for the classical non-determinism is in terms of intentional aspects of conscious experience. The superposition of different options could correspond to experience about having not yet chosen from a finite number of options. The non-determinism of SSFRs would in turn correspond to sensory experience.
- 4. The spatial braidings of nodes of a network induced by the motion of nodes defining time-like braiding store the information of time like braiding to memory as kinds of Akashic records [L189]. The reconnections, which are possible and unavoidable by the 4-dimensionality of the space-time surface, induce basic braidings even with the motion of the ends of braid strands. This is because the reconnection $AC+BC \rightarrow AD + BC$ generates basic braiding operation as the braided counterpart of a permutation of neighboring braid strands known as SWAP in topological quantum computation.
- 5. The earlier view involved some assumptions, which in the recent view look un-necessary. In particular, the former picture led to an un-intuitive idea that the mental images about geometric past are stored in the geometric future. The idea was as follows. As the size of the CD increases, there are moments at which a new $t = t_n$ hyper-plane emerges. The question was whether the emergence of this plane in the sequence of scalings of the CD is accompanied by a generation of mental images in the future half-cone of the CD.

This assumption is unnecessary in the recent picture and also in conflict with it since the upper half of CD remains unconscious to self. If the space-time surface in the interior of the new CD emerging in BSFR contains the same hyperbolic spaces H^3 as $a = a_n$ sections besides the new ones, the new space-time surface contains a lot of information about the previous space-time surface. This could explain why we can remember, perhaps unconsciously, something about the period of sleep if it corresponds to the reversed arrow of time.

The fact that the BSFR conserves information about the earlier polynomial decomposition explains why we can remember something about yesterday even if falling asleep would correspond to BSFR.

6. After images is one aspect of the memory and since approximately periodic minimal surfaces as analogs of time crystals are possible. The frames and reconnections as singularities and loci of non-determinism and mental can appear in this case repeatedly so that after images could be understood of being due the increase of CD in the sequence of SSFRs.

19.3.3 More questions related to the relationship between subjective and geometric time

The growth of the geometric time should be associated with the sequence of SFRs defining quantum jumps in the sense that some kind of time value assigned to the content of the perceptive field grows in the sequence of SFRs in a statistical sense at least.

What does this statement really mean? Does this statement hold true for the sequences of SSFRs or BSFRs or both? This question was already considered for SSFRs and it was suggests that the sequence of time values defined by light-cone proper time a assignable to the mass hyperboloids associated with Galois confined states could provide this time is the SFRs occur in the order of decreasing mass squared and thus increasing a.
Could the position of CD shift to the direction of future in BSFR?

The flow of time assignable to BSFRS would have a pair of BSFRs establishing the original time direction as a basic step. A physical interpretation could be quantum tunneling. The first guess is that both BSFRs could increase the size of CD by replacing the polynomial P with $Q \circ P$. This is however not true if the largest ramified prime associated with Q is not larger than that associated with P.

One must be careful with the ramified prime conjecture, which is just a guess. Ramified primes are divisors of discriminant of P defined as the product for the squares of root differences. The roots could be larger than the largest ramified prime. Therefore one can challenge the ramified prime hypothesis and consider the possibility that the mass squared values of the physical states satisfying Galois confinement assign to the quantum state a collection of p-adic primes defining p-adic length scales.

The size of the CDs can increase and geometric time defined by the distance from the center of the CD to its tip would increase. Also the size of sub-CDs can increase in BSFRs. Evolution in this manner would mean increase of complexity and emergence of new larger space-time sheets. NMP would force negentropy increase and as a byproduct increase of entropy [L162].

It is however difficult to understand whether and how the center of CD could shift in either time direction unless T violation at the fundamental level induces this. Could the correlation between subjective and geometric be associated only with the SFR sequences assignable to SSFRs?

Periodically appearing mental images and sleep-awake cycle

Consider first periodically appearing mental images and the sleep-awake cycle.

1. Our mental images typically die and are reborn again. After images represent a basic example of this. Could it be that this process is a sequence of birth and death of a mental image as subself?

We are mental images of a higher level self. Could the wake-up period and sleep period be related by a BSFR and time reversal? Are we after images of this higher level self? Sleep would be a small death. This could explain why we do not remember anything about the period of sleep.

2. The neuroscience based objection against the necessity of BSFRs is that the disappearance of mental images is caused by the loss of the nerve pulse activity: the neurons in some parts of the brain and CNS become hyperpolarized so that nerve pulse activity relevant to our cognitive consciousness and memory ceases [L183]. I could be conscious but would not remember anything about this period. However, the BSFR for MB associated with the part of CNS in question could induce the loss of the nerve pulse activity.

During the wake-up period the metabolic energy feed effectively increases the values of h_{eff} particles and activates higher levels to self-hierarchy. Perhaps this activates BSFRs inducing additional polynomial factors for polynomials $\circ P_i \circ \ldots$ corresponding to subselves. The size of the CD increases if BSFR occurs and the tip of the CD is in the future of the self that died. Could the tip correspond to the geometric time for the moment of wake-up of time reversed self?

3. After the second BSFR the geometric time for the self in the original time direction is determined most naturally by the center of the CD. It would not be shifted unless there is some mechanism causing a shift. If the shift occurs its direction could be fixed by the arrow of time for higher level self in the hierarchy.

Why would the center of the CD to which the geometric time is naturally assigned shift towards a preferred time direction in H? If the scaling is the basic transformation associated with BSFR, the scalings would define time evolutions as approximate translations for linear time if the hyperboloid in question has small enough curvature. There would be no reason for the shift of the cm of CD. The idea about time evolution as shift of the cm of the CD would not make sense.

4. One can indeed image another explanation for after images and sleep-awake cycle would involve a time crystal like system. In TGD this kind of system would correspond to MB as a minimal surface with an approximately periodic structure. After images and our sleep-awake cycle would reflect this kind of periodicity for subselves.

One can imagine that there is a time-like lattice of sub-CDs assignable to the periodic structure of classical nondeterminism (say reconnections appearing periodically). The sub-CDs do not shift but there would be a kind of wave which wakes up the sub-CDs, and is shifted in a preferred time direction. The time direction assignable to a larger CD representing the environment could define the preferred time direction. Time-like braids could provide a realization for these waves. Their reconnections involve classical and quantum non-determinism and if the reconnections appear periodically, their wake-up could induce a sequence of mental images of self. Note that this explanation can confirm with the explanation in terms of BSFR for the sub-CDs.

5. Directed attention is one basic aspect of consciousness. The structure of Galois entanglement is hierarchical directed downwards in the tower of relative Galois groups. This direction would be from larger to smaller p-adic length scales. Also SFRS at quark level related to the non-determinism at the frames of space-time surface as a minimal surface and at braids is involved. Could the attention shift from sub-CD to sub-CD in the preferred time direction and in this way give rise to a temporal sequence of wake-ups of sub-CDs?

How to understand memory recall?

There is also the problem of memory recall as active process rather than a spontaneous emergence of memory. Both classical and quantum description for memory recall is suggested by quantumclassical correspondence.

- 1. In the classical picture, memory recall/anticipation would involve communication with the geometric past/future. Time reflection involving BSFR for the signal as a sub-self would take place.
- 2. A lot of information is preserved almost as such in BSFR $P \to Q \circ P$ since for Q(0) = 0 mass spectrum is preserved. Note that the mass shells as roots of P in the half-cones of CD have only a different sign of energy. Therefore a lot of information about previous time reversed incarnations preserved and therefore also about previous lives in the same time direction. One could speak of Akashic records. Akashic records would be also realized in the dynamical braiding with nodes connected by flux tubes.
- 3. One could also understand memory recall as a wake-up of memory mental images during the period associated with a single SFR. If this is due to the finite classical non-determinism at frames and reconnection points, this would change the entire space-time surface but possibly only after the singular point. This change would have interpretation as classical communication and time reflection if BSFR occurs at the singular region.

Chapter 20

New results about causal diamonds from the TGD point of view

20.1 Introduction

This work is a response to two very interesting articles related to the notion of causal diamond (CD).

20.1.1 The metric for the space of causal diamonds

Dainis Zeps sent article [B8] (https://rb.gy/gcfvus) related to the space of causal diamonds (cd) of M^4 (CD is the Cartesian product $cd \times CP_2$ of cd, defined as intersection of future and past directed light-cones, and of CP_2).

Although it remains unclear whether the proposal for the identification of the moduli space is realistic in the TGD framework, where also a simpler realization of the moduli space can be considered, the article led to a clarification of many aspects related to ZEO and the space of CDs as the backbone of the "world of classical worlds" (WCW).

20.1.2 The existence of a hyperbolic generator of conformal group defining a flow, which maps causal diamond to itself

Gary Ehlenberger sent a link to a very interesting article [B23] (https://rb.gy/z7o7wj) related to causal diamonds (cd) of 4-D Minkowski space.

The article is very interesting from the TGD point view since causal diamond (CD) of $H = M^4 \times CP_2$ is the key object in zero energy ontology defining the ontology of TGD. CD is defined as the Cartesian product $CD = cd \times CP_2$ of the causal diamond $cd \subset M^4$, identified as an intersection of future and past directed light cones, and of CP_2 .

The basic findings of [B23] are as follows.

1. The generator of K of special conformal transformation in time direction, scaling generator Dand generator P_0 of time translation generate an SL(2, R) algebra. A suitable combination of these 3 generators defines a generator of what generates hyperbolic time translations, call it S. Its exponentiation generates an analog of time evolution in conformal quantum mechanics. What is remarkable is that this flow takes the CD to itself so that the time range of time evolution can be said to correspond to the distance between the tips of the CD.

The flow lines of the exponentiated Killing vector would have an interpretation as the world lines of accelerated observables with constant acceleration determined by the initial value of the radial M^4 coordinate.

The hyperbolic time evolution is time-like only in the interior of the second light-cone associated with CD. Only a single arrow of time is allowed by time-likeness. It is time-like also outside the light-cones.

2. The time evolution of a static CD observer is equivalent to a time evolution of conformal QM defined by a hyperbolic Hamiltonian. The flow states for a fixed value of radial coordinate r correspond to a time evolution from the value of hyperbolic time $\tau = -\infty$ to $\tau = \infty$. This evolution corresponds to a finite time interval with respect to the ordinary Minkowski time t.

One obtains a family of states corresponding to time evolutions for various values of t. These states are so-called coherent states, which are not orthogonal and their inner product for values $t = t_1$ and $t = t_2$ defines a correlation function of conformal QM.

The behaviour of 2-points functions of conformal QM in CD is equivalent to that for thermal QFT in M^4 . One can say that static CD observers falling freely along the flow lines of the Killing vector observe the vacuum state of the inertial M^4 system as a thermal state characterized by Unruh temperature $T = \hbar/2\pi L$ (https://rb.gy/qxyp8q), where L is the size of CD.

20.1.3 Could these findings have significance for TGD

An obvious question is whether these findings could have significance for TGD, in particular for the zero energy ontology (ZEO) [L118, L177, L169] [K132], which replaces the standard ontology as a foundation of quantum theory and in this way solves the basic paradox of quantum measurement theory.

Zero energy ontology (ZEO) and CDs

Causal diamond (CD) defines the analog of quantization volume in the embedding space $H = M^4 x CP_2$ inside which the zero energy states are superpositions of space-time surfaces, which connect the light-like boundaries of CD. In the TGD inspired theory of consciousness, CD corresponds to a 4-D perceptive field of self.

The allowed space-time surfaces are preferred extremals (PEs) analogous to Bohr orbits and satisfy almost completely deterministic holography forced by the general coordinate invariance. Quantum states can be also regarded as superpositions of pairs of 3-D states assignable the opposite boundaries of CD and constructed using second quantized fermions of H satisfying free Dirac equation or its modification in the case that also M^4 allows the analog of Kähler structure suggested by the twistor lift of TGD. At the limit of large CDs also the Poincare quantum numbers are opposite at the opposite boundaries of CD.

The TGD based proposal is that the time evolution at the level of "world of classical worlds" (WCW), which consists of these preferred extremals for given CD, is defined by a conformal scaling leaving the passive boundary of causal diamond and states at it invariant but affect the active boundary and 3-D states at it. The gradual increase of CD would correspond to the growth of geometric time correlating with the flow of subjective time defined by "small" state function reductions (SSFRs) as analogs of weak measurements and this time evolution replaces the trivial time evolution of Zeno effect in TGD and gives rise to self as a conscious entity. In "big" SFRs (BSFRs) the roles of the active and passive boundaries change and the arrow of time changes.

Under certain conditions the evolution by scaling can be approximated by a time translation. The scalings commute with the Lorentz transformations mapping the passive boundary of CD to itself. This time evolution allows us to understand spin-glass type systems [L166]).

From the point of view of ordinary time evolution defined by energy, the difference is that the relaxation processes obey fractal power law rather than exponential decay. This is a characteristic feature of the N-point functions of conformal field theories (CFTs) as opposed to those of massive quantum field theories (QFTs). The conformal invariance of 2-D conformal theories generalizes since the light-cone boundary $\delta M_{\pm}^4 \times CP_2$ and light-like 3-surfaces in general allow extended conformal invariance. $\delta M_{+}^4 \times CP_2$ allows also supersymplectic invariance for light-like radial coordinate, which takes the role of complex coordinate. One can say that in the TGD framework the 2-D conformal field theories generalize to dimension D = 4. In particular, the boundaries of space-time surfaces and the 3-D surfaces at the boundaries of CDs define 3-D holographic data for the generalized conformal field theory.

Poincare group acts in WCW rather than at the level of space-time and M^4

In the TGD framework, the great conceptual leap is made possible by the moduli space of CDs is that 4-D Poincare and conformal groups would not act at the level of space-time or of CD but at the level moduli space of CDs forming the backbone of WCW.

In TGD, Poincare invariance need not be a symmetry of the action at the space-time level as has become clear already earlier. Indeed, the twistor lift of TGD suggests that M^4 has a Kähler form contributing to Kähler action of H so that Poincare and Lorentz symmetries would be broken at the level of M^4 .

This picture would fit nicely with the breaking of Lorentz invariance implied by the momentum and polarization vectors assignable to massless particles and also with the view of hadrons based on quarks characterized by a place carrying 2-D longitudinal momenta. This kind of flexibility gives a strong support for the WCW approach.

The quantum numbers of the zero energy states assignable to a given CD must correlate or be equal with the quantum numbers, such as four-momentum and angular momentum assignable to the wave function in the moduli space of CD.

- 1. The value of mass squared for CD should correspond to that for the generator of conformal scalings realized in super symplectic and super-Kac-Moody type degrees of freedom in the interior of CD.
- 2. One can assign to the modes of the second quantized spinor field of H 4-momenta and the total momentum associated with these at either half-cone of CD would naturally correspond to the momentum assignable to CD.
- 3. Classical charges are conserved for action and also these should be identical with those assignable to CD and with the wave function in the moduli space of CDs. Here interesting questions relate to the violation of translational invariance and Lorentz invariance induced by the M^4 Kähler form.
- 4. In case of TGD, CD means actually $cd \times CP_2$: also the total quantum numbers assignable to CP_2 should be the same for CD and the wave function in the space of CDs.

Problem and questions

In the TGD framework, the existence of a hyperbolic generator S mapping cd to itself and the properties of the corresponding flow raise some questions.

1. The exponentiation of a hyperbolic generator defines a diffeormorphism of CD, which would deform the space-time surface in the interior of the CD. One would have a problem since this deformation is not expected respect the preferred extremal property.

In TGD, hyperbolic generator S, just like supersymplectic generators, can act only at the boundaries of CD and affect the data at them. These data define boundary conditions for holography, which extends this action to an action on the space-time surface inside the CD. If the hyperbolic flow is modified at all at the boundaries of CD, this induces a modification of the preferred extremal at the level of the space-time surface.

2. The flow induced by S corresponds to a flow that maps the states for a fixed value of radial coordinate r (r = constant means that system is "at rest") from time $\tau = -\infty$ to $\tau = \infty$ and this corresponds to relativistic at the level of CD accelerate motion with acceleration a = 1/L, L the size of CD. The initial and final points of motion correspond to point ($t_{\pm}(r), r$) at the boundaries of CD. Somewhat disappointgly, the flow does not affect the points at the boundaries at all.

3. What is however possible is that the time evolution as an exponentiation of the hyperbolic generator labelled by t affects the quantum states at the boundaries of CD for each value value of t. One can say that time evolution is represented as unitary time evolution at the boundary of CD.

This would relate the states at the points of boundary with different values of light-like radial coordinate. This correlation could be interpreted in terms of radial conformal invariance and could be manifested in terms of conformal correlation functions. This is just what one expects since the light-like radial coordinate for the light-cone boundary is analogous to the complex coordinate for ordinary conformal invariance.

Hyperbolic time evolution would define unitary action on zero energy states and could define "small" SFRs (SSFRs), which does not scale CD so that the geometric time defined by the distance between the tips of CD is not changed. In TGD inspired theory of consciousness this kind of SSFRs would correspond to "timeless" conscious experience. Could the sequences of these time evolutions followed by SSFRs correspond to meditative states, which are reported to be timeless? SSFRs involving scalings of CD would in turn correspond to ordinary ordinary conscious experience involving the sensation of time flow.

These findings force to reconsider the basic assumptions of ZEO.

1. The assumption has been that only SSFRs scaling the size of CD possible? Could one think that only the SSFRs corresponding to the hyperbolic time evolution are possible. The size of CD remains unaffected in the sequence of SSFRs.

Could the scalings of CD correspond to SSFRs or could they precede BSFRs in which the arrow of time changes? Note that the scalings would affect the WCW spinor fields representing zero energy states at the level of moduli space of CDs whereas hyperbolic time evolutions would affect only the WCW spinor field in "internal" CD degrees of freedom.

2. One can assign to the 2-point functions at the boundary of the CD a temperature given by $T = \hbar/L$, where L is the size of the CD. Could this temperature and thus the size of CD correlate with the physical temperature of the environment? In fact, I have already ended up with the view that L codes for the analog of cosmic temperature gradually reduces during the sequence of SFRs.

20.2 Two possible identifications for the space of CDs and its metric

The space of causal diamonds (CDs) forms the backbone of the "world of classical worlds" (WCW). Each CD interpreted as a geometric correlate for the perceptive field corresponds to a sub-WCW. Zero energy states are realized as superpositions of space-time surfaces inside CD and pairs of fermionic Fock states at boundaries of CD. The space of CDs would define cm degrees of freedom in WCW.

A possible interpretation [B20] (https://rb.gy/m1dvwq) of CDs assigned with, say geodesic lines, is that the size of the CD (temporal distance between its tips) defines the duration for a "moment of consciousness". This interpretation makes no distinction between subjective and geometric time. This distinction is however very real as many examples from everyday life demonstrate.

The increase of the size of CD in "small" state function reduction (SSFR) inducing a small scaling of CD would correspond to the increment of geometric time identified as the distance between the tips of CD. The basic TGD based proposal is that this corresponds to the duration of experienced moment of subjective time in SSFR. The duration of the moment of consciousness between two SSFRs would thus correspond to an increase of the size of the CD rather than to its size.

One can consider two very different identifications of the moduli space of CDS.

20.2.1 TGD in inspired option for the moduli space of CDs

Consider first the TGD inspired identification for the moduli space of CDs.

- 1. It is easy to see that the space of CDs is 8-D. The position of either tip or of center of the CD gives M^4 . The Lorentz transformations SO(3, 1) leaving either tip of CD invariant and the group D of scalings leaving the cm of CD invariant give new CDs. The isotropy group of the CD is SO(3). This gives 8-D space.
- 2. The first guess is that the space of CDs is the coset space $D \rtimes P/SO(3)$. The division by SO(3) is due to the fact that a given CD corresponds to a unique rest system and is invariant under rotations. Translations of M^4 , that is M^4 , code for the position of the cm or tip of CD, and D corresponds to the size of CD. Locally one would have an 8-D product $D \rtimes M^4 \times H^3$, H^3 is 3-D hyperbolic space analogous to mass shell. There might be some delicate effects changing the topology.

The naive guess that the signature of the metric is (1,7), is wrong. For the Lorentz group SO(1,3) the signature is (3,3) and for H^3 as coset space $H^3 = SO(1,3)/SO(3)$ the signature is (3,0) rather than (0,3) as one might expect. This has no physical implications. If D has space-like signature, $D \rtimes M^4 \times H^3$ has signature (0,1) + (1,3) + (3,0) = (4,4). This is what one obtains also for the $SO(2,4)/SO(1,3) \times SO(1,1)$ option so that options could be equivalent.

20.2.2 The identification of the moduli space of CDs inspired by conformal invariance

An identification of the moduli space of CDs inspired by conformal invariance is considered in [B8] (https://rb.gy/gcfvus). The 5-D $AdS_5 = SO(2, 4)/SO(1, 3)$ appears in AdS/CFT correspondence and is associated with $4 \rightarrow 5$ holography whereas the space-time surfaces inside CD realize $3 \rightarrow 4$ holography. This might have served as a motivation for the proposal: maybe the idea has been that one cold generalize holography by introducing 8-D space $SO(2, 4)/SO(1, 3) \times SO(1, 1)$ as analog of AdS and its "boundary" as a 7-D space.

The proposal for the space of CDs

The proposal of the article is that the space of CDs is given by $SO(2,4)/SO(1,3) \times SO(1,1)$ 8-D space.

1. SO(2, 4) is the 15-D conformal group of M^4 including Poincare transformations, scalings and also the 4-D group of special conformal transformations. SO(2, 4) acts linearly in 2+4-D Minkowski space M(2, 4). The action of special conformal transformation is however singular and this might mean difficulties. CD is defined by a 2-D sphere of M^4 defining the maximal ball of CD and thus CD.

The space of CDs would be 8-D have signature (4,4) also now. This can be seen by noticing that boosts correspond to time-like directions and rotations to space-like directions so that the signature of SO(2,4) is (8,7). SO(1,3) has signature (3,3) and SO(1,1) has signature (1,0). Signature (4,4) is indeed the outcome. Maybe the two candidates for the space of CDs are identical.

- 2. Why SO(2, 4) would be a correct choice for the group considered. The hyperbolic time evolution as an exponential of special conformal transformation in the time direction defined by CD maps the lower boundary of CD to the upper boundary. Special conformal transformation can be composed from an inversion with respect to the middle point of the CD followed by an ordinary translation followed by inversion. Inversion $x^{\mu} \to x^{\mu}/x^2$ performs a local scaling of the point of the point $(\pm t, r = T \mp t)$ of the CD boundary to $(\pm t, r = T \mp t)/(-T^2 \pm 2Tt)$ and scales the CD boundary. This scaled boundary is translated and preserves its shape. The inversion scales this CD down. Therefore special conformal transformations can leave the shape of CD invariant but induce Lorentz transformation, scaling, and translation.
- 3. The intuitive expectation is that the subgroup dividing SO(2, 4) should leave CD invariant. If so, SO(1, 1) should map the CD to itself. A possible identification is as the group of special conformal transformations in the time direction defined by CD. If SO(1,3) corresponds to the usual Lorentz group, it does not leave the CD invariant unlike SO(3).

This suggests a different interpretation. Perhaps the division means that $SO(1,3) \times SO(1,1)$ consists of Lorentz boosts and hyperbolic special conformal transformations leaving the center point of CD invariant. Only $SO(3) \times SO(1,1)$ would leave the CD unaffected.

4. The basic distinction from the TGD inspired proposal is that there is no holography involved with CD. Rather, it seems that one starts from the idea that one has $7 \rightarrow 8$ holography is associated with the 8-D $SO(2,4)/SO(1,3) \times SO(1,1)$. 7-D subset of CDs would provide the holographic data. One can, of course, consider this kind of holography in WCW cm degrees of freedom.

For this option, the identification $SO(3,1) \times SO(1,1)$ could have the same role as SO(3) in the case of the Poincare group or Lorentz group. This would give for CD Lorentz degrees of freedom and assignable with the SO(1,1) mapping CD to itself.

How representations of the Poincare group could be realized in $SO(2,4)/O(1,3) \times SO(1,1)$?

The representations of the Poincare group should be realized in the moduli space of CDs. How this is achieved is not obvious for the conformal group option.

- 1. It would seem that instead of finite-D possibly non-unitary representations of the rotation group SO(3) as in the case of P, non-unitary finite-D representations of $SO(1,3) \times SO(1,1)$ characterize what might be called generalized spin degrees of freedom? The situation would resemble that in Poincare invariant QFTs for which one has non-unitary finite-D representations of SO(3,1) given by say spinors. It is not clear whether the induction gives rise to a direct sum of state spaces associated with mass shells H^3 as the physical intuition would suggest.
- 2. What seems like a paradox is that the Poincare group allows 4-D translations as Cartan algebra whereas SO(2, 4) has 3-D Cartan algebra. Constant mass squared for Poincare irreps however means that only 3 momentum generators are dynamical. SO(2, 4) Lie algebra contains 3-D Cartan algebra, which consists of commuting rotation generators of SO(4) and SO(2) having a discrete spectrum. Momenta are not expected to have a similar discrete spectrum without special assumptions. Intriguingly, the number theoretical vision of TGD, involving the notion of Galois confinement TGD, predicts that the spectrum of physical stats is integer valued in suitable units.
- 3. For the TGD inspired option the moduli space is identified as $D \rtimes P/SO(3)$ and the situation is much simpler and differs from the construction of the representations of the Poincare group only by the presence of the scaling group with defines the analogs of unitary time evolutions preceding SSFRs. The scaling group would reduce by a symmetry breaking forced by the number theoretical picture to a discrete subgroup of scalings giving a discrete mass squared spectrum.
- 4. SO(2,4) acts as symmetries of massless theories to which ordinary twistor approach applies so that the proposed picture is attractive in the framework of massless QFTs in M^4 . Masslessness in M^4 sense conforms with the invariance of the state space of massless particles under scalings.

In the TGD framework, the masslessness holds true in the 8-D sense and also the twistor space of CP_2 enters the game so that masslessness in the M^4 sense is not absolutely necessary and the physical expectation is that the mass square spectrum is integer valued using as the momentum unit defined by CD size scale. Note however that the ground states of super symplectic representations are massless in this sense.

5. The space of CDs would be non-compact and would have 4 time-like directions. Holography analogous to AdS/CFT correspondence, with AdS interpreted as space-time, does not look plausible.

20.2.3 Questions about the dynamics in the space of CDs

CDs define a decomposition of WCW to sub-WCWs. The intuitive picture is that one has a network of CDs acting as analogs of interaction volumes and that "particle lines" connect the CDs to each other. One would approach standard ontology as these networks analogous to Feynman diagrams increase. In standard ontology one can speak not only about events, but something that exists. This would be like a transition from Eastern to Western world view.

Should one try to describe these particle lines by modifying the space of CDs and by introducing interactions between CDs? Does it make sense to assume that overlapping CDs interact in the sense that the space-time surfaces belonging to two different CDs touch? If CDs are interpreted as perceptive fields, this does not look like an attractive idea. The emergence of larger Feynman diagram-like structures would only mean emergence of larger CDs containing sub-CDs. Of course, understanding the interaction between CD and sub-CDs remains a challenge.

For the simplest option based one has the space of CDs, in which CDs are like particles with internal degrees of freedom. How can one construct transition amplitudes in the space of CDs?

- 1. If one can assign representations of the Poincare group to CDs, they would be analogous to particles characterized by momenta and angular momenta having also conformal weight as a quantum number associated with scalings. They would also have internal dynamics, which have been the main target of attention hitherto.
- 2. Transitions are expected to occur between CDs with different positions, sizes and different rest systems (direction of time line defined by the tips). In the recent picture, state function reductions are assumed to correspond to scalings only.

One would expect that the transition amplitude between quantum states for the moduli space propagation between two different CDs has a kinematic part, which one might hope to reduce to symmetry considerations just as for the propagation of particles in Minkowski space.

3. There is also an inner product of zero energy states related to CDs. The basis of the zero energy states characterized by holography are expected to differ by the action of an element $g(CD_1, CD_2)$ of the group SO(4, 2) or of $D \times P$ transforming the CDs to each other.

The transition amplitude should be proportional to the overlap of these states and therefore to the matrix element of $g(CD_1, CD_2)$ between the zero energy states associated with CD_1 and CD_2 .

4. Physical intuition suggests that the transition amplitudes are small for "large" transformations $g(CD_1, CD_2)$ and that in good approximation small translations, Lorentz boosts, and scalings are preferred. In the approximation that translations and Lorentz boosts affecting the center point of CD are trivial, only scalings and hyperbolic evolutions remain under consideration.

20.3 TGD inspired questions and ideas related to the interpretation of the hyperbolic flow

The interpretation of the findings related to hyperbolic time evolution in the TGD framework inspire several questions and ideas.

20.3.1 The flow lines of time-like special conformal transformation as a motion with a constant acceleration

The exponentiated hyperbolic generator S corresponds to a relativistic motion in M^4 with a constant acceleration a, which is essentially the inverse of the size L of CD: a = hbar/L for c = 1, where L is the size of CD identified as distance between its tips. Could this constant acceleration correspond to a representation for an acceleration of the system defined by CD in an external gravitational field, which is constant in the first approximation?

Note that this acceleration is huge when compared with that assignable to macroscopic systems. Gravitational acceleration g at the surface of Earth corresponds to a thermal energy of order 10^{-21} eV. The size of the CD would be in this case of order 10^{15} m.

It has been already noticed that in the TGD framework S can affect only the holographic data at the boundaries of CD. The action of S exponentiates to a unitary hyperbolic time evolution on quantum states at the boundaries of CD. The two-point functions of the conformal QM are thermal with temperature determined by the scale L of CD so that the acceleration a = 1/L can be said to make itself visible via Unruh effect (https://rb.gy/qxyp8q).

20.3.2 Can one assign thermodynamics to CD?

One can assign to the CD a temperature. I have earlier proposed that the expansion of CD by sequences of SSFRs could be interpreted as a stepwise cosmic expansion with temperature decreasing like \hbar/L . This would conform with the finding that the astrophysical objects themselves do not seem to participate in the expansion.

1. In QFT in M^4 , constant acceleration corresponds to the so-called Unruh temperature proportional to $\hbar \times a$. For the ordinary value of \hbar , this temperature is extremely small for the accelerations encountered in macroscopic quantum systems. An accelerated system sees the vacuum of an inertial system as a black body at Unruh temperature.

Note that the blackhole temperature is analogous to Unruh temperature and proportional to $\hbar GM/R^2 \propto \hbar/GM$ (this temperature is extremely small for astrophysical blackhole-like entities).

2. The conformal 2-point functions of a CFT inside a CD with "energy"/Hamiltonian associated with infinitesimal special conformal transition, behave like those for ordinary CFT at finite temperature $T_{CD} = hbar/L$, L the size of CD. T_{CD} is analogous to Unruh temperature but much larger.

For a massive particle with Compton length L, the CD temperature would be of order $T_{CD} = m = hbar/L$. This would be more like ordinary temperature for a system of mass m moving in a volume defined by Compton length. I have proposed that CDs are characterized by this temperature and the expansion of CD in the sequence of SSFRs leads to the reduction of this temperature analogous to that taking place in cosmology.

What could be the interpretation of T_{CD} ?

- 1. For the cell scale the CD temperature T_{CD} would be of order of the energy of visible light. Could T_{CD} relate to bio-photons? Could CD temperatures correspond to those in ordinary thermodynamics and could they be interpreted as a kind of sensory/cognitive representations for the real temperatures in terms of the internal physics of CD?
- 2. In p-Adic thermodynamics [K68] [L198], energy is replaced with mass squared interpreted as proportional to conformal weight as in string models. The p-adic analog of the temperature is inverse of an integer and corresponds to a dimensional p-adic temperature $T_p = \hbar log(p)/L_p$, where L_p is the p-adic length scale proportional to \sqrt{p} . p-Adic length scale corresponds to the length scale defined by the Compton length of the particle. p-Adic length scale hypothesis states that preferred p-adic primes are near to powers of 2, or possibly also other small primes and that these primes correspond to fixed points of discrete p-adic coupling constant evolution. Number theoretic vision of TGD suggests a concrete mechanism implying this [L214].

A possible interpretation is that p-adic massivation and p-adic temperature characterizes the density matrix for the particle entanglement with the environment [L198]. p-Adic temperature is assigned with a scaling which changes the size of the CD and could be perhaps associated with "big" CDs.

 T_{CD} would naturally correspond to the p-adic temperature $T_p = \hbar log(p)/L_p$.

3. $T_{CD} = \hbar/L$ generalizes to $T_{CD} = \hbar_{eff}/L$. For gravitational Planck constant $\hbar_g r/\hbar = GMm/beta_0, \beta_0 < 1$, where M is some large mass, say Earth mass, one has $T \propto (GMm/beta_0)m$. If the size scale of CD is expected to scale lik h_{eff} , one obtains a zoomed version of the system and temperature is not changed. This applies also to the temperature $T_{CD,gr} = \hbar_g r/L$ if L scales like $hbar_{gr}$. Note that for $\hbar_{gr}(Earth)$ assignal to dark particles at gravitational flux tubes, gravitational Compton L is about .45 cm and does not depend on mass m (Equivalence Principle). For electrons and protons $T_{CD,gr}$ would be unrealistically high.

20.3.3 Could the dynamics of CD define a sensory map of the exterior of CD?

The time evolution by a special conformation maps the CD into itself. This is a surprising result. The infinitesimal generator vanishes at the light-like boundaries and the generator is time-like for either half-cone of the cd.

In TGD, CD is identified both as the analog of quantization volume and the perceptive field of self. This raises some questions.

1. The special conformal transformation in time direction consists of an inversion I with respect to the center point of the CD followed by an ordinary time translation followed by the same inversion I.

Ordinary time translation in the exterior is mapped to the special conformal transformation inside the cd. Does this imply some kind of cognitive or sensory map of the exterior world to the interior world? Note that the same can be done also for the other special conformal transformations. Is this something that the monads of Leibniz might be doing?

2. Inversion is also involved with the $M^8 - H$ duality and gives a semiclassical realization of Uncertainty Principle [L127, L128]. The mass shells $H^3 \subset M^4 \subset M^8$ with mass m are mapped by inversion $m \to a = \hbar_{eff}/m$ to cosmic time a = constant hyperboloids of $M^4 \subset H$.

 M^8-H duality, has an interpretation as a generalization of momentum-position duality. This duality is natural since quantum TGD is essentially the generalization of wave mechanics obtained by replacing point-like particles with 4-D surfaces obeying holography. Could one interpret the special conformal transformations in terms of $M^8 - H$ duality. If so, special conformal transformations could be seen as mirror images of translations of in momentum space.

Twistor approach [B11] to scattering amplitudes involves a duality between two Minkowski spaces in which dual conformal groups act. $M^8 - H$ duality suggests a natural identification of these two Minkowski spaces as space-time and momentum space and could correspond to this duality.

3. In zero energy ontology (ZEO) [L118, L177, L169] [K132], the time flow corresponds to the increase of CD (at least in statistical sense) taking place in scalings of CD? For a sequence of time-like special conformal transformations realized as unitary hyperbolic time evolutions the experienced flow of time should therefore cease. Could these sequences serve as correlates for "timeless" meditative states of consciousness?

20.3.4 Could astrophysical SSFRs correspond to special conformal transformations leaving CD size unaffected?

There are also questions related to the TGD inspired cosmology, which can be quantum coherent in arbitrarily long length scales. This would explain the constancy of the temperature of CMB.

In the TGD inspired cosmology [K102, K71], the cosmic expansion does not take place for astrophysical objects (stars and planets at least) as a smooth process but as rapid "jerks" in which flux tubes as thickened cosmic strings suffer phase transitions increasing their thickness and reducing their string tension [K3, L105, L170]. This is also an empirical fact and not understood in general relativity.

On the other hand, the emergence of complex life forms in the Cambrian Explosion is a biological mystery. TGD explains it in terms of this kind of rapid expansion of the radius of Earth by factor 2 bursting highly developed life forms from underground oceans to the surface of Earth [L85, L173, L156, L205].

Should one modify the views of ZEO [L118, L177, L169] [K132]? Could one think that at quantum level the TGD analog of unitary time evolution could correspond to a sequence of "small" state function reductions (SSFRs) followed by hyperbolic time evolutions, which do not scale up the CD? This even in astrophysical scales. In this view, only "big" SFRs (BSFRs) changing the arrow of time and occurring at the level of magnetic body (MB) would correspond to the scalings of CD and a pair of BSFR would bring back the original arrow of time. This would be the case if CD size corresponds to that for a *real* physical system rather than for the perceptive field of a conscious entity as assumed hitherto.

20.3.5 About the quantum realization of hyperbolic time evolution in TGD framework

What one can say in the TGD framework about the quantum realization of the exponentiated S using holography?

- 1. The situation can be understood by noticing that in the lowest approximation the motion is given by $r = r_0 + gt^2/2$ so that a parabola intersecting the light-cone boundary is obtained in a finite time. S is well-defined at the light-like boundaries of CD.
- 2. Holography inside CD does not allow assignment of a flow inside CD to the representation of the exponentiation of S represented as an operator. S is not parallel to the light-like boundaries, in which case the action of the superposition of 3-surfaces would be non-trivial. Therefore only the action in fermionic degrees of freedom can be non-trivial.
- 3. The action of S on the quantum state at the boundary makes sense and is analogous to that of a Hamiltonian in Hilbert space at time= constant hyper-surface. Zero energy state is the sum of over pairs of 3-D states located at passive and active boundaries of CD and by holography the action of exponentiation of S at the passive boundary and determines the action of S at the active boundary. There is no flow inside the CD. Holography defines the state at the opposite boundary.

One obtains a one parameter family of exponentiations of S analogous as unitary time evolution operators $U(\tau)$. The value of the parameter τ in the exponential runs from $-\infty$ to $+\infty$ and corresponds to a finite range for the ordinary time coordinate t. This is indeed analogous to 1-D conformal QM since the angular and radial degrees of freedom are effectively absent. The light-like radial coordinates take the role of complex variable z in conformal field theories.

20.4 Motion of CDs in the moduli space and kinematic qualia

The proposal that CD serves as a correlate for the perceptive field of self implies that the motions of CDs in the moduli space of CDs gives rise to the kinematic qualia assignable to various kinds of motions.

The first thing to notice is that the transformations, which leave the position of CD that is the center point of CD invariant, are in a special role.

- 1. These transformations consist of Lorentz group SO(3, 1), scalings, plus possibly also the subgroup SL(2, R) of special conformal transformations leaving the center point of CD invariant. This group would characterize the internal degrees of freedom analogous to the orientations of a rigid body.
- 2. Besides this there are transformations of SO(2, 4) affecting the center point of the CD. The moduli space $SO(4, 2)/SO(1, 3) \times SO(1, 1)$ could correspond to these transformations in the space of generalized positions of CD.

3. $SO(1,3) \times SO(1,1)$ would leave the center point of the CD invariant and code for various shapes of the CD with one point fixed. This space would consist of various shapes of CD representing the states of motion of the CD. For instance, if a CD moves in a particular direction with some velocity. The CD would have a shape characterized by a corresponding Lorentz transformation. This group includes also scalings leaving center point invariant.

20.4.1 The motion at quantum level

One can consider the situation both at quantum and classical level.

1. At the quantum level the system would be characterized by a wave function in moduli space and small state function reduction (SSFRs) would correspond to steps in the motion.

The analogues of both position and momentum measurements are possible and these could by $M^8 - H$ duality correspond to position measurements in the space of CDs assignable to M^8 and H. This duality could correspond to the duality of twistor Grasmannian amplitude realized in terms of ordinary and momentum twistors [L68].

If a localization takes place in the degrees of freedom considered as commuting degrees of freedom at each step, one obtains a discrete motion in these degrees of freedom.

- 2. The M^4 position of CD would define naturally Cartan algebra and SSFRs involving a position measurement in E^3 would define the discrete motion in M^4 .
- 3. This discrete motion in H would give rise to kinematic qualia such as experience of motion with constant velocity and acceleration. The localization in the space of CDs with respect to scaling would fix the size of CD and therefore geometric time as a correlate of subjective time identified as a distance between the tips of CD. The localization with respect to the time coordinate of CD is impossible and does not allow to identify Minkowski time as an observable.

Scalings increasing the size of CD in a statistical sense would correspond to the growth of geometric time as distance between the tips of CD correlating with the subjective time identifiable as a sequence of SSFRs.

4. D and boost and rotation generators (call them K_z and J_z) of the Lorentz group leaving the center point of the CD invariant can serve as observables for states localized in the moduli space.

What about momentum eigenstates in the moduli space? D does not commute with momentum so that for momentum eigenstates D is not well-defined. K_z and J_z would be analogous to helicity since their identification depends on the position of CD or momentum of momentum eigenstate. The measurement of D implies delocalization with respect to the size of CD. The dual measurement of the size of CD, call it L, means a measurement of geometric time.

For a given size L of CD one can construct momentum eigenstates as analogues of plane waves so that the measurement of L seems to commute with the measurement of momentum. Geometric time as a gradual increase of the size of CD would flow only during the measurements involving measurement of L.

Can the scaling operator D correspond to the "stringy" scaling operator L_0 ?

There is a problem related to the identification of conformal weights as eigenvalues of the scaling operator L_0 as mass squared eigenvalues. In string models, the scaling operator L_0 acting in complex coordinate z of the string world sheet is proportional to the mass squared operator and commutes with it. L_0 commutes with the mass square operator but the scaling operator D does not. What could be the counterpart of L_0 in TGD?

One can consider several candidates for L_0 in TGD. Light-like 3-surfaces appear at the level of both embedding space and space-time surface so that there are two basic types of candidates. These two kinds of scaling generators could relate to the notions of inertial and gravitational masses and therefore to the Equivalence Principle.

Consider first the embedding space level.

1. The light-like radial coordinate r for the light-cone boundary would provide the first guess for L_0 as scaling $L_0 = r\partial_r$. L_0 however scales the size of the light-like boundary and therefore CD so that this interpretation can be challenged.

On the other hand, the basic assumption is that the states at the passive boundary of CD are unaffected under SSFRs so that scaling should not affect the momenta. Note that the center point of CD must be shifted in time direction under the action of CD so that one has a combination of D and P_0 .

2. The most stringy candidate for L_0 would be as the scaling generator $L_0 = zd/dz$ for the conformal transformations of S^2 of light-cone boundary representable as $S^2 \times R_+$. Remarkably, L_0 does not affect the size of the CD.

The generators of globally defined conformal transformations of S^2 are representable as Möbius transformations representing SL(2, C). One can even compensate for the conformal scaling factor associated with these transformations by a suitable radial scaling of rdepending on z so that they act as isometries.

Light-like 3-surfaces appear also at the level of space-time surfaces. Both the light-like 3-surfaces defining boundaries of space-time surfaces [L193], and the boundaries between Euclidean wormhole contacts and Minkowskian space-time regions, identified as deformed CP_2 type extremals, allow by their metric 3-dimensionality extended conformal invariance.

- 1. One assign light-like coordinate r with the light-like 3-surface and the scaling generator $L_0 = r\partial_r$ is highly analogous to L_0 .
- 2. Also now one has the representations $X^2 \times R_+$ and complex coordinate for X^2 defines counterpart of L_0 .
- 3. Could L_0 assignable to X^2 , represent gravitational mass squared? Could holography assign momenta to the light-like 3-surfaces identifiable as gravitational momenta and by Equivalence Principle be identical with inertial momenta assignable to the boundaries of CDs. Gravitational-inertial dictotomy would reflect the space-time embedding space dichotomy.
- 4. Classical TGD is an exact part of quantum TGD and the conserved classical momenta assignable to the space-time surfaces are also natural candidates for gravitational momenta. The inertial momenta would be assignable to the CDs.

20.4.2 The motion at the classical level

At the classical level would have motions in moduli space consisting of small pieces, which are geodesic lines in $D \rtimes P$ or SO(4, 2).

- 1. Causality would mean that only discretized world lines consisting of pieces which are timelike or light-like geodesic lines are considered (recall that the signature of the moduli space is (4, 4).
- 2. A small transformation of the group $D \rtimes P$ or of SO(2, 4), which is representable as an action of a Lie algebra generator, would describe a basic step in the motion. In the quantum case, one must have Cartan algebra and one can argue that all classical motions consist of small translations or scaling rotation, and boost commuting with it.

The measurements of the size and position of CD are dual measurements and the measurement of the size of CD would give rise to the experience flow of time correlating with the flow of the geometric time.

3. For $D \rtimes P$ small translations along geodesics of M^4 would be basic building bricks of translational motion and the direction of small translation would change step by step in curvilinear motion.

For SO(2, 4) also special conformal transformations affecting the center point of the CD could be considered classically. They do not however commute with translations so that at least quantum mechanically they would be excluded. The 4 special conformal transformations could however serve as a dual set of observables instead of translations.

- 4. A Lorentz boost of CD would code for the velocity associated with a given step of translational motion and would be determined by the direction and size of the step. It would be coded by the shape of the CD characterized by the direction of the time-like axis connecting its tips. The shape of the CD would change during the motion.
- 5. Rotational motion around the center point would leave center point and CD itself invariant but affect the zero energy state of CD. More general rotational motion would correspond to steps consisting of translations.

20.5 Questions related to ZEO

ZEO involves several questions which are not completely understood. Do SSFRs correspond to repeated measurements for a set O of commuting observables? Does BSFR occur when a new set of observables not commuting with the set O are measured? What exactly happens in SSFR?

20.5.1 Questions related to SSFRS

SSFRs as a generalization of Zeno effect and weak measurements

Consider once again the question related to the identification of SSFRs. SSFRs are identified as the TGD counterpart for weak measurements, generalizing the notion of repeated measurements giving rise to the Zeno effect.

- 1. The most straightforward generalization of the Zeno effect is that in the kinematic degrees of freedom for CDs the sequence of SSFRs corresponds to a sequence of measurements of commuting observables. BSFR would take place always when the set of measured observables changes to a new one, not commuting with the original set.
- 2. D, K_z and J_z leave the center point of CD, identified as position of CD, invariant. D does not commute with momenta. Should one just accept that momenta and $\{D, K_z, J_z\}$ are two sets of mutually commuting observables and that the change of this set induces BSFR.

The size of CD and therefore the value of the geometric time would change in the sequence of measurements of D, K_z and J_z but not in the sequence of momentum measurements one would have superposition over different sizes of CD and time would be ill-defined as also Uncertainty Principle requires. This would conform with the original view.

What really happens in SSFRs?

I have written a lot of what might happen in SSFRs and BSFRs but I must admit that the situation is still unclear and the proposals depend on what one takes as starting point assumptions, which can be overidealizations.

On the more general level, the sequence of SSFRs would correspond to dispersion in the moduli space of CDs and if SSFRs correspond to the measurement of same commuting observables identified as generators of SO(2, 4) or $D \rtimes P$ or their duals as generalized position in the moduli space, rather simple picture emerges of what can happen.

BSFR would take place when the new set of observables not commuting with the original set emerges. What are the conditions forcing this? If one assumes that sleep is induced by BSFR, it becomes clear that this does not happen at will but when metabolic energy resources are depleted and the system must rest. The dissipation of the time reversed system looks like self-organization and the system heals during sleep. Also homeostasis would rely on BSFRs in various scales making it possible to stay near quantum criticality.

But what exactly happens in SSFR? It seems clear that the states at the passive boundary are not changed. But what happens to the passive boundary?

1. Do the contents of sensory experience assigned with the sequence of SSFRs localize

Option a: to the active boundary of the CD or

Option b: to the 3-ball at which the half-cones of the CD meet.

2. What happens to the passive boundary itself in SSFR? The scaling occurs for the entire CD but there are two basic options.

Option 1: The scaling leaves the *center point* of the CD invariant. Passive boundary is shifted towards past just like active boundary towards future.

If the sensory experience is assigned to the active boundary (Option a)), option 1) is consistent with what happens when we wake up. The time has been flowing during sleep but we have not been aware of this. The arrow time would be determined solely by the change of the state at the active boundary.

If the sensory experience is assigned with the 3-ball (option b)) at the center of CD (Option b)), time does not flow in the sequences of SSFRs.

Option 2: The scaling leaves invariant the tip of CD associated with the passive boundary so that it is not shifted at all but is scaled. This option is consistent with both option a) and b) for the localization of the experience of time flow. However, waking-up from sleep would take at the time when we fell asleep: this does not make sense.

The model for sleep favours option a)+1) for which CDs would define ever expanding subcosmologies changing the arrow of time repeatedly. Any conscious entity would eventually evolve to a cosmology, a kind of God-like conscious entity.

3. One can also consider other empirical inputs. There are stars and even galaxies older than the Universe. Their existence is consistent with option a)+1).

CDs form a scaling hierarchy. CDs in the distant geometric past assignable to stars and galaxies are much smaller than the cosmological CD. The scaling cosmological CD inducing the time flow takes place much faster than the scaling of the much smaller astrophysical CDs. Cosmological time runs much faster and astrophysical CDs remain in the distant geometric past.

4. A third test is based on after images, which appear repeatedly. They correspond to sub-CDs of a CD. Could the after images correspond to life cycles of the *same* sub-CD as I have proposed? This is the case if the sub-CDs are comoving in the scalings of the CD shift. This looks rather natural.

20.5.2 More questions and objections related to ZEO and consciousness

The best way to make progress is to make questions and objections against the existing view, which is often far from clear. In the following I raise some questions of this kind.

What could BSFR mean biologically?

1. In have considered the possibility that BSFR could mean as biologically birth in opposite time direction. This however leads to rather complex speculations.

The most natural assumption is that it means what it says, the emergence of a new CD [L216] as a perceptive field of a conscious entity. This does not require that biological death would be a birth in the opposite time direction although this cannot be excluded. This means one counter argument less.

2. I have considered the idea that in BSFR the size of a CD could decrease dramatically so that the reincarnated CD would be much smaller than before BSFR. This would make possible what one might call childhood. The idea is that the painful memories from the end of the lifecycle could be deleted. This model however requires rather detailed assumptions about how the memories of life cycle are stored at the active boundary of CD. The oldest memories would reside near the tip of CD and newest nearest to the intersection of the half-cones of the CD.

Is this picture consistent with the view about SFR as a localization in the space of CDs? Since the number of CDs larger than given CD is much larger than those with size smaller than it, one can argue that the size of CD increases in statistical sense without limit in SFRs. If one can assume that death involves localization in the space-like degrees in the space of CDs (E^3 position and size of CD), the reduction of CD size looks rather implausible. If the preceding SSFR involved also this kind of localization then the CD after BSFR would in statistical sense be larger than it was before BSFR.

3. Can CDs interact? For instance, can a CD catch the sub-CD defining a mental image of the CD with which it overlaps? This is not the case: it is not possible to catch the spotlight of consciousness.

CD serves as a correlate for the perceptive field of self. Self is also an active causal agent. This aspect must relate to the zero energy states defined as superpositions of space-time surfaces inside a CD.

- 1. CD defines a perceptive field, a kind of spotlight of consciousness, which makes it possible to sensorily perceive the space-time surface, which continues outside CD although one can also imagine a situation in which this is not the case. Saying that mental image co-moves means that the spotlight moves.
- 2. Self has also causal powers. SSFRs change the state at the active boundary of CD. This induces changes inside the future light-cone in turn define perturbations of CDs of the geometric future possibly inducing BSFRs.

Since the superposition of 3-surfaces at the active boundary of CD changes in SSFR, SSFRs have an effect on the geometric future. This is of course the case: our acts of free will affect the world around us but conform with causality.

Almost deterministic holography for space-time surfaces and zero energy states dramatically reduces the freedom of free will due to state function reductions. The delocalization in WCW taking place in the space of CDS during the analogues of unitary time evolutions preceding SSFR improves the situation.

One can also imagine a situation in which nothing changes at the boundaries of CD: self is completely passive: this is of course true at the passive boundary and can be true also at the active boundary in special situations. The classical time evolution for preferred extremals is not fully deterministic. Space-time surface is analogous to a 4-D soap film with frames and the case of 2-D soap films suggests that a finite non-determinism is assignable to the frames. This kind of SSFRs would not affect the space-time surface around CD at all. Pure cognition or meditative states might correspond to this kind of SSFRs.

The notion of ego is central in Eastern philosophies. How could one understand this notion in the ZEO based theory of consciousness?

- 1. Ego means that mental images want to survive. Self survival instinct is an analogous notion although it refers to the biological body. The quantum state at the passive boundary of the CD defines a good candidate for ego since it is indeed preserved during the sequence of SSFRs during which the set of measured observables is preserved.
- 2. BSFRs means death of self or subself as a sub-CD. Also the external physical perturbations arriving at the passive or active boundary can affect the quantum state at it and can induce BSFR. The self assignable to CD is exposed to perturbations, which might induce BSFR. A simple example of this kind of perturbation would be a blow in the head inducing a loss of consciousness.

Ego preservation could mean that self does its best to make the periods of time with an opposite arrow of time as short as possible. This is not in conflict with the fact that the durations of sleep and awake states are roughly the same if a given arrow of time means that the time fraction spent in a state with this arrow of time dominates over that in a state with an opposite arrow of time.

At the magnetic bodies carrying dark matter as phases with large h_{eff} , the interactions perturbing the boundaries of CD are expected to be rather weak. One has something analogous to a quantum computer isolated from the external world. 3. This suggests a more quantitative definition of the period with a fixed arrow of time. One expects that consciousness with a given arrow of time can have gaps. There is indeed empirical evidence suggesting that our flow of consciousness has gaps. Perhaps the wake-up-sleep ratio of the periods with different arrows of time is what matters. For a given arrow of time, the system would be dominantly in wake-up state or in sleep state.

At a given level of self-hierarchy there is some average time for a given arrow of time and it is expected to increase at the higher levels. Magnetic bodies carrying dark matter interact only weakly with lower levels of the hierarchy, in particular ordinary matter, would make possible long periods with a given arrow of time, in the first guess proportional to say h_{eff} .

4. What could biological death as a process at the level of ordinary biomatter mean? Is biological death determined by the situation at the lower hierarchy levels? On the other hand, dark matter at MBs defines a control hierarchy and is gradually thermalized as suggested in [L225] so that the ability to perform biocontrol is reduced. Also the ability to gain metabolic energy is reduced and makes it difficult to preserve the arrow of time. Since the average value of h_{eff} is reduced, the system becomes more vulnerable to perturbations inducing a BSFR changing the arrow of time.

There are also questions related to metabolism.

- 1. A metabolic energy feed is needed to preserve the distribution for the values of h_{eff} . The energies of quantum states increase with h_{eff} and in the absence of a metabolic energy feed, the values of h_{eff} at MBs tend to decrease. The system becomes more vulnerable to perturbations and the BSFRs changing the arrow of time occur more often. The system becomes drowsy.
- 2. Sun serves as a fundamental source of metabolic energy but TGD leads to a proposal that also radiation from the core of Earth, which happens to be at the same wavelength range as solar radiation could have served and maybe still serve as a source of metabolic energy.
- 3. I have proposed remote metabolism as a mechanism in which the system contains a subsystem with an opposite arrow which emits energy, say dissipates, in opposite time direction and thus seems to gain metabolic energy if seen from the standard arrow of time.

This is possible if there is a system able to receive the *effective* negative energy signals. For instance, a population reversed laser could serve as such a system. The second option is that the environment loses thermal energy so that the second law in its standard form would be violated. For instance, heat could be transferred from a system with a given temperature to a system with higher temperature. The dissipation for the time reversed system looks like self-organization. Sleep periods would in this picture mean gain of metabolic resources and healing.

4. Also life with the opposite arrow of time needs metabolic energy. We receive metabolic energy basically from the Sun. Could the Sun serve as a source of metabolic energy also for the time reversed systems? The answer is positive.

To understand why, one must clarify what the change of the arrow of time means. Time reversed signals have positive energy and only the reversed time direction makes them look like negative energy signals. The sum of energies for the sub systems with opposite arrows of time is conserved apart from effects due to finite sizes of CDs (Uncertainty Principle). Also life with an opposite arrow of time can use solar energy as a metabolic energy source.

5. The biological death is assumed to be due to the loss of quantum coherence at the level of MBs inducing a loss of ordinary coherence in short scales implying bodily decay. What could the situation be in the next reincarnation with the same arrow of time? Does the next life with the same arrow of time end at roughly the same time so that the size of the CD would become rather stationary. There would not be much progress.

Or could the MB be able to preserve the quantum coherence for a longer time in the next reincarnation? Since the quantum coherence of MB naturally explains the coherence of the ordinary biomatter, impossible to understand in the standard physics framework, there is no reason why MB could not achieve this feat in the next incarnation.

20.5.3 Is Negentropy Maximization Principle needed as an independent principle?

The proposal has been that Negentropy Maximization Principle (NMP) [K73] [L162, L54] serves as the basic variation principle of the dynamics of conscious experience. NMP says that the information related to the contents of consciousness increases for the whole system even though it can decrease for the subsystem. Mathematically, NMP is very similar to the second law although it states something completely opposite. Second law follows from statistical physics and is not an independent physical law. Is the situation the same with the NMP? Is NMP needed at all as a fundamental principle or does it follow from number theoretic physics?

The number theoretic evolution is such a powerful principle that one must ask whether NMP is needed as a separate principle or whether it is a consequence of number theoretical quantum physics, just like the second law follows from ordinary quantum theory.

Two additional aspects are involved. Evolution can in adelic physics [L67] be seen as an unavoidable increase in the algebraic complexity characterized by the dimension $n = h_{eff}/h_0$ of extension of rationals associated with the polynomial define space-time surface at the fundamental level by socalled $M^8 - H$ duality [L127, L128]. There is also the possibility to identify a quantum correlate for ethics in terms of quantum coherence: a good deed corresponds to a creation of quantum coherence and the evil deed to its destruction.

How do these two aspects relate to the NMP? Is NMP an independent dynamical principle or a consequence of number theoretic (adelic) quantum physics?

Consider in the sequel "big" state function reduction (BSFR) as the counterpart of the ordinary state function reduction. I'm not completely sure whether the following arguments can be also applied to SSFRs for which the arrow of time does not change.

One can consider two alternative formulations for NMP.

Option I

Option I is the simpler and physically more plausible option.

- 1. BSFR divides the quantum entangled system at the active boundary of CD into two parts, which are analogous to the measurement apparatus and the measured system. The selection of this partition is completely free and decided by the system. This choice corresponds to an act of free will. Depending on conditions to be discussed, the action of the measurement to this pair can be trivial in which case the entanglement is not reduced. The measurement can also reduce the entanglement partially or completely and the p-adic entanglement negentropy and entropy decreases or becomes zero.
- 2. If the partition into two parts is completely free and if the choice is such that NMP, or whatever the principle in question is, allows BSFR, the quantum coherence decreases. Number theoretic evolution suggests that the principle telling when BSFR can occur is number theoretic.

There is a cascade of BSFRs since BSFRs are also possible for the emerging untangled subsystem and its complement. The cascade stops when the entanglement becomes stable.

3. What condition could determine whether the reduction of the entanglement takes place? What could make the entanglement stable against BSFR?

Number theoretical vision suggests an answer. Physical intuition suggests that bound states represent a typical example of stable quantum entanglement. Bound states correspond to Galois confined states [L196, L157, L175, L176] for which the momenta of fermions are algebraic integers in an extension of rationals but total momentum has integer valued components. This mechanism for the formation of the bound states would be universal.

A natural number theoretical proposal is that the entanglement is stable if the entanglement probabilities obtained by diagonalizing the density matrix characterizing the entanglement belong to an extension of rationala, which is larger than the extension, call it E, defined by the polynomial P defining the space-time surface. An even stronger condition, inspired by the fact that cognition is based on rational numbers, is that BSFR can take place only if they are rational.

This kind of entanglement would be outside the number system used and one can argue that this forces the stability of the entanglement. A weaker statement is that the reduction is possible to a subspace of the state space for which the entanglement probabilities belong to E (or are rational).

4. This option could replace NMP as a criterion with a purely number theoretical principle. This does not however mean that NMP would not be preserved as a principle analogous to the second law and implied by the number theoretic evolution implied by the hierarchy of extensions of rationals.

Could free will as the ability to do evil or good deeds reduce to number theory that is to the choice of a partition, which leads to either increase or decrease of entanglement negentropy and therefore of quantum coherence?

The basic objection can be formulated as a question. How can the conscious entity know whether a given choice of partition leads to BSFR or not? Memory must be involved. Only by making this kind of choices, a system with a memory can learn the outcome of a given choice. How could the self learn, which deeds are good and which are evil? The answer is suggested by the biologically motivated view of survival instinct and origin of ego [L216] based on SSFRs as a generalization of Zeno effect.

- 1. Conscious entity has a self characterized by the set of observables measured in the sequence of SSFRs. BSFR as a reduction of entanglement occurs when a new set of observables not commuting with the original set are measured. In BSFR self "dies" (loses consciousness). Second BSFR means reincarnation with the original arrow of time.
- 2. The perturbations of the system at both boundaries of CD are expected to induce BSFRs and to occur continually. Therefore the arrow of time is fixed only in the sense that it dominates over the opposite arrow.
- 3. Self preserves its identity (in particular memories defining it) if the second BSFR leads to a set of observables, which does not differ too much from the original one. The notions of survival instinct and ego would reduce to an approximate Zeno effect.
- 4. This mechanism would allow the self to learn the distinction between good and evil and also what is dangerous and what is not. A BSFR inducing only a brief period of life with a reversed arrow of time could teach the system when the BSFR leads to a reduction of entanglement and loss of coherence.

The harmless BSFRs could provide a mechanism of imagination making survival possible. Intelligent systems could do this experimentation at the level of a self representation of a system rather than in real life and the development of complex self representations would distinguish higher life forms from those at a lower evolutionary level.

Option II

Option II is stronger than Option I but looks rather complex. I have considered it already before. NMP would select a partition for which the negentropy gain is maximal in BSFR or at least, the decrease of the negentropy is minimal. One must however define what one means with negentropy gain.

Before considering whether this condition can be precise, it is good to list some objections.

- 1. Is the selection of this kind of optimal partition possible? How can the system know which partition is optimal without trying all alternatives? Doing this would reduce the situation to the first option.
- 2. Free will as ability do also evil deeds seems to be eliminated as a possibility to either increase or decrease entanglement negentropy and therefore quantum coherence by choosing the partition of the system so that it reduces negentropy.

- 3. If the BSFR cascade would lead to a total loss of quantum entanglement, the entanglement negentropy would always be zero and NMP would not say anything interesting. On the other hand, if the selection of the partition is optimal and the number theoretic criterion for the occurrence of the reduction holds true, it could imply that nothing happens for the entanglement. Again the NMP would be trivial.
- 4. What does one mean with the maximal negentropy gain?

What does one mean with a maximal negentropy gain?

Option II for NMP says that for a given partition BSFR occurs if the entanglement negentropy increases maximally. What does one mean with entanglement negentropy gain? This notion is also useful for Option I although it is not involved with the criterion.

- 1. Entanglement negentropy refers to the negentropy related to the *passive* edge of the CD (Zeno effect). Passive boundary involves negentropic entanglement because NMP does not allow a complete elimination of quantum entanglement (bound state entanglement is stable). The new passive boundary of CD emerging in the BSFR corresponds to the previously active boundary of CD.
- 2. For option I for which the concept of good/bad is meaningful, the number theoretical criterion could prevent BSFR and stop the BSFR cascade. There is however no guarantee that the total entanglement negentropy would increase in the entire BSFR cascade. This would make the term "NMP" obsolete unless NMP follows in a statistical sense from number theoretic evolution: this looks however plausible.

The unavoidable increase of the number theoretical complexity would force the increase of p-adic entanglement negentropy and NMP as an analog of the second law would follow from the hierarchy of extensions of rationals.

20.6 Appendix: About the action of SL(2, R) inside causal diamond

SL(2, R) appearing as conformal symmetries of conformal field theories and mapping the upper half plane of the complex plane to itself by Möbius transformations. I have collected the basic facts about how SL(2, R) is realized for causal diamonds. These facts can be found also from [B23].

The Lie algebra of SL(2, R) is spanned by the generator $D_0 r \partial_r + t \partial_t$ of scaling with respect to the center point of CD, by the generator $P_0 = \partial_t$ of time translation in the direction defined by the line connecting the tips of CD, and by the generator $K_0 = 2tr\partial_r + (t^2 + r^2)\partial_t = 2tD_0 + (r^2 - t^2)P_0$ of a special conformal transformation in time direction obtained as IP_0I , where I is the inversion with respect to the center point of CD. Conformal Killing vector is linear combination of form

$$\xi = aK_0 + bD_0 + cT_0 \quad . \tag{20.6.1}$$

For b = 0 the center of point of the CD is at origin (t = 0, r = 0). The generators obey the Lie-algebra

$$[P_0, D_0] = P_0$$
, $[K_0, D_0] = -K_0$, $[P_0, K_0] = m2D_0$. (20.6.2)

The time evolution of conformal QM is defined by a Hamiltonian which in its most general form is given as $G = i(uP_0 + vD_0 + wK_0)$. The conformal Hamiltonians G can be classified by the Casimir invariant

$$C = D_0^2 - \frac{1}{2}(K_0 P_0 + P_0 K_0) \quad . \tag{20.6.3}$$

This corresponds to the invariance of the determinant of the matrix (b, 2c; 2a, b given by $\Delta = b^2 - 4ac$.

1. For $\Delta < 0$ one has generators of elliptic transformations analogous to rotations in the Lorentz group.

$$R = \frac{1}{2} \left(\alpha P_0 + \frac{K_0}{\alpha} \right) \quad . \tag{20.6.4}$$

is a representative of this class. One has $\alpha = L$, where L is the radius of CD defined by the maximal radial distance from the time axis of CD. In the sequel will use the notation α used also in [B23] The distance between the tips of the CD is 2L. The radial conformal Killing vector is everywhere time-like.

- 2. Generators with $\Delta = 0$ generate parabolic transformations, null rotations. Also now the radial conformal Killing vector is time-like everywhere except for the light-cone emanating from t = -b/2a, r = 0
- 3. Generators with $\Delta > 0$ generate hyperbolic transformations analogous to Lorentz group perspective. Dilation D and the generator

$$S_0 = \frac{1}{2} \left(\alpha P_0 - \frac{K_0}{\alpha} \right) \quad . \tag{20.6.5}$$

serves as a representative for this class. In this case the conformal Killing vector is null at the tips of the light-cone $(t = t_{\pm}, r = 0)$, $t_{\pm}0 - b + \sqrt{\Delta}/2a$, time-like inside either light-cone or outside both light-cones, and space-like everywhere else.

One can assign to S_0 resp. R_0 time coordinates T resp. τ in such a way that one has

$$R_0 = \partial_T \quad , \quad S_0 = \partial_\tau \quad . \tag{20.6.6}$$

These time coordinates are related to Minkowski time t by

$$t = \alpha tan(T/2) = \alpha tanh(\tau/2) \quad . \tag{20.6.7}$$

One finds that the range $(-\alpha, \alpha)$ for t corresponds to the range $(-\infty, \infty)$ for τ and to the range $(-\pi, \pi)$ for T.

 S_0 has a representation as a differential operator

$$S_0 = \frac{1}{2\alpha} [(\alpha^2 - t^2 - r^2)\partial_t - 2tr\partial_r] \quad . \tag{20.6.8}$$

 S_0 maps CD identifiable as the region $|t| + vertr| < \alpha$ to itself.

One can identify so-called diamond coordinates via the formulas

$$t = \alpha \frac{\sinh(\tau)}{\cosh(x) + \cosh(\tau)} \quad , \quad r = \frac{\sinh(x)}{\cosh(x) + \cosh(\tau)} \quad . \tag{20.6.9}$$

The ratio of the equations gives $t/r = \sinh(\tau)/\sinh(x)$. For small values of τ and x this gives $(t \simeq \alpha \tau, r \simeq \alpha x)$. From $t = \alpha tanh(\tau/2)$ one can solve $\sinh(\tau)$ and use it to the expression of t/r to get

$$\sinh(x) = 2\frac{t}{\alpha}/(1-(\frac{t}{\alpha})^2)$$
 (20.6.10)

sinh(x) is constant for the flow lines.

In diamond coordinates, the line element of Minkowski metric reads as

$$ds^{2} = \frac{\alpha^{2}}{(\cosh(x) + \cosh(\tau))^{2}} \left(-d\tau^{2} + dx^{2} + \sinh(x)^{2} \Omega^{2} \right) \quad . \tag{20.6.11}$$

and the flow lines correspond to a particle at rest. Diamond coordinates are analogous to the natural coordinates of a freely falling system.

The integral curves of the Killing flows defined by S_0 are obtained as

$$t^2 - (r - \alpha \omega)^2 = \alpha^2 (1 - \omega^2) , \quad \omega = \frac{1}{tanh(x)} .$$
 (20.6.12)

 ω is constant along these curves and varies in the range $[1, \infty)$. This equation should be equivalent with the equation already obtained. The integral curves correspond to a relativistic motion with constant acceleration given by $a(x) = \sinh(x)/\alpha$ which is constant along each integral curve for which x indeed remains constant. For the line passing through origin one has a = 0.

Chapter 21

The based view about dark matter at the level of molecular biology

21.1 Introduction

This chapter has been written together with Reza Rastmanesh as a kind of appendix to an article representing TGD based model for language [L226, L227]. The basic idea of the TGD based vision about living matter is that dark matter having effective Planck constant $h_{eff} = nh_0$ ($h = 6h_0$) located at the flux tubes of magnetic body controls ordinary matter: MB would be the boss and biological body the slave. This hypothesis can be justified by number theoretic vision about TGD, which unifies ordinary physics as physics of sensory experience described by real number based physics and the physics of cognition based on p-adic number fields: real and various p-adic number fields are fused to adele.

21.1.1 Physical motivations for the TGD notion of dark matter

The notion of dark matter as control of biomatter emerged before its number theoretic justification.

- 1. The findings of Blackman *et al* [J7] about the effects of ELF radiation (in EEG frequency range) on vertebrate brain led to the hypothesis that besides protons also ions have dark variants having $h_{eff} = nh_0$ with $h_{eff} = h_{gr}$.
- 2. Also electrons could have these phases but now the value of h_{eff} would be much smaller and satisfy generalized Nottale hypothesis $h_{eff} = h_{em}$, where h_{em} is the electromagnetic analogue of h_{gr} assignable to flux tubes assigned with valence bonds [L62]. This leads to a model of valence bond [L62] predicting that the value of $h_{eff}/h_0 = n = h_{em}$ increases along the rows of the periodic table. This would explain why the molecules such as proteins containing atoms towards the right end of the rows serve as carriers of metabolic energy and why biologically important ions like C⁺⁺ are towards the left end of the rows.

The energy scale of dark variants of valence electrons is proportional to $1/hef f^2$ so that the orbital radii are scaled up and the identification as a Rydberg atom is the only possibility in the standard physics picture: could dark valence electrons be in question? There is empirical evidence known for decades for the mysterious disappearance of valence electrons of some rare earth metals. The article "Lifshitz transition from valence fluctuations in YbAl3" by Chatterjee et al published in Nature Communications [L64] discusses the phenomenon for Yb.

The finding [D6] about misbehaving Ruthenium atoms supports the view that covalent bonds involve dark valence electrons. Pairs of Ru atoms were expected to transform to Ru dimers in thermo-dynamical equilibrium but this did not happen. This suggests that valence electrons associated with the valence bond of Ru dimers are dark in TGD sense and the valence bonded Ru dimer has a higher energy than a pair of free Ru atoms. TGD based explanation [K40] could be justified by a resonant coupling of the dark electron with an ordinary Rydberg state of the valence electron. In the lowest approximation dark valence electron has energies in the spectrum of ordinary valence electrons so that a resonant coupling with Rydberg states can be considered. The evidence found by Randell Mill [D7] for atoms with an abnormally large scale of binding energy suggests the formula $h = 6h_0$. Color vision is a possible application [L83]. Adelic physics [L66] predicts h_{eff} hierarchy and allows to understand the findings.

3. Nottale hypothesis [E1] introduces the notion of gravitational Planck constant $\hbar_{gr} = GMm/v_0$ and is in the TGD framework identified as a particular value of h_{eff} assignable to gravitational flux tubes [K101, ?, K85, K18] [L78]. One trivial implication reflecting Equivalence Principle is that the cyclotron energy spectrum $E_c = n\hbar_{gr}eB/m = nGMeB/v_0$ does not depend on the mass *m* of the charged particle and is thus universal. The energies involved are proposed to be in the range of biophoton energies (at least) suitable for control of the transitions of bio-molecule.

The difference between non-organic and in-organic matter would be the presence of dark protons and electrons. The notions of acids and bases would reduce to the presence of dark protons: pH would characterize the fraction of dark protons. The notion of reduction and oxidation (REDOX reaction) would reduce to dark electrons associated with valence bonds [L62].

In biochemistry the density of dark protons would be much stronger and Pollack effect it in which the irradiation of water in presence of gel phases generates exclusion zones (EZs) as negatively charged regions by transferring every 4^{th} proton to dark proton at flux tubes forming dark proton sequences as dark nuclei. Also dark ions become important in biochemistry, at least positively charged ions would have an important control role in TGD based view about biochemistry.

21.1.2 Realization of the vision about MB as controller of ordinary biomatter

 $M^8 - H$ duality [L112, L110] concretizes the general vision. This duality states the representability of space- times as a 4-D surfaces in either complexified M^8 or $H = M^4 \times CP_2$. $n = h_{eff}/h_0$ has interpretation as dimetinsion of extension of rationals and would the degree of a polynomial determining the space-time surface in M^8 as a root of polynomial of degree n. Roots would correspond to different sheets of n-sheeted space-time surface and Galois group of extension would permute the sheets with each other and act as a number theoretic symmetry group. Dark matter states at the flux tubes of B_{end} would be in representations of Galois group and Galois confinement [L137] forcing n-particle states to behave as single unis like hadrons as color confined states.

The model of bio-harmony [L23, L24, L124] based on the icosahedral and tetrahedral geometries in turn predicts that genetic codons correspond to dark photon triplets as 3-chords of lights. The representation of 12-note scale as a sequence of quints reduced by octave equivalence fixes the harmony for a given Hamiltonian cycle and realizes the symmetries of the harmony defined by some subgroup of the icosahedral group.

Combination of 3 icosahedral harmonies with 20 chords and having different symmetries with tetrahedral harmony with 4 chords gives bioharmony 20+20+20+4=64 chords assigned to DNA codons. Amino-acids are identified as orbits of 3-chords under the symmetries of a given harmony, and one obtains 20 amino acids. DNA codons coding for a given amino acid correspond to the chords at the corresponding orbit and the numbers of DNA codons coding for a given amino acid come out correctly.

Bio-harmony assigns the binary aspects of information to the 6 bits of codon and emotional aspects to the bio-harmony characterized by allowed chords fixed by a given Hamiltonian cycle at icosahedron and the unique tetrahedral cycle. The model of bio-harmony requires that the values of B_{end} correspond to those associated with Pythagorean scale and defined by quint cycle. These frequencies would correspond to energies that a molecule must have to serve as a candidate for a basic biomolecule.

In the model of genetic code [L36, L77] identifying codons as dark proton triplets, the numbers of dark proton triplets correspond to numbers of DNA, RNA, tRNA codons and amino acids and one obtains correctly the numbers of DNA and RNA codons assignable to given amino-acid in the vertebrate genetic code. Genes would correspond to sequences of dark proton triplets. Dark proton triplet would be analogous to baryon and Galois confinement [L137] would force it to

behave like a single quantum unit. Dark codons would in turn bind to Galois confined states of the Galois group of extension of the extension associated with the codons.

Galois confinement would be realized also for the dark photon triplets as representation of genetic codons and also for the sequences of N dark-photon representing genes as dark 3Nphoton states. Genes would serve as addresses in the communications based on dark 3N-photon resonances. For communications between levels with the same value of h_{eff} there would be both energy and frequency resonance and for levels with different values of h_{eff} only energy resonance. It is an open question whether for dark-ordinary communications dark photon 3N-plets transforms to single ordinary biophoton.

The basic hypothesis is that both DNA, RNA, tRNA, and amino acids are paired with their dark analogs, and that energy resonance mediates the interaction between the members of pairs. In this article the goal is to clarify the dark-ordinary pairing and the interaction between the members of the pairs. To achieve this, we first propose some questions below and then synthetize the answers to them.

21.1.3 Questions

In the sequel we will address the following questions about the roles of MB in the biochemistry of the basic biomolecules.

1. Do dark protons appear already in non-organic chemistry? Does acid/base tend to give/bind with a dark proton? The basic process is $OH \rightarrow O^- + H_+$. Water represents the basic example containing ions H_3O^+ and OH^- : the dark proton from H_2O would bind to the second H_2O acting in the role of base. pH characterizes the fraction of protons equal to 10^{-7} for pH = 7.

Does the transition to biochemistry mean Pollack effect [I162, L20] in which the fraction of dark protons becomes 1/4 corresponding to $pH = log_{10}(4)$. This would be the case for DNA, RNA, amino-acids, and tRNA also? Are the transitions between dark and ordinary states a key element of biochemistry. Could the gravitational flux tubes of MB take an active role in biochemistry?

- 2. Could the proton in hydrogen bond be dark? Could length of the hydrogen bond vary corresponding to different values of $h_{eff} = h_{gr}$. Could this explain the behavior of water below 100 C, in particular at physiological temperatures, challenging the standard thermo-dynamical model.
- 3. Do dark electrons play a role in chemistry as suggested in [L62]? Does oxidation/reduction mean almost giving/receiving a dark valence electron in the valence bond? REDOX reactions are central also in biochemistry. The basic example is combustion in which O==O in presence of hydrocarbon such as sugar C_nH_{2n} gives rise to CO_2 and H_2O and $C_{n-1}H_{2n-2}$. O is reduced so that it almost receives valence electrons from C and H and C and H are in turn oxidized. The notion of electronegativity parametrizes the tendency to receive an electron. Is it possible to state that in inorganic and organic chemistry the electromagnetic part of MB is by far more important than the gravitational part of MB whereas in biochemistry also the gravitational part becomes important.

Also ions are proposed to appear as dark variants and one can wonder whether the valence electrons of positively charged biologically important dark ions like Ca^{++} are actually dark.

The following question can be asked about the role of MB in biochemistry of basic biomolecules.

- 1. Does the energy resonance for dark proton triplets and even for their sequences between biomolecules and their dark variants select the basic biomolecules like DNA, RNA, tRNA, and amino-acids having dark proton counterparts? Base pairs in DNA double strand involve also hydrogen bonds. Could these hydrogen bonds have also dark variants?
- 2. Dark proton triplets would neutralize the negative charges assignable to the phosphates of DNA and RNA nucleotides and could be imaged as coming from $POH \rightarrow PO^- + H^+$ by

a transformation of proton to dark proton by the analog of Pollack effect making DNA negatively charged.

What about the cell membrane, whose lipids have also phosphate ions at their ends? Could this give a higher level representation of the genetic code and genes at cell membrane level making possible dark 3N-photon communications between genome and cell membrae? Or do the dark protons serve at least as an energy storage? In fact, it has been proposed that cell membranes could involve a genetic code [I157].

Microtubules are accompanied by negatively charged GTP molecules possibly associated with tubulins. 6-bit code defined also by DNA codons has been proposed by Hameroff *et al* as a memory code [J25]. Could it be associated with genetic code represented using dark proton triplets?

- 3. The amino-acids in proteins should pair with dark variants of amino-acids by energy resonance. Amino-acid backbone does not however carry negative charge. Are the dark protons coming from NH₂ and COOH neutralized by electrons so that one would have dark hydrogens?
- 4. Also the ATP molecule has a negative charge of 3 units. Is it neutralized by a dark proton triplet serving as a temporary storage of metabolic energy? Could this energy at least partially explain the somewhat questionable notion of the high energy phosphate bond (also dark valence electrons would contribute)? Could ATP \rightarrow ADP liberate metabolic energy by splitting one dark valence bond and transforming one dark proton to ordinary one? Do the dark protons assigned with the proteins serve as metabolic energy storage besides valence electrons, whose reduced Coulombic binding energies also give rise to higher than expected bond energies?

The next sections will be devoted to the possible answers to these questions.

Note: This chapter was prepared in collaboration with Dr Reza Rastmanesh who provided a lot of biological knowhow and made inspiring questions.

21.2 Some number theoretical aspects of quantum biology

In this section the number theoretical aspects of TGD inspired quantum biology relevant to the recent article are considered. The role of the number number theory in TGD inspired view about cognition relying on adelic physics [L66] is not discussed here.

Fig. 24.1 summarises the role of number theory in the TGD inspired vision concerning consciousness, cognition, and quantum biology and Fig. 24.2 the role of dark matter in TGD inspired quantum biology.

21.2.1 Dark proton representation of genetic code

Fig. 24.3 summarizes the TGD based vision about genetic codes.

Codons as dark nucleons?

The model for codons of genetic code emerged from the attempts to understand water memory [?] The outcome was a totally unexpected finding [?] the states of dark nucleons formed from three quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAs, 20 amino acids, and tRNA and there is natural mapping of DNA and RNA type states to amino acid type states such that the numbers of DNAs/RNAs mapped to given amino acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks - just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional



Figure 21.1: Adelic physics as physics of sensory experience, cognition and intentionality

assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η .

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as a string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would not be separable to letters but entangled states of 3 quarks anymore.

Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allows immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4\oplus 2\oplus 2)\otimes(5\oplus 3)$ to the states of 4×5 with the same or opposite spin projection. This would give the degeneracies D(k) as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies D = 1, 2, 3, 4, 6 are predicted. The numbers N(k) of amino acids coded by D codons would be

$$[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3]$$
.

The correct numbers for vertebrate nuclear code are (N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3). Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in the second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result (2, 9, 1, 5, 3)!



Figure 21.2: Dark matter in TGD inspired quantum biology

Codons as dark proton triplets?

The model of codon as dark nucleon predicts analogs Δ resonances whose masses differ from those of nucleons.

The hint comes from the fact that DNA nucleotides have a negative charge, which is problematic from the point of view of DNA stability. This suggests that dark codons should have a charge of 3 units screening the charge of the ordinary DNA codon. Pollack effect [?]eans formation of negatively charged exclusion zones as protons are transferred to dark protons at magnetic flux tubes. Could DNA be formed by Pollack effect? Could codons be represented as dark proton triplets?

The problem is that protons however have only 2 spin states: 4 states would be needed as in the case of quarks having also color. Where could the counterparts of spin and color come from?

One could consider adding a neural pion-like and/or ρ_0 meson-like bond connecting neighboring protons. Since ρ_0 has spin 1, this would give 1+3=4 states per bond. However, 2 states are enough and one must get rid of 2 states. The string-like structure of the proton triplet suggests that the rotation group reduces to $SO(2) \subset SO(3)$ so that ρ meson states split into singlets with helicities 0,1,-1. The doublet (-1,1) would serve as the analog of the isospin doublet (u,d) for baryons and enough to achieve a correct effective number N = 4 of states per single DNA codon. Helicity would replace isospin and the tensor product states could be constructed effectively as tensor products of 3 representations $2 \otimes 2$.

There is also an issue related to the fermionic statistics. Protons are fermions and the total wave function for them must be antisymmetric. For baryons color singlet property allows this. Can one require statistics in the ordinary sense also now? Or could the effective 1-dimensionality



Figure 21.3: Genetic codes in TGD framework

of the magnetic flux tube allow braid statistics?

The following variant gives good hopes about the ordinary statistics.

- 1. Adelic physics [?]rings in additional discrete degrees of freedom assignable to the group algebra of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele [?]
- 2. Galois group acts on the space of space-time surfaces, and one can say that one has wave function at the orbit of the Galois group consisting of space-time sheets. At quantum level quantum states correspond to wave functions in the group algebra of Galois group of extension.
- 3. The role of color degrees of freedom in helping to achieve correct statistics in the case of baryon could be taken by Galois degrees of freedom. One can even consider the notion of Galois confinement as a generalization of color confinement [?]inding codons as dark proton triplets to dynamical units. Codons should be antisymmetric under exchange of dark protons in Galois degrees of freedom. Also genes as sequences of codons could be bound to dynamical units as Galois singlets. Could this allow ordinary statistics.

One can consider the replacement of u and d quarks with proton and neutron: color degrees of freedom would be missing but also now Galois confinement could come in rescue. Now however the charge screening of DNA by dark DNA would not be complete.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics or even at the level of ordinary nuclear physics if the nuclei of ordinary nuclear physics are nuclear strings. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be a kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of the DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

Cell membrane and microtubules as a higher level representation of genetic code?

Also the representation of genetic code at the level of cell membrane can be considered [L97]. This kind of proposal have been made with different motivations by Okecukwu Nwamba [I157]. The motivation for the current proposal is that the lipids have at their ends negatively charged phosphates just as DNA nucleotides have. The generalization of DNA as a 1-D lattice like structure to a 2-D cylindrical lattice containing nucleotide like units - letters - possibly assignable to lipids and realized as dark protons. Single lipid could be in the role of ribose+nucleotide unit and accompanied by a neutralizing and stabilizing dark proton. For axons one would have cylindrical lattice dark DNA lattice. The two lipid layers could correspond to two DNA strands: the analogs of the passive and active strand.

The finding is that membrane affects protein's behavior. This would be understandable in the proposed pictures 2-D analog of 1-D nucleotides sequences with codons replaced with counterparts of genes as basic units. That lipids are accompanied by phosphates with charge -1 gives the hint. Phosphate charge is neutralized by a dark proton as an analog of a nucleotide.

The notion of Galois confinement identifying genes as units consisting of N dark proton triplets representing genetic codons suggests that genes possibly assignable to the lipid layers of the cell membrane could communicate using dark 3N-photon sequences with the proteins, genome, RNA and DNA. Dark variants of the control genes could initiate a nerve pulse pattern. An interesting possibility is that ganglions, nucleus like structures assignable to sensory organs and appearing as basal ganglia in brain [I99] could communicate with genes.

Also microtubules have GTPs with charge -3 bound to tubulins. In dynamical instability known as treadmilling the transformation of GTP \rightarrow GDP bound to β tubulin by hydrolysis induces the shortening of the microtubule at minus end whereas the addition of tubulins bound to GTP induces the growth at plus end. Also actin molecules bound to ATP show a similar behavior. Could they be accompanied by dark DNA codons? Are all codons allowed or does the absence of XTP, X= T,C,G mean that only codons of type GGG would be present?

For the dark codons for the cell membrane the p-adic length scale $L(151) \simeq 10^{-8}$ m would correspond to the lipid's transversal size scale and would be the distance between the dark protons. The scale of dark nuclear energy would be proportional to 1/L(151) and scaled down by factor ~ 10^{-3} from that for DNA. The energy scale should be above the thermal energy at room temperature about .025 eV. If the energy scale is 2.5 eV (energy of visible photon) for DNA, the condition is satisfied. Note that 2.5 eV is in the bio-photon energy range. For p-adic large scales longer than L(151) thermal instability becomes a problem.

It is interesting to compare the number of codons per unit length for ordinary genetic code (and its dark variant) and for various membranes and microtubules.

For the ordinary genetic code there are 10 codons per 10 nm defining p-adic length scale L(151). This gives a codon density $dn/dl = 10^3/\mu m$ in absence of coiling. The total number of codons in human DNA with a total length $L \sim 1$ meter is of order $N \sim 10^9$ codons. The packing fraction of DNA due to coiling is therefore huge: of order 10^6 .

If each lipid phosphate is accompanied by a dark proton and if lipid correspond to square at axonal cylinder with side of length d = L(151) and the radius R of axon corresponds to the p-adic length scale $L(167) = 2.5\mu$ m (also of the same order as nucleus size), there are about $dn/dl = 2\pi (R/d)^2 \sim (2\pi/3) \times 10^4 \sim 1.3 \times 10^5/\mu m$. Axon should have length $L \sim 1$ cm to contain the entire genome.

The same rough estimate applies to microtubules except that there would be one codon per GTP so that the estimate would be 3 times higher if GTP corresponds to length scale L(151) of tubulin molecule. It has been proposed that genetic code is realized at the microtubular level.

The nuclear membrane assumed to have a radius about $L(167) = 2.5\mu$ m could represent $N \sim (4/3)R^2/d^2 \sim .8 \times 10^5$ codons. This is a fraction 10^{-5} about the total number of codons. For a neuronal membrane with radius $R \sim 10^{-4}$ meters assignable to a large neuron the fraction would be roughly 10^{-1} . The fraction of dark codons associated with membranes could correspond to genes involved with the control and communication with genome and other cell membranes. Note that the non-coding intronic portion dominates in the genome of higher vertebrates. One can ask whether the chromosome structure is somehow visible in the membrane genome and microtubular genome.

21.2.2 Bio-harmony as a realization of genetic code

TGD leads to a notion of bio-harmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron [L23, L24, L124]. The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino acid are predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bio-harmony in question corresponds to DNA codons coding for the amino acid assigned with the orbit.

Codon corresponds to 6 bits: this is information in the usual computational sense. Bioharmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bio-harmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it. For emotional expression at RNA level possibly involved with conditioning at synaptic level see [L81].

Does the generation of nerve pulse patterns by a gene mean at the cell membrane from dark DNA to dark protein map to dark protein (it could be also dark RNA or dark DNA even) associated with the cell membrane. What about communications with RNA and enzymes involved with transcription and translation. Do all basic biocatalytic processes involve them.

What about a generalization of Josephson currents? Dark ions certainly define them but could also dark proton triplets and their sequences associated with proteins give rise to oscillating Josephson currents through cell membrane and therefore to dark Josephson radiation with 3N dark photon units! Proteins themselves need not move much!

The universal language could be restricted to the genetic code which would be realized by dark proton triplets. The 64 codons are formed from 3 20-chord harmonies associated with icosahedron and the unique 4-chord harmony associated with tetrahedron. Bio-harmonies are associated with the so-called Hamiltonian cycles ,which go through every vertex of Platonic solid once. For icosahedron the number of vertices is 12, the number of notes in 12-note scale.

Also tetrahedron, cube, octahedron and dodecahedron are possible and one can consider the possibility that they also define harmonies in terms of Hamiltonian cycles. Dodecahedron would have 5-chords (pentagons as faces) as basic chords and there is only single harmony. Same mood always, very eastern and enlightened as also the fact that scale would have 20 notes.

Also octahedron gives 3-chords (triangular faces) whereas cube gives 4-chords (squares as faces). One can of course speculate with the idea that DNA could also represent this kind of harmonies: sometimes the 3N rule is indeed broken, for instance for introns.

Galois confinement [L139] allows the possibility to interpret dark genes as sequences of N dark proton triplets as higher level structures behaving like a single quantal unit. This would be true also for the corresponding dark photon sequences consisting of 3N dark photons representing the gene in bio-harmony as an analog of a music piece consisting of 3-chords and played by transcribing it to mRNA.

The picture can be viewed even more generally. Any discrete structure, defining graph, in particular cognitive representation providing a unique finite discretization of space-time surface as points with the coordinates of the 8-D embedding space coordinates in the extension of rationals, defines harmonies in terms of Hamiltonian cycles. Could also these harmonies make sense? The restrictions of the cognitive representations to 2-D partonic 2-surfaces would define something analogous to bio-harmony as Hamiltonian cycle of 2-D graph (Platonic surfaces solids can be regarded as 2-D graphs). The interpretation as representations of Galois groups and the notion of Galois confinement is possible although one loses the symmetries of the Platonic solids allowing to identify genetic code.

Brief details of the genetic code based on bio-harmony

TGD suggests several realizations of music harmonies in terms of Hamiltonian cycles representing the notes of music scale, most naturally 12-note scale represented as verticehttps of the graph used. The most plausible realization of the harmony is as icosahedral harmony [L23, L24].

- 1. Icosahedron (for basic facs see the Wikipedia article) has 12 vertices and Hamiltonian cycle as a representation of 12-note scale would go through all vertices such that two nearest vertices along the cycle would differ by quint (frequency scaling by factor 3/2 modulo octave equivalence). Icosahedron allows a large number of inequivalent Hamiltonian cycles and thus harmonies characterized by the subgroup of the icosahedral group leaving the cycle invariant. This group can be Z_6 , Z_4 , or Z_2 which acts either as a reflection group or corresponds to a rotation by π .
- 2. The fusion of 3 icosahedral harmonies with symmetry groups Z_6 , Z_4 and Z_2 gives 20+20+20=603-chords and 3+1+5+10=19 orbits of these under symmetry group and almost vertebrate genetic code when 3-chords are identified as analogs of DNA codons and their orbits as amino acids. One obtains counterparts of 60 DNA codons and 3+1+5+10=19 amino acids so that 4 DNA codons and 1 amino acid are missing.
- 3. The problem disappears if one adds tetrahedral harmony with 4 codons as faces of tetrahedron and 1 amino acid as the orbit of the face of tetrahedron. One obtains 64 analogs of DNA codons and 20 analogs of amino acids: this harmony was coined as bio-harmony in [L23, L24]. The predicted number of DNA codons coding for given amino acid is the number of triangles at the orbit of a given triangle and the numbers are those for genetic code.
- 4. How to realize the fusion of harmonies? Perhaps the simplest realization found hitherto is based on the union of a tetrahedron of 3 icosahedrons obtained by gluing tetrahedron to icosahedron along its face which is a triangle. The precise geometric interpretation of this realization has been however missing and some possibilities have been considered. The model could explain the two additional amino acids Pyl and Sec appearing in Nature [L23, L24] as being related to different variant for the chemical counterparts of the bio-harmony.

There is also a slight breaking of symmetries: ile 4-plet breaks into ile triplet and met singlet and trp double breaks into stop and trp also leu 4-plet can break in leu triplet and ser singlet. This symmetry breaking should be understood.

21.2.3 Galois group of space-time surface as new discrete degrees of freedom

Galois confinemenent

The problem is to understand how dark photon triplets occur as asymptotic states - one would expect many-photon states with a single photon as a basic unit. The explanation would be completely analogous to that for the appearance of 3-quark states as asymptotic states in hadron physics - the analog of color confinement [L142]. Dark photons would form Z_3 triplets under the Z_3 subgroup of the Galois group associated with corresponding space-time surface, and only Z_3 singlets realized as 3-photon states would be possible.

The invariance under Gal(F) would correspond to a special case of Galois confinement, a notion introduced in [L137] with physical motivations coming partially from the TGD based model of genetic code based on dark photon triplets.

Cognitive measurement cascades

Quantum states form Galois group algebra - wave functions in Galois group of extension E. E has in general decomposition of extension E_1 as extension of E_2 as extension of ... to a series . Galois group of E has decomposition to product of $Gal(E) = Gal(E/E_1)Gal(E_1)$ and same decomposition holds true for $Gal(E_1)$ so that one has hierarchy of normal subgroups corresponding extension of extension of...hierarchy defined by a composite polynomial $P(x) == P_1(P_2(x))$ with P_2 having similar representation. P defines in M^8 picture the space-time surface. This maps a tensor product composition for group algebra and the factors of group algebra entangle. SSFR corresponds to a cognitive quantum measurement cascade: SSFR in $Gal(E/E_1)$, SSFR in $Gal(E_1/E_2)$ etc.. The number theoretic measurement cascades for purely number theoretic Galois degrees of freedom are discussed in [L145].

Could this cascade be analogous to the parsing of a linguistic or mathematical expression as cognitive measurements proceeding from higher to lower abstraction levels? Could the cascade correspond to a sentence S_1 about a sentence S_2 about ... such that one substitutes a concrete sentence for S_1 first, then to S_2 , etc...? This is indeed suggested by the cascade of SSFRs since $h_{eff}/h_0 = n$ is the dimension of E_n .

Could cascade of flux tubes decaying to smaller flux tubes with smaller value of h_{eff} should correspond to this hierarchy. Certainly this is linguistics but the sentence as argument could correspond to several sub-sentences - different flux tubes. Could a neural pathway defined by the branching axon correspond to a concretization of this kind statement about statement (or multistatement, perhaps nerve pulse pattern generated by nerve pulse patterns arriving to a given neuron) about...

21.2.4 Energy and frequency resonance as basic elements of dark photon communications

Dark photon realization of genetic code leads to a view about fundamental linguistic communication based on resonance and we will write a separate paper connecting TGD with language soon. Two systems can be in communication when there is resonance. $E = h_{eff} f$ and energy conservation implies

$$h_{eff,1}f_1 = h_{eff,2}f_2 \quad . \tag{21.2.1}$$

For $h_{eff,1} = h_{eff,2}$, energy conservation implies that both energies and frequencies are identical: $E_1 = E_2$ and $f_2 = f_2$. Both energy and frequency resonances in question.

In the general case one has $f_1/f_2 = h_{eff,2}/h_{eff,1}$ and frequency scaling takes place. The studies of water memory lead to the observation that this kind of phenomenon indeed occurs [I52]. The communications of dark matter with ordinary matter and those between different values of h_{eff} involve only energy resonance. Frequency and wavelength scaling makes it possible for long scales to control short scales. Dark photons with EEG frequencies associated with the big part of MB transform to bio photons with a wavelength of say cell size scale and control dynamics in these short scales: for instance, induce molecular transitions. This is impossible in standard physics.

The resonance condition becomes even stronger if it is required there is a large number of biomolecules in resonance with dark matter realized as dark variants of biomolecules and dark ions. Cyclotron resonance energies are proportional to \hbar_{eff} characterizing magnetic flux tubes and to the valued of the magnetic field strength dictated by the quantization of the monopole flux quantization by the thickness of the flux tube which can be do some degree varied by varying the thickness of the flux tube giving rise to frequency modulation.

The findings of Blackman *et al* [J7] suggest that $B_{end} = 0.2$ Gauss defines an important value in the spectrum of B_{end} values. It could correspond to the field strength for the predicted monopole flux part of the Earth's magnetic field $B_E \simeq .5$ Gauss not allowed by Maxwell's theory. Besides B_{end} there would also be a non-monopole flux part allowed also in Maxwell's theory. Monopole flux part requires no currents as sources: this allows the understanding of the presence of magnetic fields in cosmological scales and also why B_E has not dissipated away long time ago [L30].

There are however indications that the value B_{end} is quantized and is proportional to the inverse of a biologically important p-adic length scale and thus would be quantized in octaves. This could relate directly to the octave equivalence phenomenon in music experience. The model of bio-harmony [L23, L24, L124] suggests a further quantization of the octave to Pythagorean 12-note scale of music. This would not be only essential for the music experience but communications of emotions and molecular level using the music of light.

Selection of basic biomolecules by energy resonance

The dark particles must have energy resonance with bio-molecules in order to induce their transitions. This seems to pose extremely strong conditions possibly selecting the bio-molecules able to form interacting networks with dark matter and with each other. One expects that only some amino acids and DNA type molecules survive.

Nottale's hypothesis provides a partial solution to these conditions. Nottale proposed the notion of gravitational Planck constant

$$\hbar_{gr} = \frac{GMm}{v_0} \tag{21.2.2}$$

assignable in TGD to gravitational flux tubes connecting large mass M and small mass m and v_0 is velocity parameter. The gravitational flux tube presumably carries no monopole flux. The TGD based additional hypothesis that one has equals to

$$\hbar_{gr} = h_{eff} = nh_0 \quad . \tag{21.2.3}$$

This implies that the cyclotron energy spectrum

$$E_c = n\hbar_{gr}\frac{eB}{m} = n\frac{GM}{v_0}eB \tag{21.2.4}$$

of the charged particle does not depend at all on its m. Therefore in a given magnetic field, say B_{end} , the cyclotron resonance spectrum is independent of the particle.

The energy resonance condition reduces to the condition that the charged ion or molecule has some cyclotron energy coming as a multiple of fundamental in its spectrum in the spectrum of its transition energies. Even this condition is very strong since the energy scale for cyclotron energy in B_{end} is in the bio-photon energy range containing energies in visible and UV. The fact that bio-photons have a quasi-continuous spectrum strongly suggests that B_{end} has a spectrum. The model of bio-harmony [L16, L103] suggests that the values of B_{end} correspond to Pythagorean scale constructible by quint cycle familiar for jazz musicians that is by taking $(3/2)^k$ scalings of the fundamental frequency and by projecting to the basic octave by octave equivalence.

The above simplified picture is formulated for single dark photon communications. The dark proton and dark photon realizations of the genetic code requires 3-resonance that is a simultaneous energy resonance for the 3 members of dark photon triplet. In dark-dark pairing also frequency resonance is possible. In dark-ordinary pairing frequency increases and couples long scales with short scales. Also resonant communications between genes with N codons involving 3N dark photon frequencies must be possible. This requires new physics provided by number theoretical vision.

What happens in the cyclotron resonance?

3 cyclotron energies for flux tubes characterize dark 3-proton triplet and Nottale's hypothesis predicts that they depend on the values of B_{end} for the flux tubes only. Bio-harmony suggests that the spectrum of frequencies and thus B_{end} corresponds to Pythagorean 12-note scale for a given octave. The allowed chords of bioharmy would characterize the emotional state at the molecular level and correspond to the holistic emotional aspects of the communication beside the binary information.

The resonance would require that the dark cyclotron energy changes are equal to corresponding energies in molecular transitions. Galois confinement [L137] makes possible also 3-N resonance. The resonance condition would select basic biomolecules and the ability of dark analogs of biomolecules to simultaneously resonate with several biomolecules would give additional conditions. In particular this would select DNAs and amino acids.

An open question is whether the coupling to ordinary biomolecules involves a transformation of a dark photon triplet or an N-plet to a single ordinary photon. For instance, does the sum of the 3 cyclotron excitation energies appear in the coupling of dark 3-proton state to amino acid in protein? This would have an analog as 4-wave coupling [D1] in laser physics allowing in biology the transformation of dark photon triplet to single biophoton/or 3 bio-photons or *vice versa*. 6-wave coupling of laser physics would be analogous to the coupling of ordinary 3-photon state to dark 3-photon and back to ordinary 3-photon state.

The resonance itself would mean a process in which dark 3-proton cyclotron excitation returns to the ground state and generates dark 3-photon transforming transforming to ordinary photon (or 3-photon) and absorbed by the ordinary codon or amino acid excitation to hither energy state. This state would in turn emit an ordinary photon transforming to dark 3-photon absorbed by dark codon. This mechanism generalizes to 3N-proton states representing genes or dark proteins.

21.3 Some applications

21.3.1 How to understand the pairing between basic biomolecules and their dark variants?

There are interesting questions concerning the analogs of transcription and translation. Could dark DNA send signals also to dark RNA and amino acids and dark RNA to dark amino acids and dark tRNA? Could 3-photon resonance make it possible for biomolecules to find each other in the molecular crowd as proposed. This would be possible when the moods (bio-harmonies are the same - only an unhappy person can really understand an unhappy person!). For genes the 3-flux tube would be replaced with 3N-flux tube made possible by Galois confinement [L137].

Where do the dark proton sequences associated with proteins come from?

In the formation of protein 3 dark protons drop to a larger space-time sheet. The charges of amino acid residues vary in sign, vanish, or they are neutral, polar, or non-polar. Therefore the dark proton triplets must somehow be associated with the protein backbone as they do in the case of DNA and RNA. This implies that it is ionization of acidic groups OH (as in case of phosphates in DNA) or NH₂. The pairing with the residues would come from 3-photon cyclotron resonance.

Where do the dark protons come from? The backbone of protein is in the same role as sugar phosphate backbone in DNA and RNA. Amino acid residues are in the same roles as DNA nucleotides.

1. Amino acids are acids: NH_2 and COOH groups make them acidic. They tend to release protons and become negatively charged. They could give dark protons. In the formation of protein $NH_2 \rightarrow NH$: one proton and electron lost. Does the proton come dark?

Where does the electron go? Is it also dark and bound with a dark proton to form a dark atom? This kind of option in the case of the TGD based model for cold fusion [L27, L56] involving dark dark proton sequences in a smaller scale.

- 2. C-OH loses H as C-O-N is formed. Both electron and proton are lost. Also this proton could become dark and bind with the dark electron to form dark hydrogen atom.
- 3. Where does the third dark proton come from? Is also NH in C-NH of the peptide acidic? Can it lose a proton, which becomes dark? Just as in the case of DNA codon, electrons would neutralize the dark proton. One would have instead of a dark proton sequence a dark H sequence. The additional charge of amino acid can be positive or negative and its possible polarity relates to the residues and to chemistry. The backbone would serve as the interface between dark matter and chemistry. The resonant interaction between the dark amino acid and residue would give the pairing between amino acid and its dark counterpart.

Denaturation of proteins and DNA

One can wonder how the denaturation of proteins and DNA could relate to dark protons.

1. Do the dark hydrogens become ordinary in the case of protein? h_{eff} would be reduced and the protein would decay. The energy liberated from dark protons and be used to store metabolic energy in the catabolism of proteins.
2. In the denaturation of DNA double strand hydrogen bonds between strands are lost. This also happens in DNA strand opening during transcription and translation. This cannot relate to a loss of dark proton sequences, which would lead to depolymerization.

Why does the loss of hydrogen bonds lead to the denaturation? Is there binding between dark codon sequences inducing the formation of hydrogen bonding? Is Galois singletness for Z_3 replaced with Z_6 singletness so that a bound state of 2 dark proton triplets corresponding to codon and conjugate would be formed: this would be codon pairing at the level of the dark genome. This is considered in [L137].

Hydrogen bonds and energy resonance

If also hydrogen bonds involve dark proton, there should be an energy resonance in which the dark proton returns from an excited cyclotron state and gives energy to the molecule to which it is bound and excites it. This would then decay to ground state and give the energy back to the dark proton. This would be kind of quantum tennis.

Hydrogen bonds would be also present between the paired bases: depending on the base pair their number would be 2 or 3. These dark protons would not correspond to those associated with dark DNA strands. An interesting question is how important the pairing of dark DNA strands and analog of hydrogen bonds of base pairs is and whether it relates to the energetics assigned with hydrogen bonds.

For instance, one can ask why A-T pairing by hydrogen bonds rather than A-C pairing is good.

- 1. Suppose that the dark codons DA and DT have the same 3-frequency giving rise to frequency resonance between them so that they can pair. DA and DC do not have the same 3-frequency and cannot pair. Pairing is therefore unique at the dark level.
- 2. The energy resonance condition assigns to a dark codon a unique codon so that one obtains only A-T pairing induced by dark pairing.

21.3.2 Does high energy phosphate bond involve 3 dark protons?

High energy phosphate bond plays a key role in the modelling of ATP hydrolysis [I5] in the framework of standard chemistry. The official view is that everything is well-understood but for instance Ling has criticised both the notion of the high energy phosphate bond and the reduction to the molecular level [I114, I115, I90, I108, I109] and also emphasised the importance of a network like structures assignable to the cellular water: in TGD these networks would relate to MB. The work of Ling is discussed from TGD point of view in [L13, L14] [?].

From the TGD point of view the notion of high energy phosphate bond would be a mistake at the level of fundamental physics: dark matter and MB would be neglected. Thermo-dynamical chemistry can cope with this phenomenologically by introducing the notion of chemical potentials effectively describing the presence of dark matter. What is lost is quantum coherence in longer than atomic scales needed to really understand life.

The energy carried by 3 dark protons should replace the notion of high energy phosphate bond. Pollack effect indeed requires energy feed and this energy would go to dark protons taken from water.

Remark: Pollack effect would be an extreme example of adicity. Every fourth proton would become dark proton at flux tubes. pH would be $log_{10}(4)$! Also ordinary acidity could mean presence of dark protons but their number would be extremely small: one has fraction 10^{-7} for pH = 7.

This view would hold also more generally. The dark protons associated with proteins would also serve as a metabolic energy storage. In the denaturation this energy would be liberated. This happens in composts in which the organic material decays and causes heating of the compost. Of course, also the valence bonds which are dark carry energy as energy of dark electrons: by $h_{eff} > h$ the Coulombic bindin energy would be reduced and the energy of the valence bond would increase.

ATP \rightarrow ADP and also ADP \rightarrow AMP [I66] are possible. Dark electrons associated with the valence bonds could contribute to bond energy since large \hbar reduces the negative Coulomb interaction energy assignable to the bond.

Also the dark protons associated with the phosphates could contribute the energy assigned usually with high energy phosphate bond. Pollack's finding [I162] about the formation of exclusion zones (EZs) in presence of irradiation, most effectively IR radiation, led to the TGD based model. A considerable fraction of protons (fraction of 1/4) would be transferred to dark protons at the dark flux tubes. This requires (metabolic) energy and IR radiation would provide it and the energy is stored as energy of dark protons. Hence the pure chemistry based view about high energy phosphate bond would be wrong.

ATP has three phosphates and negative charge of -3 units. It would be screened by charges of 3 dark protons at the flux tube associated with ATP defining possibly a dark DNA codon (adenine triplet?). Dark RNA is not allowed since RNA does not allow A but U instead of it. In ATP \rightarrow ADP the energy is given as a photon to the enzyme catalyzing the reaction allowing to overcome activation energy barrier. In microtubules one has GTPs binding stably to α tubulins but not β tubulins.

Microtubules (MTs) define an interesting candidate for the realization of genetic code. One can also try to understand MTs and their dynamics in terms of Galois confinement.

- 1. The model of 6-bit memory code [J25] discussed by Hameroff *et al* relies on the hexagonal lattice formed by tubulin dimers consting of a pair of α and β tubulins, the 6-foot structure of CaMKII kinase domains, and the fact that the hexagon and CaMKII fit nicely together. The dynamical tubulins must be β tubulins for which the phosphorylation is not stable. The phosphorylation state of a given foot of the CamKII kinase domain represents a single bit so that CaMKII stores 6 bits. Its attachment at the hexagon of 6 tubulin dimers containing one tubulin dimer at is center could transfer the GTPs and thus 6 bits of information to the center tubulin. The proposed interpretation is as a transfer of information from neuronal to microtubular level involved with the synaptic learning.
- 2. The TGD inspired question is whether the CaMKII kinase domains are accompanied by dark proton triplets transferred to the tubulin dimer at the center of the hexagon so that microtubules would provide a 2-D representation of genetic code. If CamKII affects only the dark codon at the center of the hexagon, the center hexagon can behave as indepent 6-bit units making possible 2-D lattice representation of the genetic code. This framework does not allow charge neutrality, and microtubules are indeed negatively charged having positively charged and negatively charged ends. Second option would be that the stable GTPs associated with α tubulins define an analog of genome with single codon per GTP.
- 3. GTPs at the minus end of MT stabilize it, and GTP \rightarrow GDP transition liberating energy occurring for β tubulins causes the thread mill instability illustrated by a video of the Wikipedia article about MTs. The 13 linear strands of tubulin dimers separate and bend radially outward. Are the 13 tubulin strands Galois confined states of tubulin dimers? Do also the 13 strands form a Galois confined state? Does the liberated energy overcome the activation energy barrier against the decay to 13 separate tubulin strands?

The video of the Wikipedia article illustrates the formation of the structure. Could the decay correspond to a cascade of cognitive measurements leading from a state in Galois group algebra to an entangled product state in the tensor product of states assignable to the group algebras of normal Galois subgroups associated with an extension of extensions of ... of rationals [L145].

The energetics at the dark proton flux tube

The energetics of the flux tube containing 3 dark protons must be considered.

- 1. Consider first the Coulombic interaction energy between dark protons. The interaction energy includes Coulombic interaction energy of nearest neighbor dark protons with distance R and those with distance of 2R.
 - (a) If the flux tube is open, then we have

$$E_c = \frac{2e^2}{R} + \frac{e^2}{2R} = \frac{5}{2}\frac{e^2}{R} \equiv \frac{5}{2}E_0.$$
(21.3.1)

(b) If the flux tube is closed one has

$$E_c = 3E_0$$
 . (21.3.2)

- 2. There is also strong interaction energy (one has a dark nucleus). Strong interaction is short ranged.
 - (a) If the flux tube is open one has strong interaction energy $2E_s$ and total energy is

$$E_{open} = \frac{5}{2}E_0 + 2E_s \quad . \tag{21.3.3}$$

(b) If the flux tube is closed one has

$$E_s = 3E_0 + 3E_s \quad . \tag{21.3.4}$$

3. There is also the total negative Coulomb interaction energy of dark protons with the total charge of phosphates.

$$E(c,N) = K(N)E_P , (21.3.5)$$

where E_P is interaction energy between dark proton and phosphate. N = 3, 2, 1 for ATP, ADP, AMP If the dark protons interact as independent entities with 3 different phosphates one has K = N. If both ATP and protons act as single charged entities this energy one has $K = N^2$

4. The total energies for ATP, ADP, AMP are given by

$$\begin{split} E_{open,3} &= \frac{5}{2} E_0 + 2E_s + K(3) E_P \quad , \quad E_{closed,3}(ATP) = 3E_0 + 3E_s + K(3) E_P \quad . \\ E_{open,2} &= E_0 + E_s + K(2) E_P \quad , \quad E_{closed,3}(ATP) = E_0 + E_s + K(2) E_P \quad . \\ E_{open,2} &= K(1) E_P \quad , \quad E_{closed,3}(ATP) = K(1) E_P \quad . \end{split}$$

where K = N or $K = N^2$. Note that for N = 1 there is no difference between open and closed cases.

5. What happens in ATP \rightarrow ADP and ADP \rightarrow AMP? One organic phosphate (P) transforms to inorganic phosphate ion P_i without dark proton and one dark proton is lost. There are two left. Energy is liberated. There are also other contributions but let us forget them for a moment. The energy liberated is $E \simeq .5$ eV, metabolic energy quantum, energy of an IR photon.

The liberated energy is in various cases

$$\Delta E_{open}(ATP) \to ADP) = \frac{3}{2}E_0 + E_s + [K(3) - K(2)]E_P ,$$

$$\Delta E_{closed}(ATP \to ADP) = 2E_0 + 2E_s + [K(3) - K(2)]E_P ,$$

$$\Delta E(ADP \to AMP) = E_0 + E_s + [K(2) - K(1)]E_P .$$
(21.3.7)

Empirical input

The reconstruction of ATP requires 1 dark proton and free energy about $\Delta G = -.5$ eV is needed. Actually 3 or 4 protons arriving through the cell membrane and getting kinetic energy in the membrane potential are used. Where does the surplus energy go? Or is there any surplus energy at all?

- 1. Mitochondrial membrane potential for proton which is determined by Coulomb potential and chemical potential due to the proton concentration difference at two sides of the membrane is about .15 eV [I95]. Multiplying this by the number of protons 3 (4) gives .45 eV (0.5 eV) so that 3 dark protons are needed and 1 goes to ADP to give ADP. This gives a nice fit in both cases.
- 2. It is claimed that the free energy ΔG liberated in ATP \rightarrow ADP is the same as in ADP \rightarrow AMP. If ΔS matters, one has for the liberated free energy metabolic energy currency -

$$\Delta G = \Delta E + T \Delta S \quad . \tag{21.3.8}$$

 $\Delta G = -.5eV < 0$, the nominal value of metabolic energy currency, holds true approximately.

Can the free energies liberated in ATP \rightarrow ADP and ADP \rightarrow AMP be the same?

The condition that the metabolic energies as free energy changes are same for various options gives the following conditions.

1. For open and closet flux tube option one would obtain the condition:

$$\begin{array}{ll} Open & \frac{3}{2}E_0 + E_s + [K(3) - K(2)]E_P + T\Delta S(ATP) \to ADP) = \\ & E_0 + E_s + [K(2) - K(1)]E_P + T\Delta S(ADP \to AMP) \\ Closed & 2E_0 + 2E_s + [K(3) - K(2)]E_P + T\Delta S(ATP \to ADP) = \\ & E_0 + E_s + [K(2) - K(1)]E_P + T\Delta S(ADP \to AMP) \end{array}$$
(21.3.9)

We obtain the following results form $K = N^2$ and K = N options respectively:

$$\begin{array}{ll} (Open, K = N^2): & E_0 = -10E_P - 2X \ , \\ (Open, K = N): & E_0 = -2X \ , \\ (Closed, K = N^2): & E_0 + E_s = -2E_P - X \ , \\ (Closed, K = N): & E_0 + E_s = -X \ , \\ & X = (\Delta S(ATP \to ADP) - \Delta S(ADP \to AMP)) \ . \end{array}$$
(21.3.10)

For $K = N^2$ option E_0 is positive even when X = 0 is true. For $K = N E_0 = 0$ holds true for X = 0 and one must have X < 0 meaning that the entropy increase in ADP $\rightarrow AMP$ is larger than in ATP $\rightarrow ADP$.

- 2. One obtains the following values for E_0 in various cases. All terms are manifestly positive in the expressions as they should be.
 - $\begin{array}{ll} (Open, K = N^2): & E_0 = -10E_P 2X \ , \\ (Open, K = N): & E_0 = -2X \ , \\ (Closed, K = N^2): & E_0 = -2E_P X E_s \ (21.3.11) \\ (Closed, K = N): & E_0 = -X E_s \ , \\ X = (\Delta S(ATP \to ADP) \Delta S(ADP \to AMP)) \ . \end{array}$

3. Liberated free energy can be positive in all cases unless $E_P < 0$ has too large a magnitude.

$$\begin{array}{ll} (Open,K=N^2): & \Delta G=-7E_P-2X+Y \ , \\ (Open,K=N): & \Delta G=E_P-2X+Y \ , \\ (Closed,K=N^2): & \Delta G=-E_P-X+Y \ , \\ (Closed,K=N): & \Delta G=E_P-X+Y \ , \\ & X=-T(\Delta S(ATP\rightarrow ADP)-\Delta S(ADP\rightarrow AMP))>0 \ , \\ & Y=T\Delta S(ADP\rightarrow AMP)>0 \ . \end{array}$$

One can argue that $\Delta S > 0$ in both reactions since the number of $h_{eff}/h_0 > 0$ protons decreases and the "IQ" of the system decreases. Hence one has Y > 0. The term E_P in K = N case is negative. The term proportional to X is positive for all cases if X < 0 is true. This would mean that $\Delta S(ATP \rightarrow ADP) < \Delta S(ADP \rightarrow AMP)$. Entropy would increase more in the latter reaction. $K = N^2$ options are favored and the most favored is (Open, $K = N^2$) option: open flux tube with 3 dark protons interacting with phosphate charges like single charge of 3 units as the identification as a Galois confined state suggests.

Chapter 22

Homeostasis as self-organized quantum criticality?

22.1 Introduction

This chapter has been written together with Reza Rastmanesh. The article started as an attempt to understand the properties of cold shock proteins (CSPs) and heat shock proteins (HSPs) in TGD framework. As a matter of fact , these proteins have great deal of similarity and have much more general functions, so it is easier to talk about stress proteins (SPs) having two different modes of operation.

As we proceed, it will be revealed that this issue is only one particular facet of a much bigger problem: how self-organized quantum criticality (SOQC) is possible? Criticality means by definition instability but SOQC is stable, which seems to be in conflict with the standard thermodynamics. In fact, living systems as a whole seem to be quantum critical [I171] and manage to stay near criticality, which means SOQC. Note that the self-organized criticality (SOC) is generalized to SOQC.

Topological Geometrodynamics (TGD) [?] [K6, K9] is a 43 year old proposal for a unification of fundamental interactions. Zero energy ontology (ZEO) [L148] is basic aspect of quantum TGD and allows to extend quantum measurement theory to a theory of consciousness and of living systems. ZEO also leads to a quantum theory of self-organization [L125] predicting both arrows of time. Could ZEO make SOQC possible as well?

22.1.1 Summary of the basic properties of CSPs and HSPs

Let's consider a summary of CSPs and HSPs or briefly SPs.

1. There is a large variety of cold shock proteins (CSP) and heat shock proteins (HSPs). CSPs and HSPs are essentially the same proteins and labelled by HSPX, where X denotes the molecular weight of the protein in kDaltons. The value range of X includes the values $\{22, 60, 70, 90, 104, 110\}$ and HSPs are classified into 6 families: small HSPs, HSPX, $X \in \{40, 60, 70, 90, 110\}$. At least HSP70 [I22] and HSP90 [I20] have ATPase at their end whereas HSP60 has ATP binding site [I21]. CSPs and HSPs consist of about $10^3 - 10^4$ amino acids so that X varies by one order of magnitude.

Their lengths in the un-folded active configuration are below 1 micrometer. CSPs/HSPs [I18, I8, I153, I183] are expressed when the temperature of the organism is reduced /increased from the physiological temperature. CSPs possess cold-shock domains [I7] consisting of about 70-80 amino-acids thought to be crucial for their function. Part of the domain is similar to the so called RNP-1 RNA-binding motif. In fact, it has turned that CSP and HSP are essentially the same object and stress protein (SP) is a more appropriate term.

Wikipedia article about cold shock domain [I7] mentions Escherichia Coli as an example. When the temperature is reduced from 37 $^{\circ}$ C to 10 $^{\circ}$ C, there is 4-5 hours lag phase after which growth is resumed at a reduced rate. During lag phase expression of around 13

proteins containing cold shock domains is increased 2-10 fold. CSPs are thought to help the cell to survive in temperatures lower than optimum growth temperature, by contrast with HSPs, which help the cell to survive in temperatures greater than the optimum, possibly by condensation of the chromosome and organization of the prokaryotic nucleoid. What is the mechanism behinds SP property is the main question.

2. SPs have a multitude of functions involved with the regulation, maintenance and healing of the system [I184, I48, I62, I133, I183]. They appear in stress situations like starvation, exposure to cold or heat or to UV light, during wound healing or tissue remodeling, and during the development of the embryo. SPs can act as chaperones [I48] and as ATPAses [I116, I156].

SPs facilitate translation, and protein folding in these situations, which suggests that they are able to induce local heating/cooling of the molecules involved in these processes. CSPs could be considered like ovens and HSPs like coolants; systems with very large heat capacity acting as a heat bath and therefore able to perform temperature control. SPs serve as kind of molecular blacksmiths - or technical staff - stabilizing new proteins to facilitate correct folding and helping to refold damaged proteins. The blacksmith analogy suggests that this involves a local "melting" of proteins making it possible to modify them.

What "melting" could mean in this context? One can distinguish between denaturation in which the folding ability is not lost and melting in which it is lost. Either local denaturation or even melting would be involved depending on how large the temperature increase is. In a aqueous environment the melting of water surrounding the protein as splitting of hydrogen bonds is also involved. One could also speak also about local unfolding of protein.

- 3. There is evidence for large change ΔC_p of heat capacity C_p ($C_p = dE/dT$ for pressure changing feed of heat energy) for formation ion nucleotide-CSP fusion [I156]. This could be due to the high C_p of CSP. The value of heat capacity of SPs could be large only *in vivo*, not *in vitro*.
- 4. HSPs can appear even in hyper-thermophiles living in very hot places. This suggests that CSPs and HSPs are basically identical more or less but operate in different modes. CSPs must be able to extract metabolic energy and they indeed act as ATPases. HSPs must be able to extract thermal energy. If they are able to change their arrow of time as ZEO suggests, they can do this by dissipating with a reversed arrow of time.

To elucidate the topic from other angles, the following key questions should be answered:

- 1. Are CSPs and HSPs essentially identical?
- 2. Can one assign to SPs a high heat capacity (HHC) possibly explaining their ability to regulate temperature by acting as a heat bath? One can also ask whether HHC is present only *in vivo* that is in a aqueous environment and whether it is present only in the unfolded configuration of HP?

22.1.2 The notion of quantum criticality

The basic postulate of quantum TGD is that the TGD Universe is quantum critical [K6, K9] [L34, L33]. There is only a single parameter, Kähler coupling strength α_K mathematically analogous to a temperature and theory is unique by requiring that it is analogous to critical temperature. Kähler coupling strength has discrete spectrum labelled by the parameters of the extensions of rationals. Discrete p-adic coupling constant evolution replacing continuous coupling constant evolution is one aspect of quantum criticality.

What does quantum criticality mean?

1. Quite generally, critical states define higher-dimensional surfaces in the space of states labelled for instance by thermo-dynamical parameters like temperature, pressure, volume, and chemical potentials. Critical lines in the (P,T) plane is one example. Bringing in more variables one gets critical 2-surfaces, 3-surfaces, etc. For instance, in Thom's catastrophe theory [A30] cusp catastrophe corresponds to a V-shaped line, whose vertex is a critical point whereas butterfly catasrophe to 2-D critical surface. In thermodynamics the presence of additional thermodynamical variables like magnetization besides P and T leads to higher-dimensional critical surfaces.

- 2. There is a hierarchy of criticalities: there are criticalities inside criticalities. Critical point is the highest form of criticality for finite-D systems. Triple point, for instance, for water in which one cannot tell whether the phase is solid, liquid or gas. This applies completely generally irrespective of whether the system is a thermo-dynamical or quantal system. Also the catastrophe theory of Thom gives the same picture [A30]. The catastrophe graphs available in the Wikipedia article illustrate the situation for lower-dimensional catastrophes.
- 3. In TGD framework finite measurement resolution implies that the number of degrees of freedom (DFs) is effectively finite. Quantum criticality with finite measurement resolution is realized as an infinite number of hierarchies of inclusions of extensions of rationals. They correspond to inclusion hierarchies of hyperfinite factors of type II_1 (HFFs). The included HFF defines the DFs remaining below measurement resolution and it is possible to assign to the detected DFs dynamical symmetry groups, which are finite-dimensional. The symmetry group in never reachable ideal measurement resolution is infinite-D super-symplectic group of isometries of "world of classical worlds" (WCW) consisting of preferred extremals of Kähler action as analogs of Bohr orbits. Super-symplectic group extends the symmetries of superstring models [K6] [?, ?, ?, ?].
- 4. Criticality in living systems is a special case of criticality and as the work of Kauffman [I171] suggests of quantum criticality as well. Living matter as we know, it most probably corresponds to extremely high level of criticality so that very many variables are nearly critical, not only temperature but also pressure. This relates directly to the high value of h_{eff} serving as IQ. The higher the value of h_{eff} , the higher the complexity of the system, and the larger the fluctuations and the scale of quantum coherence. There is a fractal hierarchy of increasingly quantum critical systems labelled by a hierarchy of increasing scales (also time scales).

In ZEO classical physics is an exact part of quantum physics and quantum physics prevails in all scales. ZEO makes discontinuous macroscopic BSFRs to look like smooth deterministic time evolutions for the external observer with opposite arrow of time so that the illusion that physics is classical in long length scales is created.

Number theoretical physics or adelic physics [L66, L67] is the cornerstone of TGD inspired theory of cognition and living matter and makes powerful predictions.

p-Adic length scale hypothesis deserves to be mentioned as an example of prediction since it has direct relevance for SPs.

- 1. p-Adic length scale hypothesis predicts that preferred p-adic length scales correspond to primes $p \simeq 2^k$: $L(k) = 2^{(k-151)/2}L(151)$, $L(151) \simeq 10$ nm, thickness of neuronal membrane and a scale often appearing molecular biology.
- 2. TGD predicts 4 especially interesting p-adic length scales in the range 10 nm- 25 μ . One could speak of a number theoretical miracle. They correspond to Gaussian Mersenne primes $M_{G,k} = (1+i)^{k-1}$ with prime $k \in \{151, 157, 163, 167\}$ and could define fundamental scales related with DNA coiling for instance.
- 3. The p-adic length scale $L(k = 167) = 2^{(167-151)/2}L(151) = 2.5 \ \mu$ m so that SPs could correspond to $k \in \{165, 167, 169\}$. L(167) corresponds to the largest Gaussian Mersenne in the above series of 4 Gaussian Mersennes and to the size of cell nucleus. The size scale of a cold shock domain in turn corresponds to L(157), also associated with Gaussian Mersenne. Note that the wavelength defined by L(167) corresponds rather precisely to the metabolic currency .5 eV.
- 4. HSPX, $X \in \{60, 70, 90\}$ corresponds to a mass of X kDaltons (Dalton corresponds to proton mass). From the average mass 110 Dalton of amino acid and length of 1 nm one deduces that the straight HSP60, HSP70, and HSP90 have lengths about .55 μ m, .64 μ , and .8 μ m.

The proportionality of the protein mass to length suggests that the energy scale assignable to HSPX is proportional to X. (HSP60, HSP70, HSP90) would have energy scales (2.27, 1.95, 1.5 eV) for $h_{eff} = h$ naturally assignable to biomolecules. The lower boundary of visible photon energies is a 1.7 eV.

Remark: One has $h = h_{eff} = nh_0$ for n = 6. What if one assumes n = 2 giving $h_{eff} = h/3$ for which the observations of Randel Mills [D7] give support [L73]? This scales down the energy scales by factor 1/3 to (.77,.65,0.5) eV not far from the nominal value of metabolic energy currency of about .5 eV.

There are strong motivations to assign to HSPs the thermal energy E = T = .031 eV at physiological temperature: this is not the energy $E_{max} = .084$ eV at the maximum of the energy distribution, which is by a factor 2.82 higher than E. The energies above are however larger by more than one order of magnitude. This scale should be assigned with the MBs of SPs.

5. The wavelengths assignable to HSPs correspond to the "notes" represented by dark photon frequencies. There is an amusing co-incidence suggesting a connection with the model of bio-harmony [L23, L24]: the ratios of energy scales of HSP60 and HSP70 to the HSP90 energy are 3/2 and 1.3, respectively. If HSP90 corresponds to note C, HSP60 corresponds to G and HSP70 to note E with ratio 1.33. This gives C major chord in a reasonable approximation! Probably this is an accident. Note also that the weights X of HSPXs are only nominal values.

22.1.3 Hagedorn temperature, HHC, and self-organized quantum criticality (SOC)

Self-organized criticality (SOC) is an empirically verified notion. For instance, sand piles are SOQC systems. The paradoxical property of SOQC is that although criticality suggests instability, these systems stay around criticality. In standard physics SOQC is not well-understood. TGD based model for SOQC involves two basic elements: ZEO and Hagedorn temperature.

- 1. ZEO predicts that quantum coherence is possible in all scales due to the hierarchy of effective Planck constants predicted by adelic physics. "Big" (ordinary) state function reductions (BSFRs) change the arrow of time [L148]. Dissipation in reversed arrow of time looks like generation of order and structures instead of their decay - that is self-organization. Hence SOQC could be made possible by the instability of quantum critical systems in non-standard time direction. The system paradoxically attracted by the critical manifold in standard time direction would be repelled from it in an opposite time direction as criticality indeed requires.
- 2. Surfaces are systems with infinite number of DFs. Strings satisfy this condition as also magnetic flux tubes idealizable as strings in reasonable approximation. The number of DFs is infinite and this implies that when one heats this kind of system, the temperature grows slowly since heat energy excites new DFs. The system's maximum temperature is known as Hagedorn temperature and it depends on string tension for strings.

In the TGD framework, magnetic flux tubes can be approximated as strings characterized by a string tension decreasing in long p-adic length scales. This implies a very high value of heat capacity since very small change of temperature implies very large flow of energy between the system and environment.

 T_H could be a general property of MB in all scales (this does not yet imply SOQC property). An entire hierarchy of Hagedorn temperatures determined by the string tension of the flux tube, and naturally identifiable as critical temperatures is predicted. The temperature is equal to the thermal energy of massless excitations such as photons emitted by the flux tube modellable as a black body.

Remark: If the condition $h_{eff} = h_{gr}$ [L102], where h_{gr} is gravitational Planck constant introduced originally by Nottale [E1], holds true, the cyclotron energies of the dark photons do not depend on h_{eff} , which makes them an ideal tool of quantum control.

Hagedorn temperature would make them SOQC systems by temperature regulation if CSP type systems are present they can serve as ovens by liberating heat energy and force the local

temperature of environment to their own temperature near T_H . Their own temperature is reduced very little in the process. These systems can also act as HSP/CSP type systems by extracting heat energy from/providing it to the environment and in this way reduce/increase the local temperature. System would be able to regulate its temperature.

A natural hypothesis is that T_H corresponds to quantum critical temperature and in living matter to the physiological temperature. The ability to regulate the local temperature so that it stays near T_H has interpretation as self-organized (quantum) criticality (SOC). In the TGD framework these notions are more or less equivalent since classical physics is an exact part of quantum physics and BSFRs create the illusion that the Universe is classical in long (actually all!) scales.

Homeostasis is a basic aspect of living systems. System tends to preserve its flow equilibrium and opposes the attempts to modify it. Homeostasis involves complex many-levels field back circuits involving excitatory and inhibitory elements. If living systems are indeed quantum critical systems, homeostasis could more or less reduce to SOQC as a basic property of the TGD Universe.

22.2 The basic ideas about SPs

The TGD based model for SPs relies on the notion of MB carrying dark matter as $h_{eff} > h$ phases and the notions of heat transfer and heat capacity. The basic idea is that at least in aqueous environment the MBs of biomolecules in general have a large number of DFs and act as heat reservoirs with a stable temperature near a Hagedorn temperature. MBs of SPs have also high heat transfer rates between the thermal environment of the ordinary matter. ZEO - in particular time reversal - makes it possible to realize thermal regulation in terms of SOQC. On the other hand, information carrying biomolecules cannot have high heat transfer rate with environment.

22.2.1 Conditions on the heat transfer rates between the systems involved

To avoid lengthy explanations, it is appropriate to introduce some shorthand notations. Denote by $j_H(X - Y)$ heat transfer rate between systems X and Y. Denote by E. Denote BB(X) the biological body of system X. X can denote the ordinary biomolecule (DNA,RNA,protein) denoted by BM or stress protein SP.

There are several conditions on the model explaining the HHC

1. $j_H(MB(SP) - E)$ should be high so that the MB of SP can rapidly adapt to temperature changes and extract thermal energy from the environment and act as an oven or a coolant. $j_H(MB(SP) - BM$ should be high so that CSPs could rapidly warm up BMs for processes like translation, transcription and folding.

 $j_H(MB(SP) - BM$ can be also high if heat transfer occurs indirectly via MB(BM). This requires that both $j_H(MB(BM) - BM$ and $j_H(MB(SP) - MB(BM))$ are high. However, the large value of $j_H(MB(BM) - BM)$ implies that BMs can take care of temperature regulation without the help of SPs. Hence this option does not seem to be consistent with empirical facts. Hence $j_H(MB(BM) - BM)$ must be low.

There is also a deeper rational for this. The MBs of ordinary bio-molecules must carry information and cannot be thermalized so that the energy transfer rate between them and their BB and between them and the environment must be low.

2. In CSP mode the MBs of SPs should actively extract energy from fats. The BMs should extract thermal energy from MBs of SPs. In HSP mode MBs of SPs at temperature than that of the local thermal environment (including BMs) should cool it by absorbing thermal energy from it.

The following table summarizes the constraints on the symmetric matrix of heat transfer rates $j_H(A, B)$ for various combinations of subsystems X and Y. The shorthand notations are (SP, BM, E) for (stress protein, basic biomolecule, environment) and MB(X) for the MB of molecule X. Environment E is taken as the thermal environment at the level of ordinary matter. The diagonal heat transfer rates are not considered. H/L for the matrix element $j_H(X, Y)$ of the table means that its value can be large/small. The symbol "*" means that this particular transfer is not relevant.

X/Y	SP	MB(SP)	BM	MB(BM)	E	
SP	*	\mathbf{H}	*	*	*	
MB(SP)	\mathbf{H}	*	\mathbf{H}	*	\mathbf{H}	(22.2.1)
BM	*	\mathbf{H}	*	\mathbf{L}	*	(22.2.1)
MB(BM)	*	*	\mathbf{L}	*	*	
Ē	*	н	*	*	*	

In the minimal scenario the only constraints are on $j_J(SP, MB(SP)$ (H), $j_J(BM, MB(SP)$ (H), and $j_J(BM, MB(BM)$ (L).

The natural question is what makes it possible for the MBs of SPs to gain energy.

- 1. The first manner to get energy is heat transfer from the environment. Passive heat transfer would involve either ordinary photons transformed to dark photons and absorbed by MB(SP) or active heat extraction in time reversed mode involving emission of dark photons transformed to ordinary photons and absorbed by ordinary matter. The energies should be in the range of thermal energies at physiological temperatures.
- 2. The negative energy photons from the MB of biomolecule can be also received by other MBs acting as analogs of population reversed laser. Thermalisation is expected to occur if there is large number of this kind of states. MB should allow almost continuum of cyclotron energy state in the energy resolution defined by the size scale of the molecules.
- 3. At least some SPs such as HSP70 and HSP90 could act as ATPases providing the heat energy at their MBs to drive ADP → ATP process. They would act as general purpose quantum heat engines with MB acting as a heat bath running the ATPase machinery. Heat engine function requires a heating of the MB SP to a temperature above the local physiological temperature but below the Hagedorn temperature: in ZEO time reversal for the MB of SP allows this: it would look like extraction of thermal energy from the environment. Part of the energy heating MB of SP could come from the binding of ATP to ATPAse part of PS. This energy is in the range of 3-7 eV for nucleotides and could heat the MB of SP.

One could also consider remote metabolism for the molecules receiving the metabolic energy quantum with a negative energy photon inducing $ATP \rightarrow ADP$. Note that the metabolic energy quantum .5 eV is in infra-rede (IR) range and corresponds to 2.4 μ m wavelength very near to the largest p-adic length scale L(167) in the quadruplet of primes $k \in \{151, 157, 163, 167\}$ defining four Gaussian Mersennes and defining the size scale of nucleus.

Now, consider the extraction of heat energy from the environment:

- 1. The energies assignable to the photon wavelengths defined by the lengths of HSPX proteins are proportional to 1/X and above 1.5 eV, which is considerably above the energy of thermal photon at the maximum of Planck distribution for energy is $E_{max} = .084 \text{ eV}$).
- 2. The energy transfer would be based on energy resonance and is possible only if the cyclotron frequency spectrum of dark particles contains energies possessed by molecules in their spectrum in infrared range. This poses a condition on the cyclotron energies $E = \hbar_{eff} eB/m$ assumed to be in bio-photon energy range: this requires that $h_{eff} = nh_0 = \hbar_{gr} = BMm/v_0$ is large: one has $E = GMB/v_0$ does not depend on the mass of charged particle. Cyclotron energies involve also the contribution from a longitudinal motion along the flux tube. The energy scale for dark photon is now \hbar_{eff}/L and also universal since L scales as \hbar_{gr} . If L is small the energy scale is so large that longitudinal DFs are not excited and thermalization does not occur. Same is true if B is large enough.

Magnetic field strength is expected to scale like $1/L^2(k)$, where L(k) is the p-adic length scale characterizing the molecule. The endogenous magnetic field $B_{end} = 2B_E/5$ identified

as the monopole flux part of the Earth's magnetic field is expected to define an important value in the spectrum of magnetic fields. The corresponding p-adic length scale corresponds to the length scales assignable to SPs. Also octaves of this value are expected and the model of bio-harmony [L23, L24] suggests that the preferred values are given by 12-note scale.

For short linear molecules the energy scales would be too high to allow thermalization so that these molecules can serve as information molecules. For long DNA one has length scale hierarchy and thermalization can occur only in long enough length scales. Human DNA has total length of order 1 meter but if the size of DNA defines the p-adic length scale, then DNA does not thermalize since the size of nucleus is not larger than $L(167) = 2.5 \ \mu m$. Note that DNA defines a length scale hierarchy in codons, genes, and also coiling scales define hierarchy levels. When the length of the molecules is longer than the wavelength of thermal photon at room temperature, one expects thermalisation to occur. SPs have lengths below 1 μm .

- 3. The thermalization should take place for the MBs of SPs. There are two energy scales associated with the cyclotron energies and the free motion along the flux tube respectively. Thermal energy scale could correspond to either of these length scales.
 - (a) Cyclotron energy scale is given by $E_c = GMB/v_0$ for $h_{eff} = h_{gr}$ and the scales are proportional to *B*. Longitudinal energy scale dose not depend on h_{eff} since the flux tube length scales like h_{eff} . Since *B* scales like $1/L^2(k)$, cyclotron length scale increases for small protein sizes. This suggests that thermalization is associated with the cyclotron DF and appears for large enough p-adic length scales characterizig protein size.
 - (b) Longitudinal energy scale naturally corresponds to the length of protein for $h_{eff} = n$. The energy scale of longitudinal excitations is consirably above the thermal energy scale so that thermalization would not be possible. It might be however possible to transfer energy from these DFs to the MB of SP where it is transformed to thermal energy.

22.2.2 A new physics model for HHC

Now, consider a more concrete new physics model for HHC:

- 1. HHC suggests the existence of new DFs to which energy is stored so that temperature is not raised as new DFs become available.
- 2. In the theory of extended objects like strings, the very large number (infinite) of degress of freedom (DFs) implies a maximal temperature T_H known as Hagedorn temperature. Flux tubes are extended objects. This suggests that the MBs of SPs are near to the Hagedorn temperature defining the maximal temperature for their MBs. Also the assumption that the physiological temperature is near but usually below T_H : this condition allows SP to act as heat engine. This cannot be true for the information carrying biomolecules such as DNA, RNA and proteins since thermalization destroys information. Therefore they must have a temperature much below T_H .
- 3. In a hot environment the existence of Hagedorn temperature T_H for the MB of HSP means that the thermal energy is transferred from the environment to the MB of HSP. This tends to reduce the local temperature of the environment towards T_H . HSP would act as an ideal coolant. Their presence would faciliate the basic functions of cells.
- 4. CSP and its MB would be at temperature near T_H and could act as an oven. Their presence around DNA, RNA, and proteins would raise their temperature locally and facilitate transcription, translation and protein folding and unfolding otherwise prevented by a low temperature.
- 5. SPs could act as heat engines providing heat energy to molecular motors [?]. This entails SP to have a temperature higher than the temperature of environment. In ZEO this is possible by using a time reversed mode for SP to extract energy from the environment. Many SPs

have ATPase at their end and this would make them universal heat engines providing the work as metabolic energy currency for any molecular user.

- 6. Quite generally, by their ATPase property, many SPs could act as metabolic energy sources in stressful situations - this comprises many other situations in addition to low and high temperatures. Metabolic energy feed increases h_{eff} and would increase the scale quantum coherence reduced in the damage of DNA, proteins and tissue, for instance. After this, the system could self-organize to the healed state. For instance, CSPs could induce local melting of misfolded proteins leading to a repair. CSPs act as chaperones and their basic tool would be local "melting" (remind our operational definition of "melting") by feeding heat energy allowing to establish a correct conformation.
- 7. The MBs of SPs could extract their thermal energy from the thermal energy of the environment in time reversed mode allowed by ZEP allowing the temperature of SP to even exceed that of environment in the final state of BSFR.

Consider a quantitative estimate.

- 1. For a typical flux tube length is larger than the radius of the flux tube. The critical temperature identified as Hagedorn temperature corresponds to a typical thermal energy of the flux tube and is determined by flux tube length and its string tension. The critical temperature is inversely proportional to the length of the flux tube.
- 2. Critical temperature T_H roughly corresponds to the energy of a photon with wavelength equal to the flux tube length $L : E = T_H \sim h_{eff}/L$. For $h_{eff} = h$ the flux tube length corresponds to the length scale of CSP but for large values of $h_{eff} = h_{gr}$ it corresponds to a scale of even Earth. The energies and temperature T_H are however the same irrespective of the value of h_{eff} and thus length of flux tube.
- 3. The rough estimate is that for physiological temperatures T_{ph} around T_H , the length for $h_{eff} = h$ the wave length for a thermal photon at temperate 310 K the maximum of energy distribution is around 14.7 μ m: note that the sizes of most animal and plant cells are oin the rage of 10-100 μ m. For the wavelength distribution the wavelength for the maximum is roughly 7 μ m. CSPs and HSPs consist of about 100-1000 amino acids or so. Length would be in the range .1-1 μ m. The energies of photons with a wave length of straight SP are definitely above thermal energy range.

Some questions are in order.

- 1. If the new DFs are associated with MB, what can one say about the value of h_{eff} serving as IQ could be? SPs are possessed already by bacteria which suggests that the value of h_{eff} cannot be very large. Acting as a chaperon is a control function, which suggests a higher than normal value of h_{eff} . Higher than normal value ignites intriguing question whether they have higher IQ (as a value of h_{eff} characterizing number theoretic complexity) than other proteins helping to survive in difficult situations. On the other hand, the thermalization means that SP flux tubes cannot carry information unlike the flux tubes of basic bio-molecules with their MBs at very low temperature.
- 2. Cell membrane must stay flexible as temperature is lowered. This is known to be achieved by a generation of unsaturated bonds to lipids. This involves desaturase enzyme creating C-C double bond. Desaturase enzymes are not SPs. SPs can however faciliate the transcription and translation of desaturase enzymes.

22.2.3 Physiological temperature as Hagedorn temperature, local temperature regulation, and self organized quantum criticality

The notions of quantum criticality, self-organized quantum criticality (SOC) and Hagedorn temperature leads to a new physics based model for the explanation of SP functions. 1. Hagedorn temperature T_H as a maximal temperature of MB of stress protein would be crucial for its functioning. Why the physiological temperature is around 310 K is one of the puzzles of biology. The work of Kauffman [I171] suggests that the interpretation as a quantum critical temperature is appropriate. TGD predicts a hierarchy of quantum critical temperatures. The natural guess would be that this quantum critical temperature is Hagedorn temperature realized at the level of MB asymptotically: in practice, the temperature of MB would be somewhat below T_H .

This would facilitate temperature regulation or perhaps even make it possible. At quantum criticality also long length scale quantum fluctuations are possible and this makes modifications of the system possible - say damaged proteins. If the temperature T of the environment at BB is above T_H , the thermal energy flows to MB of SP and its temperature T is reduced. MB can also make BSFR reversing the arrow of time and extract thermal energy from the environment.

2. Self-organized criticality (SOC) generalizes to self-organized quantum criticality (SOQC) in the TGD framework. SOC is well-known but it is not understood. For instance, sand piles are SOC systems. They tend to approach a critical state, which looks paradoxical since just the opposite should hold for critical systems by their defining property which makes them unstable! Critical system is optimal for measuring and representing since it has a large number of different states with roughly the same energy. Therefore biosystems should be critical systems.

The basic objection against SOC and SOQC is that SCs are unstable by definition. In ZEO this objection can be circumvented. Quantum coherence is possible in all scales and in BSFRs the arrow of time is changed. This transforms the critical manifold from a repeller to an attractor and time reversals make SOQC possible. The occurrence of SOQC would be direct empirical proof for the ZEO and its most dramatic predictions.

What is the distinction between CSP and HSP modes of SPs? SOQC according to ZEO suggests that time reversal could explain this difference. How do the time reversals for CSP and HSP modes differ? The following picture is suggestive.

- 1. The time reversal occurs for the MB of SP in HSP mode so that they extract thermal energy from environment.
- 2. The time reversal occurs for the MBs molecules interacting with SPs in CSP mode so that they can extract heat energy from the MB of CSP.

It has been already told that homeostasis in presence of quantum criticality is essentially quantum critical SOC.

22.2.4 $\Delta C_p > 0$ for HSP90-nucleotide binding as support for the model

Chistopher *et al* have studied enthalpy driven reactions involving nucleotide or ansamycin bimnding to HSP90: the title of the article [I156] is "*Structural–Thermodynamic Relationships ofInteractions in the N-Terminal ATP-Binding Domain*". These reactions occurring in constant pressure are enthalpy driven meaning that heat is liberated in these reactions - the second option would be entropy driven reaction in which the large entropy gain makes reaction possible. The formation of a bound state means a reduction of DFs suggesting a decrease of the heat capacity C_p of the combined system.

Researchers however find $\Delta C_p > 0$ when another reactant is nucleotide but not for the ansamycin case. Intuitively, the number of DFs should increase to explain this. The authors of the article discussed a number of explanations for their unexpected finding.

The presence of MB means new hidden DFs and the neglect of its presence could lead to thermo-dynamical anomalies. Could $\Delta C_p > 0$ in an enthalpy driven reaction leading to a formation of bound state be such an anomaly?

1. Suppose HSP90 has MB can have large C_p and that it is at the temperature of the environment. The temperature varies in the range 2-25 °C being considerably below the physiological

temperature 37 C proposed to correspond to a maximal temperature - Hagedorn temperature - for the magnetic flux tubes of SPs. C_p for the MB of SP is expected to increase as the temperature rises since new DFs are thermally excited.

 C_p could be rather high already for the initial state if it corresponds to the sum of heat capacities for nucleotide/ansamycin and HSP90. The size of the MB of nucleotide for $h_e f f = h$ should be small if it correlates with the size of nucleotide/ansamycin. Nucleotide is an information molecule and therefore its MB should be at a low temperature and have low C_p (thermal energies cannot excite the states at low temperature).

- 2. Since binding reaction is in question, C_p for the combined system should be reduced unless something happens at the level of MBs. Could the heat capacity of MB of HSP90 increase for nucleotide binding? Could even the value of ΔH for the nucleotide case be larger than thought due to the fact that part of ΔH is transferred to MB of HSP90?
 - (a) A lot of heat is liberated in the exothermic binding reaction in both cases. The measure part of the liberated heat goes to the standard DFs discussed in the article. Part of ΔH is transferred to the MB of HSP90 and can heat it to a higher local temperature. New DFs open and heat capacity of MB of CPS90 increases so much that the net heat capacity can increase despite the reduction of ordinary contribution to C_p .

This would happen for the nucleotide but not for ansamycin. Why would the fraction of liberated heat going to the MB of HSP be so small for ansamycin that ΔC_p remains negative?

- (b) Could the heat ΔH liberated in the nucleotide case be considerably larger than assumed and larger than for ansamycin plus CSP. This is quite possible since only the fraction going to the environment is measured, not that transferred to MB. Theoretical estimates do not of course take the possible presence MB into account. If ΔH for the nucleotide case is larger than believed, then MB of HSP90 can be heated more and $\Delta C_p > 0$ is possible.
- (c) The inspection of tables of [I156] shows that the values of ΔH for the nucleotide case are in the range 3-8 eV *per* reaction and correspond to UV energies. For reactions $\Delta C_p < 0$ the values of ΔH are of order .3 eV and correspond to IR photons but with energies larger than thermal energies. The difference is more than order of magnitude and suggests a similar difference for ΔH transferred to MB, which supports the proposed explanation.

22.2.5 Some functions of SPs in TGD perspective

SPs as heat baths for molecular heat engines and providers of heat energy to ATPs

Heat is produced as a side effect of metabolism and HSPs could extract this heat using remote metabolism and transform it to heat energy resources liberated when needed.

SPs could be used for heating as in the basic biological processes like transcription and transcription. SPs could also act as heat engines transforming heat energy to work in the case of molecular motors [?].

There are reports about the role of HSPs in doing molecular work [I48, I146, I133]: the new element would be heat energy coming from the MB of SP. At least SPs such as HSP60, HSP70, HSP90, HSP104 binding to ATP could serve as general purpose heat engines transforming heat energy at their MB to metabolic energy currency used in various biological processes.

1. All processes produce heat and the very idea of HSPs would the that HSPs gather this heat energy and act as heaters as in the case of transcription, translation, and replication or as heat engines liberating the heat energy as ordered energy. Action as ATPase would make HSP a general purpose molecular heat engine. Currently, we know that HSPX for $X \in \{60, 60, 90, 104\}$ at least act as ATPases.

Very important question: Is ATPase property a general property of HSPs?*

By the second law of thermodynamics these heat engines have some maximal efficiency proportional to the difference of the temperatures for heat bath - now MB - and the system receiving the energy. Hence HSP MBs must be at a temperature higher than the systems receiving the energy. The formation of HSP90-ATP bound state would liberate binding energy about 3-7 eV *per* reaction (metabolic energy quantum is .5) eV and this heats MB of HSP and would lead to the reported increase of heat capacity.

2. There is, however, a reason to worry. By Carnot's law maximal effectiveness is proportional to $\Delta T/T$, where ΔT is the temperature difference between the system receiving the work and heat bath, now the MB of SP, and T the temperature of the heat bath. Is the temperature difference high enough to give a reasonable effectiveness?

ZEO provides a quantum manner to get rid of worries. Time reversal could make possible for the MB of HSP to develop a temperature higher than that of environment by what looks for an observer extraction of thermal energy from the environment but is actually BSFR leading to final state which dissipates in reverse time direction to a state in which the temperatures are equal. T_H should be however somewhat higher than the physiological temperature.

Heat shock protein 70 and ATP in homeostasis

ATP depletes in stress situations due to the lack of ordinary metabolic energy feed as in ischemia. The role of HSP70 and its co-function with ATP in this kind of situation is discussed in [I146]. Also HSP70 involves ATPase and the lack of the ordinary metabolic energy could be replaced by thermal metabolic energy feed from the MBs of say HSP70.

SPs and infection

One can distinguish between immune response, which is specific to the invader organism (say bacterium or virus) or molecule and non-specific immune response involving inflammation and fever. Infection includes both the effects of the invader and those caused by the non-specific immune response.

1. The invader specific immune response would be basically an action of the MB: this is the basic vision of TGD. Already the MB of water recognizes the invader molecules by the cyclotron energy spectrum of their MBs: this is just water memory [I52, I145, I91] discussed from TGD point view in [L6]. "Homeopathy" is he ugly synonym for "water memory" and involves mechanical agitation feeds energy to the MBs of water clusters forming a population mimicking invader molecules.

MBs of water clusters are varying its flux tube thicknesses and in this manner changing corresponding cyclotron frequencies to get in tune with possible invaders: this is similar to what we do when we search for a radio station. When a hit occurs, MB of the water cluster fixes the flux tube thickness. After getting to resonance, the MBs of water molecules clusters can reconnect with U-shaped flux tubes to corresponding bacterial flux tubes: a pair of flux tubes connecting the water cluster MB to the invader molecule is formed. Invader is caught. The chemical side of the immune system emerged later and would involve sequences of dark proton triplets associated with proteins as addresses - 3N-fold resonance.

2. When bacteria infect cells, they induce inflammation and fever by raising the body temperature as a non-specific immune response. Inflammation can be seen as the body's protective response against infection. The fever helps immune cells to migrate to infection by a process known as chemotaxis. What fever and inflammation could mean in the proposed picture about SPs?

A possible explanation is as follows.

1. Quite generally, the loss of quantum coherence as a reduction of h_{eff} induced by the attack by bacteria should transform ordered energy to heat and produce entropy and also raise the temperature inducing fever. One possible mechanism producing heat in the loss of quantum coherence could be the decay of dark cyclotron condensates and dark photon states to biophotons with $h_{eff} = h$ and with energies around Hagedorn energy of order the energy associated with the physiological temperature. Also the decay of dark proton sequences in the reduction $h_{eff} \rightarrow h$ to ordinary protons would liberate energy as photons: Pollack's experiments show that IR irradiation produces exclusion zones (EZs) most effectively so that the energy would be in IR range.

2. Inflammation involves HSPs, in particular HSP70 [I88]. If the heat produced by the infection causing the fever can be seen as an entropic waste energy, SPs such as HSP90 would do its best to transform it to ordered energy realized as metabolic energy quanta with the nominal value around .5 eV. As discussed, this would mean a formation of bound states liberating energy - for instance, HMP90-ATP bound state would liberate energy with part going to the MB of HSP70/90 and part to a local environment.

HMP70/90 acting as ATPases in the bound state and generate metabolic energy quanta by the ADP $\rightarrow ATP$ process. The liberated binding energy could cause the observed raise of C_p of the MB of HMP90 and allow it to absorb more effectively heat energy from the environment by temporary time reversal and transform it to metabolic energy quanta. HSPs would be thus generated to absorb the surplus heat to be used as a metabolic energy resource and fever would be reduced as a consequence.

22.2.6 Could 1/f noise be interpreted as a signature of time reversal?

Reza Rastmanesh sent a paper by Dmitri Zhukov with the title "How the theory of self-organized criticality explains punctuated equilibrium in social systems" [J9] (https://cutt.ly/YJUYxOn)

Self-organized criticality (SOC) is a very interesting phenomenon. Systems with SOC are able to stay near criticality. This is difficult, maybe even impossible, to understand in standard ontology since critical states are repellors of the dynamics and the system is expected to approach a stable state rather than remaining near criticality.

One can understand SOC as a manifestation of zero energy ontology (ZEO), which forms the cornerstone of TGD-based quantum measurement theory and TGD inspired theory of conscious experience. "Big" and "small" state function reductions (SFRs), BSFR and SSFR are the basic notions. BSRR is the TGD counterpart of ordinary state function reduction but reverses the arrow of time. SSFR is the counterpart of "weak" measurement and much like classical measurement: in particular, the arrow of change is preserved.

- 1. In TGD the magnetic body of a SOC system would be quantum critical and involve BSFRs in arbitrarily long scales at the level of MB. Since BSFR changes the arrow of time, the repellor becomes an attractor and the system would return to the vicinity of what was a repeller earlier. Homeostasis, which means an ability to stay near criticality, would be made possible by BSFRs: no complex biological control programs would be needed [L225].
- 2. The period of time reversed time evolution for BSFR would correspond from the viewpoint of an outsider with an opposite arrow of time to an apparently stable state. The time reversed evolution to the geometric past would send classical signals to the direction of the geometric past of the observer and they would not be received by an outsider in the geometric future. Hence time reversed states are difficult to observe if the time reversed system is totally in the geometric past of the receiver.

In the case of MB this need not be the case and the receiver could be in the geometric past with respect to the signal source at MB and receive the "negative energy" signal of MB just as would happen in memory recall. This could correspond to anticipation. This was discussed in one of our articles.

- 3. It would seem that BSFR corresponds to the "avalanche" from the point of view of an observer. Earthquakes represent one example of this kind of BSFR [L106].
- 4. 1/f noise is one basic characteristic of SOC and ZEO provides an explanation for it so that 1/f noise could be seen as evidence for ZEO. If the states of time reversed MB are near quantum criticality for BSFR, there are quantum fluctuations and by the scale invariance of the quantum dynamics of TGD they have 1/f spectrum.

[Supersymplectic symmetry involves super-conformal symmetry and scaling invariance justifying 1/f, I just wrote an article about this related to p-adic mass calculations [L198].]

There are two ways in which 1/f noise could be interpreted as signals sent by the time reversed SOC MB. There are two options.

1. Suppose that the time reversed SOC MB is in the geometric past of the observer.

Could the 1/f noise be induced by signals sent by the MB with a reversed arrow of time from the geometric past? These signals would be impossible in the standard classical world since they would propagate in the "wrong" time direction (which would now be the "right" time direction for their receiver!).

"Negative energy signals" are assumed in the model of memory based on time reflection, which involves a BSFR for the system receiving or sending the signal. Could a subsystem of time reversed MB make BSFRs reversing their arrow of time so that they would send signals to the geometric future?

2. Suppose that the observer is in the geometric past of the time reversed SOC MB. In this case the observer would receive the signal sent by MB propagating into geometric past and the receival would involve BSFR for some subsystem of the receiver.

If this picture makes sense, 1/f signals could be seen as communications of time reversed systems with signals propagating in the observer's direction of time.

So: if the time reversed systems exist and if they are also able to send signals also in the time direction of the receiver with some probability, the 1/f noise could be understood as a support for ZEO and TGD based model of memory recall as time reflection.

There is an amusing correspondence with everyday life. A period of sleep would be a counterpart for the silent period predicted by ZEO (sleep as a "small death") and near the wakeup the 1/f fluctuations would become stronger. EEG indeed shows 1/f noise. During aging the noise level increases: old people have problems with sleep as I know so well!

22.3 Speculative mechanisms explaining some biological observations

In the sequel some speculative applications will be considered.

22.3.1 Obesity, failing diets, and SPs

The effects of diets on HSP expression and activation have recently been studied, see for instance [I63, I168, I180, I172]. During the initial phase of diet the weight is lost. After that the weight often starts to regain. Does a new energy source emerge or is the level of metabolic energy consumption reduced so that the weight regain starts although the nutrient feed stays at the same albeit reduced level?

- 1. The fractality of TGD Universe suggests an analogy to our society. Living organism is a molecular society, and the fractality of the TGD Universe encourages looking at the situation from the point of view of our own society. Our energy resources have been depleting and we have learned to save energy, and also to recycle thermal energy to increase thermal efficiency. Could the organism learn to use remote metabolism to extract thermal energy from the environment besides SPs. Note that the thermal energy of a thermal photon at room temperature is rather near to the Coulomb energy of a unit charge assignable to the cell membrane voltage perhaps defining another metabolic energy currency.
- 2. The TGD explanation relies on the proposed ability of at least some SPs to act as ATPases transforming heat energy of their MB to ordered energy realized as metabolic energy quanta. The binding of SPs to ATP [I156] would also liberate binding energy transformed to heat,

which is partially transferred to MB as heat energy serving as an additional metabolic energy source. Also the reduction of heat losses would mean more effective use of metabolic energy.

People having obesity predisposition might generate HSP60 or HSP70 and HSP90 even in situations without stress. Also psychological stress such as depression might generate HSPs [I65]. HSP60 is known to be associated with obesity [I180]. HSP60 is associated with mitochondria and has ATP binding site but does not have ATPase. Could ATP binding site give HSP60 a role analogous to that of ATPase using heat energy of MB of HSP70 to generate ATP from ADP? A more plausible option is that the binding of ATP provides energy for HSP60 and only HSP70 and HSP90 act as ATPases.

HSP70 [I167] expression is considerably higher in obesity without metabolic syndrome but lower in obesity with metabolic syndrome [I172]. This would suggest that the diet induces expression of HSP70 and therefore brings an additional metabolic energy source available. In metabolic syndrome the level of HSP70 utilizing thermal energy and reducing entropy of the system would be abnormally low. Besides the expression of HSP70, also its activation is needed [I103]. If the activation takes a considerable time, one could understand why it takes time for the additional metabolic energy source to emerge.

3. The ability to act as heat engines and ATPases relies on ZEO: the MBs of SPs could extract thermal energy from the environment in a mode with reversed arrow of time: instead of a disappearance of the necessary temperature gradient it would be generated. One can also say that system learns during diet to use remote metabolism.

The phenomenon of remote metabolism or quantum credit card has been previously proposed by Pitkänen [L12]: system would actively extract energy rather than receive it passively. The receiver of effective negative energy signal would be analogous to a population reversed laser assignable to MB. Quantum credit card would facilitate rapid access to energy via bypassing "bureaucratic formalities". This mechanism applies also to information transfer and makes communications possible with effective signal velocity exceeding the maximal signal velocity.

Quite recently, it has been learned that quite simple physical systems can "breathe" by extracting the energy of Brownian motion [D14]: the finding is discussed from the point of view of ZEO in [L130].

- 4. The utilization of metabolic energy becomes more effective during diet and there is less waste of energy. Less nutrients would be required and if the dietary consumption stays at the same albeit reduced levels, fat begins to be regenerated. Dietary stress would induce the generation of SPs. SPs acting as APTases would extract thermal energy from the environment and also from the liberated binding energy in the formation of SP-ATP complex and liberate it as ordered energy by ADP→ ATP process. The slow rate for the generation of enzymes needed to generate and activate SPs might be the reason for the slow response
- 5. One could see the situation also in the following manner. ZEO and time reversal are involved with the extraction of thermal energy from the environment by the MBs of SPs. One can also say that the system learns during the diet to use remote metabolism. The time reversal would be the analog of sleep period. Also we get metabolic energy resources during sleep and the same mechanism could be involved. This could be also seen as hibernation/sleeping at the molecular level and the hibernation/sleep even at the level of organisms could rely on the same mechanism.

22.3.2 Sleigh dogs which run for days without eating, and starving bacterial colonies

Suppose that the general view about SPs is correct. Assume also there is a fractal hierarchy of MBs. Not only those of biomolecules and of smaller systems, but also of cells, organelles, organs, bodies, larger units like populations...

Assume also that $h_{eff} = h_g r$ holds true so that the cyclotron energy spectrum does not depend on the mass of the dark charged particle. This implies that MBs at all levels of the hierarchy can communicate with the lowest level and also exchange energy and serve as metabolic energy sources. SPs would thus allow the transfer of energy to all these levels.

This admittedly speculative picture could explain the reported ability of sled dogs to run several days without eating [I57]: they could store the energy to their MBs and use it during substrate lack. A possible storage to their collective MB would increase further the energy storage ability. This would mean a connection to collective levels of consciousness predicted by TGD and receival of metabolic energy feed as dark photons from these levels [L12]. h_{eff} hierarchy indeed makes possible energy transfer and communications between widely different scales characterizing a hierarchy of conscious entities.

This picture could partially explain also why bacteria in media lacking substrate form tightly bound colonies looking like multicellulars. They could store energy to their MB and use it during its substrate lack. Perhaps also the dissipation is reduced because h_{eff} increases.

The cells could also learn to extract thermal energy of the cellular environment besides the thermal energy of SPs, which is more or less another manner to say the same. Starvation could have been the evolutionary pressure leading to the formation of multicellulars. Indeed, the embryos of multicellulars are found to form tightly bound bacterial colonies [I105]: the TGD based model is discussed in [L146]. There is also anecdotal evidence about analogous abilities of Tibetan monks and people regarded as saints.

To summarize, the proposed general model involves several new physics elements. the new view about space-time and fields, the new view about quantum theory based on ZEO predicting time reversal in BSFRs and a new view about self organization and a realization of SOQC, the h_{eff} hierarchy labelling dark matter as phases of ordinary matter predicted by number theoretic vision about TGD, and the hierarchy of collective levels if consciousness having as a correlate the hierarchy of MBs carrying dark matter in TGD sense. This vision can be defended only by its internal consistency and ability to solve a long list of deep problems of recent day physics.

Chapter 23

Aging from TGD point of view

23.1 Introduction

This article was inspired by a birthday gift. The gift was a highly inspiring book "Lifespan" by David Sinclair and Matthew LaPlante [I58]. The book tells about the recent understanding concerning aging. The general vision about aging represented in the book can be summarized as follows.

- 1. The key idea is that genes do not determine everything. DNA has also continuum degrees of freedom characterized by its shape. These degrees of freedom are related to epigenesis which is higher level control activity controlling what genes are expressed. The basic mechanisms are prevention and allowance of gene expression. Acetylization [I3], methylation [I27] and many other modifications affect the gene expression by attaching to proteins known as histones forming kind of pearls in the necklace defined by DNA: genes follow nucleosomes in the DNA strand. Also the reversals of these processes for instance, deacetylation [I12, I94] and demethylation [I27] are essential for the control of gene expressions.
- 2. Aging involves the emergence of various diseases. Usually the attention is directed to dealing with these diseases. Now the view is however more general. Aging is seen as a gradual approach to chaos manifesting as various diseases. In order to prevent the diseases one should slow down the approach to chaos.
- 3. Epigenetic chaos hypothesis suggests that some control systems associated with information molecules and related to the control of DNA transcription and translation by epigenesis must approach chaos. This is seen as the gradual randomization of DNA conformations causing problems in the transcription of DNA: DNA becomes loopy. The DNA coding for the ribosome acting as the translation machinery of DNA is of special importance and becomes also loopy. What comes first in physicist's mind, is an approach to thermal equilibrium. Is there some system controlling epigenesis which approaches thermal equilibrium with the environment? In standard chemistry it is difficult to identify this kind of system.
- 4. Biology has invented ingenious mechanisms to slow down aging. For instance, there are molecules having two functions. There are proteins making the translation of the genes related to cell replication possible.

When the DNA coding for the ribosome gets loopy their function changes. The translation of genes ceases as the proteins leave the histone molecules and enter the damaged DNA and freeze it so that it can be prepared. This however slows down cell replication and also causes other problems leading to various diseases related to aging. One can say that a cell is like a hospitalized patient.

The slowing down of aging would be in this framework basically fighting against the thermo-dynamical arrow of time. Is it really possible to understand the processes involved in the framework of standard bio-chemistry with a single arrow of time?

Even the understanding of the biocatalysis is difficult: how the reacting molecules are able to find each other in the molecular soup and how the huge increase for the rate of these processes is possible. The TGD based solution of these problems will be discussed later.

What could TGD inspired theory of consciousness and quantum biology rely on zero energy ontology (ZEO) inspired biology allow to say about the mechanism behind aging?

1. Negentropy Maximization Principle (NMP) as the variational principle of consciousness replaces the second law and implies it for ordinary matter. State function reduction (SFR) means a reduction of the entanglement for a pair $S_a - S_b$ of sub-system S_a and its complement S_b in S. Measurement cascade proceeding from long to short scales decomposes at each step a system to a pair of unentangled subsystems is in question. NMP as a variational principle of consciousness states that negentropy gain in these reductions is maximized and selects the pair $S_a - S_b$ at given step.

In adelic physics [L67, L66] the negentropy $N = -S_1 - S_2$ is sum of real and various padic negentropies but p-adic negentropy can be positive so that for non-trivial extensions of rationals one can have N > 0. This kind of entanglement is stable against NMP so that the process stops. One can assign positively colored emotions to this kind of entanglement and it distinguishes between living and inanimate matter and also between dark and ordinary matter.

2. TGD inspired theory of consciousness is basically an extension of quantum measurement theory allowing to get rid of the basic paradox of quantum measurement theory. There are two kinds of state function reductions (SFRs) "big" SFR and "small" SFR (briefly BSFR and SSFR) [L118].

SSFRs are counterparts of "weak" measurements which are much like classical measurements and do not involve any dramatic changes. The sequence of SSFRs gives rise to a conscious entity -self - as a sequence of moments of consciousness. Subjective time as a sequence of SSFRs correlates with the geometric time. BSFRs are counterparts of ordinary quantum measurements and have a dramatic effect: in a very general sense one can say that self dies and reincarnates with an opposite arrow of geometric time.

3. There is a hierarchy of magnetic bodies carrying dark matter as phases of ordinary matter with effective value $h_{eff} = nh_0$ of Planck constant. n corresponds to the dimension of an extension of rationals. The extensions define evolutionary hierarchies with increasing complexity. n serves as a measure of algebraic complexity and as a universal IQ, and also characterizes the scale of quantum coherence. For instance, genes are characterized by the value of h_{eff} associated with their MB.

Since MBs have higher universal IQ than ordinary biomatter, they control the biochemistry. In particular, they would control DNA and DNAs MB would actually realize genetic codons in terms of dark proton triplets. Also dark photon triplets would provide this kind of realization crucial for control of and communication with ordinary biomatter.

- 4. ZEO implies a theory of self-organization [L113] and of self-organized quantum criticality (SOQC) relying on time reversal [L225]. The dissipation of a system looks like in reversed time direction extraction of energy from the environment. Also SOQC becomes possible since criticality, since a state, which is a repeller, becomes an attractor in reversed time direction. The system seems to tend to criticality for an observer with an opposite arrow of time.
- 5. In this framework the aging could be seen as the approach of the system formed by MBs of the information molecules and of ordinary biomatter to a thermal equilibrium. The temperature of MB gradually grows and eventually reaches a maximal temperature (due to the stringy character of flux loops) known as Hagedorn temperature and identifiable as the physiological temperature. System dies.

23.2 Very brief summary about some aspects of aging?

The book of Sinclair and LaPlante [I58] is about aging and how to slow down it. The basic hypothesis is that aging need not mean getting sicker and sicker all the time. Biology has developed molecular tools for slowing down aging and there are longevity genes analogs to SPs taking care of this. It might be possible to help them by a healthy lifestyle.

The books represents a vision involving the following pieces.

- 1. Aging is information loss and molecular level, in particular DNA level. Ribosomal DNA seems to be in a special role assignable to nucleolus. Physicist could try to understand this from the second law: entropy un-avoidably increases . Entropy increases for isolated system but it is perhaps not so simple.
- 2. It has been learned that damage to DNA alone cannot explain aging. There must be additional degrees of freedom assignable to epigenesis as a control of genome. Besides genetic code there should exist additional continuous information carrying degrees of freedom.

Epigenesis involves these degrees of freedom and DNAs conformation (involving coilings of coilings of ...) represents these degrees of freedom. Histones appear tangles along the DNA double strand selecting which genes are expressed. Acetyl tag in the histome allows gene expression to take place. When acetyl is absent, nothing happens. The effect of acetyl tag can be also silenced.

3. There are enzymes Sirn, n = 1, 2, ...7, called sirtuins [I34, I126] (https://cutt.ly/Hjkh0ia). In particular, Sir2 silences so-called mating type genes so that the cell replicates normally. If Sir2 is not present in mating type genes, they are expressed and replication does not take place normally. I understood that for yeast, the cell loses its sexual identity and does not replicate.

During this non-replication period the cell would concentrate on maintenance. Under stress situations this would occur quite generally and make survival possible. If you cannot eat and replicate, sleep, and generate metabolic energy from thermal energy for instance. Also SPs would be at work. On the basis of [L225], one could guess that a kind of hibernation state with a reversed arrow of time could be in question. To live longer it is good to die sufficiently often!

4. This is not the only function of Sir2. When DNA double strand is broken, Sir2 must leave its job and hurry to the broken DNA and catalyze expression of SIRn coding for histone deacetylase HDAC, which removes acetyl tags from histones and deactivates DNA. After this the broken DNA is prepared. This is like putting a victim of a traffic accident to a hospital bed or even artificial coma.

As cells get older, this kind of DNA breaks occur more often and Sir2 must leave its basic job more often and the cell loses its ability to replicate more often. It can also happen that Sir2 does not find its original position in the mating gene and starts to silence a wrong gene. This leads to epigenetic noise inducing aging.

5. In particular, ribosomal DNA in the nucleolus, the largest structure of the nucleus, can end up with chaos. Loops are formed and recombination between portions of the same strand can occur (remember the reconnection mechanism and time reversal). Ribosome plays a fundamental role in translation so that there is no wonder that difficulties emerge. Important class of damage consists of breaking DNA double strands. This leads to a chaotic conformation involving loops. Sir2 must rush to the nucleolus and this means that mating genes activate and the replication stops. When these accidents occur too often, the cell becomes senescent.

23.3 Negentropy Maximization Principle (NMP) and Second Law

The natural expectation is that second law relates to aging. This motivates a section devoted to the recent view about Negentropy Maximization Principle (NMP) [K73] defining the variational

principle of consciousness in the TGD framework and implying in adelic physics [L66, L67] second law in the case of non-negentropic entanglement (in standard physics entanglement is always nonnegentropic).

Mathematically NMP is analogous to the second law in that it is not deterministic like the variational principles of classical physics. For a given entangled system NMP allows state function reduction (SFR) for that sub-system-complement pair for which the negentropy gain is maximal. The state function reduction can occur to any eigenstate of the density matrix of the selected subsystem in accordance with standard quantum measurement theory. This would lead to a product of pure states and the negative entanglement negentropy of the initial state would become vanishing in the final state so that negentropy would increase. The inclusion of p-adic contribution to negentropy identifiable in terms of cognitive information assignable to entanglement changes the situation and the entanglement can be stable against NMP and state function reduction cascade stops to entangled state representing cognitive fixed point. Since negentropy gain is not anymore popssible in SSFRs, death is bound to take place.

23.3.1 General observations about second law

First some general observations about second law.

- 1. Second law is an empirical fact. Second law forces the increase of entropy in statistical sense. Thermo-dynamical equilibrium is the most probable equilibrium. Second law in the standard form assumes a fixed arrow of time. Zero energy ontologuy (ZEO) forces to give up this assumption and allow both arrows of time.
- 2. Quantum physics is certainly behind second law. If you have an entangled system state, SFRs occur for subsystems with reduction probabilities determined by its entanglement with the environment. This eventually leads to a loss of entanglement and quantum coherence and one must apply statistical using density matrix for individual sub-system and eventually justifies thermo-dynamical description. It is important to notice that in SFR the entanglement entropy of an individual system is reduced in SFR but that in the case of ensemble of identical systems this generates entanglement entropy identical to the entanglement entropy of single particle giving thermo-dynamical entropy as a special case.

One can consider two interpretations: a) the generation of entanglement generates single particle entropy although actually the entropy of the entire system does not increase in unitary evolution or b) the transformation of this entropy to ensemble entropy corresponds to second law. Option b) looks more realistic.

This is however only a description for what happens. One can ask what is behind second law. Is there some deeper principle as one might suspect because quantum measurement is so poorly defined theory. For instance, von Neumann proposed that only humans cause SFRs. It is often assumed that decoherence occurs without making any proposal how this happens. What is known and well-tested is that reduction probabilities for a measurement reducing the entanglement are coded by the measured density matrix, and one can say that the system goes to an eigenstate of the density matrix as the entanglement is reduced. For an ensemble of identical particles this process transforms entanglement entropy to ensemble entropy with the same value.

Negentropy Maximization Principle (NMP) is the TGD based proposal for the variational principle behind SFRs.

23.3.2 The new physics elements involved with NMP

NMP involves several new physics elements.

1. What is new is the hierarchy of systems having the hierarchy of space-time sheets as a geometric correlate. At the level of consciousness theory it would have self hierarchy as a correlate. Quantum measurements are assumed to correspond to SFR cascades proceeding from higher to lower levels of the hierarchy.

- 2. ZEO brings in the notions of "small" SFR (SSFR) as counterpart of "weak" measurement and "big" SFR (BSFR) as counterpart of ordinary quantum measurement [L118] and forces giving up the assumption about a fixed arrow of time. This modifies standard thermodynamics and leads to a new view about self-organization self-organized quantum criticality [L113, L225].
- 3. In the standard physics framework there is no definition of negentropy as a measure of conscious information. Negentropy can be only defined as the negative of ordinary entropy and is therefore non-positive. The best that one could have would be vanishing negentropy. This failure is understandable since standard physics does not even try to describe cognition. One manner to solve the problem is to claim that only entropy gradients, whose sign can be also negative matter and thus consider only information flows. In TGD different view is adopted.
- 4. To bring in conscious information one must introduce cognition. In the TGD framework it is assumed to be described by adelic physics [L67, L66]. This brings in p-adic spacetime surfaces as correlates of cognition. Real space-time surfaces are replaced with their adelic counterparts forming a kind of Cartesian product of real and various p-adic space-time surfaces obeying the same algebraic equations.

By $M^8 - H$ duality [L127, L128] one can regard space-time surfaces as surfaces in M^8 or in $H = M^4 \times CP_2$. M^8 is a subspace of the space of complexified octonions O_c and space-time surface is determined as a 4-D "root" of a real polynomial algebraically continued to an octonionic polynomial. If the coefficients of the polynomial are rational numbers, the polynomial makes sense for both real and p-adic number fields implying number theoretical universality. The dynamical principle is simple: the normal space of the space-time surface is associative/quaternionic.

 $M^8 - H$ -duality maps these 4-surfaces to 4-surfaces in H. In both cases one has minimal surfaces. Also the notion of cognitive representation emerges and is essential for the number theoretical universality. It is also crucial for the construction of the scattering amplitudes [L141, L127, L128].

23.3.3 Detailed formulation of NMP

Consider now the formulation of NMP [K73] in this conceptual framework.

1. In adelic physics cognition is described in terms of p-adic degrees of freedom. Entropy is a sum of two terms: $S = S_1 + S_2$.

 S_1 is the ordinary entropy describing the amount of ignorance of the observer about the state of either entangled system - say Schrödinger cat and the bottle of poison.

 S_2 , as the p-adic variant of entropy (also real valued) assignable to cognitive information has an analogous formula and similar defining properties but can be *negative*(!) and is interpreted as a measure for the information carried by entanglement.

The possibility of having negative sign is basically due to the fact that the logarithms $log(p_k)$ of probabilities p_k in the Shannon formula $S = -\sum_k p_k log(p_k)$ for entropy are replaced by the logarithms of their p-adic norms $|p_k|_p$ given by p^{-n} for $p_k = p^n(a_0 + a_1p + ...)$ (note that the exponent changes sign!): $log(p_k) \rightarrow log(|p_k|_p)$. Entropy remains additive since the p-adic norm of product is product of p-adic norms.

A more general formula for the real Shannon entropy S_1 is as $S_1 = -Tr(\rho log(\rho))$ (ρ is the density matrix). Even in the case that the matrix elements of ρ are in the extension of rationals used, this formula need not generalize for S_2 since also $log(\rho)$ should have this property. The manner to avoid the problem is to diagonalize ρ . This is possible if the eigenvalues of ρ - having an interpretation as entanglement probabilities p_k (equivalently reduction probabilities) - belong to the extension of rationals considered.

At the fundamental level this extension is defined by the space-time surface determined by a polynomial with rational coefficients $(M^8 - H \text{ duality } [L127, L128])$: the roots of the polynomial determine the extension and space-time surface (number theoretic holography). If the entanglement probabilities are not in the extension, one might argue that the entanglement is stable - note however that NMP alone could make it stable.

Quantum coherence involves stable entanglement carrying cognitive information measured by S_2 . The destruction of coherence if allow by NMP destroys information defined as the sum $N = -S = -S_1 - S_2$. In absence of cognition one would have $N = -S_1$ and NMP would transform to second law.

- 2. The cascade of "small" state function reductions (SSFRs) eventually leads to a state in which the remaining entanglement is stable. There is no subsystem-complement pair for which SSFR could take place in such a way that negentropy $N = -S = -S_1 S_2$ would increase. The resulting states are analogous to bound states.
- 3. Remarkably, in its adelic formulation NMP states that the total entropy, which tends to be negative for extensions of rationals, gets smaller and negative: information is generated! The pessimistic second law transforms to an optimistic NMP! The gloomy character of second law would be due to the neglect of cognition from physics.

Cognitive entropy gets more and more negative but real entropy which is closely related to it but tending to have a smaller magnitude than p-adic entropy for extensions of rationals also increases [K73] [L118]. Hence their sum tends to increase with the dimension $n = h_{eff}/h_0$ of the extension.

What makes entanglement stable against SSFR? One can consider two mechanisms.

- 1. Adelic physics allows negentropic entanglement, which tends to be stable against SSFRs since it can only become even more negentropic.
- 2. One can also consider another stabilization mechanism. The rule would state that if the density matrix of the subsystem-complement pair does not allow eigenvalues in the extension of rationals considered, the reduction is not possible. For a stable entanglement density matrix would not allow eigenvalues in the extension of rationals considered. One can of course criticize this rule as somewhat *ad hoc* and the first option might be enough. One can also ask whether this mechanism is equivalent with the first mechanism.
- 3. What could be the interpretation of the negentropic entanglement? I have assigned positive emotions like love to this entanglement, also experience of understanding, etc...

NMP implies increase of ordinary entanglement entropy

NMP implies increase of the ordinary entanglement entropy. The hasty conclusion would be that this implies also increase of thermal entropy and thus second law. Here one must be however cautious.

1. Second law as an increase of ordinary entropy would still hold true but the increase of cognitive information would be larger than the increase of the real entropy for non-trivial extensions of rationals (this is always the case).

The asymptotic states with maximum negentropy and with stable entanglement would have maximal real and minimal p-adic entanglement entropy and their sum would be negative - and N = -S would therefore serve as a measure for the amount of conscious information.

2. One might argue that intelligent systems tend to pollute their environment: they are entanglement entropy generators and by witnessing what has been happening to our environment, it would be easy to agree.

One must be however extremely cautious with formulas. The stability of negentropic entanglement means that the real entanglement entropy cannot transform to ensemble entropy and cannot therefore actualize! Is this what distinguishes loving attention as something unique and positive: the entanglement is stable and cannot transform to ordinary entropy?

Could NMP allow the failure of second law in some situations?

The dream about eternal youth seems to be in conflict with the second law. For physicist second law is usually the absolute authority. Working with the details of NMP however force to challenge this view.

A generalization of second law taking into account time reversals is required in ZEO and already this implies apparent breakings of second law. Furthermore, NMP implies second law as the increase of entanglement entropy. NMP does not allow SFRs transforming negentropic entanglement entropy to thermodynamic ensemble entropy unless the SFRs occurs at higher level of hierachy so that the local reduction of negentropy is compensated by its increase in a longer scale. The implications of this fact remain to be understood.

Could NMP break the second law? Can this be consistent with empirical facts? Could the breaking of second law occur at the level of dark matter only? Second law would apply only to the entropy transformable to thermal entropy. The sum $N = -S_1 - S_2$ is what matters: for a trivial extension one has N = 0 so that this transformation is possible. N = 0 can be however true also for non-trivial extensions. Could the total entanglement negentropy assignable to the ordinary matter satisfy N = 0 and be therefore transformable to thermal entropy whereas "dark" entanglement negentropy satisfying N > 0 would not allow this. Could one identify dark/living matter as negentropic matter and ordinary/inanimate matter as non-negentropic thermalizable matter? Note that also the phases with $h_{eff}/h_0 = n$ could in principle have N = 0. The stability of dark entanglement could directly relate to the failure to observe dark matter.

Comparison with the proposal of Jeremy England

Jeremy England [I159] has noticed that living systems increase entropy and has proposed it as a basic principle of biology. England's proposal is discussed from TGD point of view in [?]. I did not however realize in this article the fact, that negentropic entanglement entropy need not allow a transformation to thermal entropy.

One can represent several objections against England's idea.

- 1. Second law cannot force or even allow the generation of life. Second law relates to the occurrence of SFRs but we do not have a real theory of quantum measurement.
- 2. Second law assumes preferred arrow of time and there is a lot of support for its violation in living matter as realized first by Fantappie [J33]: in particular, self-organization processes could involve dissipation with reversed arrow of time.
- 3. To understand life one must take it seriously. Living system is somehow different from inanimate matter. The emergence of life means the generation of conscious information but in the framework of standard physics there is no definition of conscious information.

These objections raise several questions. Why the emergence of life would be accompanied by a generation of entropy? What could serve as a measure for conscious information? How to describe cognition? To these questions adelic physics provides a possible answer. If entropy that England talks about is identified as the entropy produced in SFRs of systems having N = 0, TGD view is consistent with the proposal of England.

Cognitive fixed point instead of thermal equilibrium?

The analogy with the second law strongly suggests that the system approaches a cognitive fixed point (negentropy maximum) during the sequence of SSFRs followed by the analog of unitary time evolution. SSFRs cannot generate negentropy anymore. Since the system does not learn anymore, BSFR is bound to occur. A possible number theoretic formulation for the fixed point could be following.

1. The time evolution following SSFR generates entanglement. This entanglement is maximally reduced in measurements of observables, which correspond to operators, whose action does not affect the states at the passive boundary.

2. Cognitive measurements define an important class of such measurements [L139]. The cognitive quantum states correspond to wave functions in the Galois group G of the extension - that is elements of the group algebra F(G) of G. G can be decomposed to a product $G = \prod G_i$ of subgroups defined by the hierarchy of normal subgroups of G defined by the representation of the extension as an extension of an extension of ... of rationals.

Elements of F(G) decompose to superpositions of products of functions in G_i and the factors are entangled. Note that the order of G_i matters and is induced by the inclusion hierarchy for the extensions considered: the largest extension is at the top of the hierarchy. One has "ordered" entanglement. This is analogous to the directedness of attention which is difficult to understand in the standard physics framework.

Eastern philosophies speak also of states of consciousness in which there is no distinction between observer and observed and not division. Could this kind of attention involve negentropic entanglement between systems, which correspond to the same extension of rationals so that the. attention cannot be directed? Or could it correspond to negentropic cognitive entanglement allowing cognitive SSFRs?

The first cognitive measurement leads to a product decomposition in $F(G/(G_2...G_n)) \times F(G_2...G_n)$ if the entanglement coefficients between $G_1 = G/(G_2...G_n)$ and $F(G_2...G_n)$ are in the extension of rationals considered. Same can happen at the next step and leads to a similar decomposition of $F(G_2,...G_n)$. The maximal cognitive measurement cascade leads to a product of wave functions in $F(G_i)$ but it can happen that there is no measurement cascade at all.

3. The picture leads to ask whether one could speak of cognitive analogs of particle reactions representing interactions of thoughts. Finite group G has always a decomposition in terms of simple factors G_i induced by the hierarchy of normal subgroups. The simplest situation corresponds to a Cartesian product of simple subgroups: $G = \prod_i^{\times} G_i$. In this composition the order of factors does not matter and the situation is analogous to a many particle system without interactions.

The group algebra of G is a Cartesian product of group algebras of G_i and the natural group representations are unentangled tensor products as analogs of free many-particle states. One might say that there are no cognitive interactions. This situation is representable as a product $P = \prod_i P_i$ of polynomials P_i assignable to the factors. This polynomial is not irreducible. Note that the polynomial associated with a given Galois group is highly non-unique and that cognitive representations are discrete and preferred ones correspond to algebraic integers [L127, L128].

An irreducible polynomial representing a composite of polynomials with Galois group G having composition in terms of Galois groups of extension of extension of ... with extension at level i having Galois group G_i . Functional composition $P_{n_1} \circ P_{n_2} \circ \ldots$ can produce a decomposition of Galois groups G_i identified as Galois group of E_i as extension of E_{i-1} . It is not clear to me whether any composition is possible. For a given ordering of the G_i there can be several decompositions. Could non-trivial decompositions, which do not reduce to a Cartesian product, represent cognitive interactions?

The intuition about what happens in particle reactions suggests that the reduction of cognitive entanglement could correspond at space-time level a process in which incoming cognitive many-particle state is represented by a product of polynomials P_{n_i} and outgoing many particle state by the product of polynomials Q_{m_i} such that conservation of degree holds true: $\sum n_i = \sum m_i$. In the interaction region defined by CD, the polynomial would be some irreducible polynomial constructed as a functional composite of polynomials R_i . Do the continuity conditions at the boundaries of CD allow nontrivial interactions not requiring $P_i = Q_i$? Cognitive dynamics based on the representations of the Galois group assignable to cognitive representations would define a number theoretical analog of topological quantum field theory.

4. Suppose that the time evolution following SSFR for individual mutually unentangled subsystems is in good approximation unitary (their interactions with other such subsystems can be neglected) so that they do not entangle, the density matrix of an individual system

suffers a unitary automorphism so that entanglement entropies remain unaffected and the negentropy gain vanishes. One could speak of "asymptotic freedom" as a condition for the cognitive fixed point.

The cognitive fixed point would define the "silent wisdom" of the re-incarnate having the formerly active boundary of CD as a passive boundary of CD. What would be learned during life would help during the next life cycle.

23.4 TGD based model for aging

In this section the TGD based view about aging is discussed. The king idea is that the magnetic bodies (MBs) of information molecules and linear molecules formed from them (DNA,RNA, amino-acids,tRNA) are at very low temperature in the beginning. The temperature of MB starts to raise and approach the physiological temperature. The entropy of MB increases. Since the MB of the molecule controls the molecule, the control by MB starts to fail and this leads to the diseases accompanying aging.

23.4.1 Aging as approach of MB and BB to thermal equilibrium

Ordinary entropy increases for an isolated system, it approaches thermal equilibrium - thermalizes. Aging must correspond to thermalization in some sense. There are two views about this.

- 1. The weak form of the proposal making sense in the standard physics context would identify aging as thermalization. For ordinary biomatter, which already is in thermal equilibrium in good approximation, this idea does not lead to anything interesting.
- 2. Ordinary matter and the dark matter at MBs carrying dark matter as phases of ordinary matter with $h_{eff} = nh_0$ have widely different temperatures at the moment of birth. Aging means that these systems approach thermal equilibrium in the sense that temperatures become identical. MB has infinite number of degrees of freedom and therefore maximal temperature known as Hagedorn temperature identifiable naturally as physiological temperature [L225]. This option will be considered in the sequel.

Consider the situation in TGD.

- 1. What are the continuous degrees of freedom whose entropy growth would lead to aging. In the TGD framework they would be naturally the geometric degrees of freedom associated with the flux tubes of dark DNA controlling ordinary DNA. Their number is infinite implying that temperature is below Hagedorn temperature around physiological temperature. One can assign a temperature to the flux tubes and also to these degrees of freedom and this is below Hagedorn temperature. When temperature at flux tubes increases, the geometric shape starts to thermally fluctuate and the overall size increases. Cells indeed increase in aging as do also we!
- 2. For information molecules the temperature of MB must be very low: dark DNA flux tubes have a very precise shape and therefore also ordinary DNA. For SPs the situation is different and this makes possible their basic functions.
- 3. Aging could simply mean that the dark genome approaches thermal equilibrium with ordinary biomatter at physiological (Hagedorn) temperature and entropy of dark genes and magnetic flux tubes increases. Flux tubes get more and more irregular shaped and induce a development of loops for ordinary DNA and breaks DNA double strand. Nucleosomes are loop like structures associated with histones and also these are known to be lost. Epigenetic chaos is induced. When thermal equilibrium is achieved death as heat death occurs and changes the arrow of time at the level of the entire body which is left in the geometric past of the standard observer to continue life with an opposite arrow of time.

Remark: ELF em fields at EEG frequency range have quantal effects affecting the behavior and physiology of vertebrate [J7]. EEG photons however have energies many

orders of magnitude below thermal energies so that effects should be completely masked. My first proposal for explanation was that the temperature at the space-time sheets of ions is extremely low and below the energy of EEG photons. Later I gave up this option in favor of h_{eff} hypothesis. The two explanations are actually consistent. Thermal energy is proportional to the temperature. For an n-sheeted structure one has by the additivity of thermal energy for different identical sheets $T_H = nT_H(sheet)$ implying $T_H(sheet) = T_H/n$. For the huge values of h_{eff} and thus of n, $T(sheet) \leq T_H(sheet)$ is indeed extremely small!

- 4. There is a connection to the article [L223] about DNA and arrow of time. One can argue as follows. As the electric field along DNA double strand decreases by the shortening of the sticky ends, the string tension as density of electric energy per length decreases, the stiffness of DNA decreases, and the fluctuations start to develop. Second possibility is that the shortening of telomeres and sticky ends is a controlled process causing a programmed aging.
- 5. There are molecules devoted to preparation of the damaged DNA. The epigenetic tags on histones of mating genes could control the arrow of time for the gene involved. If the tag is present, the gene is expressed. If not or if inhibited by say Ser2, the arrow of time is reversed.

Objections related to metabolism

Metabolic energy feed is needed to keep the distribution of h_{eff} :s and even increase the values of h_{eff} - defining universal IQ and characterizing quantum coherence scale. This relates to the second important aspect of life: quantum coherence in long length scales is needed to generate the coherent behavior of ordinary biomatter and is not possible in standard bio.chemistry framework. Ageing would be a gradual reduction of this quantum coherence by thermalization of MBs of the basic information molecules, in particular the dark variants of the basic biomolecules. If you want to live long, take care of your personal quantum coherence!

One can develop some objections against the vision about ageing as thermalization of the MBs of information molecules.

1. Aging is viewed as changes of the body after birth. What about the processes before birth? When sperm and gametes inoculate and divide and divide and form some distinguished organs, this process needs a high amount of energy; that is why mothers get to eat more during pregnancy.

Fetus generates new structures - parts of MBs containing dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter with increasing value of h_{eff} . This requires high metabolic energy feed provided by mother. Information molecules are however still very far from thermal equilibrium and the gradual increase of the temperature of MBs has practically no effects. The situation remains the same also at the young age. At later age MBs approach thermal equilibrium and problems with the bio-control by MB emerge.

2. Reactive Oxygen Species (ROS) cause also damage for DNA: the more ROS, the shorter the life of the cell. That is why food with low calories content or fastings or low carbohydrates (which need less oxygen to burn) diets are good for longevity.

ROS have been also seen as a cause of aging and one could argue that they should cause a lot of damage during the fetus period involving intense metabolism. The repair mechanisms of MB work almost optimally for fetus and at young age and allow handling of the problems due to ROS. The authors of [I58] argue that it is now known that ROS are not the basic reason for aging. As a matter of fact, ROS are essential for the demethylation [I14].

Is apoptosis as programmed cell death consistent with the proposal?

Also programmed cell death - apoptosis - could be treated as an objection against aging as approach to thermal equilibrium. Apoptosis as a programmed cell death cannot be purely thermal event. It could be induced by MB at the higher level of hierarchy as BSFRs. Perhaps by MB of cell group as in the development of fingers from the cell mass. Apoptosis could have several motivations.

1. The basic prediction is that giving systems are intentional systems having free will at all levels. MB at the higher level could act like dictator and destroy quantum coherence locally leading to the death of the cells but generating quantum coherence and generation of structures in longer scales which would also take the metabolic energy resources used by the dead cells.

Negentropy Maximization Principle (NMP) would be the deeper principle behind the second law. Apoptosis would be consistent with the NMP which implies second law as a by-product and as its name tells, implies negentropy increase. Therefore thermalization would not the only cause of cell death.

Apoptosis would indeed generate more complex structures when fingers develop from tissue. Destruction of lower level structure would be the price paid for the generation of a higher level structure and negentropy gain in longer scales.

2. Evolution means steps in which h_{eff} increases in BSFRs and longer scales of quantum coherence at the level of MB emerge. Extinction of cells and sauri would be part of evolution.

A controlled BSFR causing the analog of death/hibernation of a subsystem could be also represented as an objection. The BSFR would have the survival of a larger system as a motivation [L225]. In fact, all motor actions can be seen as BSFRs at some lower level so that life is continual dying! Death/hibernation of a subsystem means savings of metabolic energy and can be seen as one manner to fight against second law since the dead subsystem lives with the opposite arrow of time: living system is basically 4-D entity in ZEO - not just the time slice which corresponds to conscious experience!

Is the biochemical approach trying to describe dissipation as a controlled process?

A general comment related to the distinction of the standard approach and the TGD approach relying on ZEO is in order. Standard approach does its best to identify control mechanisms leading from state A to state B. Huge amount of information exists about reaction pathways and one can only admire these data mountains.

This approach is very natural as long as time reversal is not involved. If this is the case, there are processes, basically healing and repair processes, that occur in a reversed time direction as dissipative processes and each BSFR leading to a time reversed state involves its own reaction pathways. The tragedy would be that the standard approach tries desperately to understand loss of order as a controlled process inventing endlessly reaction pathways!

Of course, this work would not be useless. The problem is however that a deeper understanding is missing and prevents seeing how incredibly simple the picture is at the fundamental level.

- 1. The increase of entropy in reverse time direction apparently breaks second law in the standard time direction. Stress proteins (SPs) discussed in [L225] are involved with this battle. The magnetic bodies of SPs can extract heat energy from the environment in heat shock and heat DNA and proteins in cold shock, and also act as heat engines for molecular motors.
- 2. As also the authors of [I58] emphasize: diseases are a consequence of a loss of information. Disorder increases as quantum coherence is lost, and manifests as numerous diseases. Quite concretely, the h_{eff} distribution flattens in the sequence of SSFRs. System gets less intelligent and is unable to cope with the hard reality! Second law would eventually win although this process can be slowed down by BSFRs of subsystems.
- 3. Things can go wrong in very many ways: as Tolstoy said, families can be unhappy in myriads of different ways but there are very few ways to be a happy family! Therefore the disease centered thinking of medicine is perhaps not the best approach. One should do something which helps to prevent all diseases simultaneously. One can avoid diseases by choosing a healthy lifestyle. Also a medicine relying on the idea that BSFRs for subsystems could help. BSFR could be seen also as falling sleep and resting and gathering metabolic energy even from thermal energy.

- 4. Time reversed dissipative evolution looks like healing in the reversed arrow of time. If this is the case, the tragedy of biology would be the attempt to understand time reversed dissipation in terms of complex control actions based on complex reaction pathways or even as some kind of computer programs.
- 5. MB would be in a key role since most diseases would be problems in the control performed by MB and basically due to the reduction of h_{eff} and therefore of information contents. About detailed criteria for when one has a disease this approach cannot say much.

Loss of the control of housekeeping genes causes vicious circle leading to death

The basic problem from the point of view of longevity would be that during aging MB gradually loses control of not only methylation, acetylation and their reversals but also other modification processes.

A possible explanation for hypermethylation is that the control actions inducing demethylation fail. The observed hypomethylation in the complement of CpG islands could be due the failure of methylation so that the state becomes stable. More generally, this suggests that the loss of control of all modifications is the mechanism leading to the situation in which the modifications cannot be changed. For instance, the differential methylation of hippocampus is known to be relevant for memory recall, which could relate to the emergence of memory problems at the old age.

CpG:s which are hypermethylated appear in the promoter regions of almost all housekeeper genes so that housekeeping [I19] (https://cutt.ly/2jQgOSD), in particular transcription and translation machineries, metabolism, functioning of stress proteins, etc.... becomes difficult.

The enzymes responsible for the methylation and demethylation are especially important for housekeeping genes [I19] whose promoter regions contain CpG islands. Metabolism related enzymes like Cytochrome P450 are involved also with demethylation as enzymes. Methylation of the promoter region of housekeeping genes means also methylation of genes coding for demethylase. This vicious circle - not so positive positive feedback - leads to death.

What causes the loss of the control of these modifications? The mechanisms leading to the loss of control would relate to modifications of the chromatin and DNA organization. These include reduced global heterochromatin, nucleosome remodeling and loss, changes in histone marks, global DNA hypomethylation with CpG island hypermethylation, and the relocalization of chromatin modifying factors [I149, I47, I100]. In the TGD framework these changes would be caused by the thermalization of the MBs of DNA and chromosomes.

Also cancer induces these changes about which the appearance of additional chromosomes in the mitochondrial DNA in cancer is an example. It has been found that a very weak oscillating magnetic field with strength in nanotesla range and with oscillation frequency around 60 Hz (Schumann frequency) leads to the disappearance of additional chromosomes [I192]. The loss of quantum coherence is the general explanation but it is not clear whether this can be due to thermalization at the level of DNA in this case. A possible explanation is that the control by MB at a higher level of hierarchy is lost and the presence of magnetic field re-establishes a connection with this MB in turn re-establishing quantum coherence [L82].

MB controls the conformations of DNA and chromosomes. MB is identifiable as a flux tube network and its control relies on its motor actions involving reconnections and shortenings of the flux tubes by a temporary reduction of h_{eff} . These motor actions of MB would become fuzzy by the thermal motion. The precise motor performance of MB is crucial for the realization of modifications occurring at the promoter regions near histones and at histone tails. Therefore the thermalization of the flux tube degrees of freedom of MB could be the basic reason for the problems.

When does death occur?

Aging could simply mean that the dark genome approaches thermal equilibrium with ordinary biomatter at physiological (Hagedorn) temperature [L225] and entropy of dark genes and magnetic flux tubes increases. Flux tubes get more and more irregular shaped and induce a development of loops for ordinary DNA and breaks DNA double strand. Epigenetic chaos is induced. When thermal equilibrium is achieved death as an analog of heat death occurs and changes the arrow of time at the level of the entire body which is left in the geometric past of the standard observer to continue life with an opposite arrow of time.

BSFR means death and death is bound to occur. But when? TGD proposes a general criterion: at a given step either SSFR or BSFR occurs and the SFR that means maximum negentropy gain takes place. This SFR is not unique. It can be either SSFR or BSFR and in both cases there are a lot of options for the final state.

When would BSFR win in the comparison?

- 1. Total entropy can be defined as the sum of p-adic and real Shannon entropies. p-Adic Shannon entropies involving p-adic norms $N_p(p_k)$ of probabilities p_k in the logarithmic factors $log(N_p(p_k))$ can be negative. In this case they characterize the information (associated with cognition) assignable to the entanglement.
- 2. Real entropy characterizes the lack of information about the state of either entangled system and is associated with sensory input (is the cat dead or alive?). The sum of the real and p-adic entropies can be negative for non-trivial extensions of rationals so that one would have genuine cognitive information. One could also speak of mere cognitive information as the p-adic contribution to the entropy and this can be negative.
- 3. Intuitively it seems obvious that thermalization meaning that the temperature difference between MBs and systems such as genes is reduced, means loss of information defined in this manner. Information molecules cease to be information molecules at least in the geometric degrees of freedom.
- 4. BSFR becomes the winner if SSFRs can give only very small negentropy gain or if the negentropy gain becomes negative. The fact that we do not learn much anymore at the old age, could reflect the reduction of the negentropy gain in SSFRs.

Also the distribution of $h_{eff} = n \times h_0$ values could reduce IQ. As found in [L139], a complete cognitive measurement inducing maximal reduction of entanglement for an extension with dimension n would reduces the state to a product state with state space with dimensions n. which are factors of n and thus smaller than n: instead of single MB with high IQ several with lower IQs. It might happen that the next SSFRs are not anymore able to regenerate larger values of n and the system becomes less intelligent.

An objection against this picture is that there are also situations when resurrection seems to occur: this has happened for people having had near-death experiences. One can also slow down the process of aging by a appropriate diet.

- 1. The slowing down of the aging process is possible by the reversal of the arrow of time at lower levels so that time reversed dissipative processes at these levels look like self-organization and generate order from the point of view of the organism. This would be a general. mechanism used by living matter to slow down the approach of MB to thermal equilibrium with MB.
- 2. This does not however explain resurrection. The opposite BSFR can however occur at the level of the entire organism but with a suitable stimulation like resuscitation opposite BSFR can take place. Taking into account the fact that also the organism is only one level in the hierarchy of conscious entities, this reduces to the first option.

The analog of resuscitation occurs at the atomic level in the experiments of Minev *et al* [L104]. Although the deterministic process apparently leading to the final state of BSFR had already occurred, it could be stopped by a suitable stimulus. In TGD framework the interpretation is that the BSFR had already occurred and the time reversed time evolution apparently leading to the final was observed. A suitable stimulation however induced the opposite BSFR so that the process apparently stopped [L104].

DNA and the arrow of time

There is a connection with the article about DNA and arrow of time by Rastmanesh and Pitkänen [L222]. The proposal is as follows. As the electric field along DNA double strand (with dark DNA strands included) decreases by the shortening of the sticky ends, the string tension as

density of electric energy per unit length decreases, the stiffness of DNA is reduced, and thermal fluctuations start to develop.

Biologist might wonder how various biological and homeostatic maneuvers like weakening of acetylation/phosphorylation/methylation eventually translate to a decrease of the electric field strength along DNA! In the TGD framework one can see the situation in a different manner: chemistry is not the boss now but is controlled by MB.

1. Modifications (or rather, the loss of the control of modifications) are not the primary cause of the weakening of the electric field. What happens at the control level, at MB, is the primary cause. The weakening of the electric field along DNA would correlate with the shortening of the sticky ends carrying electric charges creating the longitudinal electric field.

This would also correlate with the reduction of the level of consciousness at the level of DNA if one is ready to generalize Becker's findings [J5] about the correlation of the strength of the longitudinal electric field along the body axis with the level of consciousness. Similar correlation with consciousness can be assigned to the electric field directed from visual cortex to frontal lobes.

2. The reduction of the electric field strength reduces energy density of DNA and therefore string tension. DNA begins to fluctuate geometrically, which generates epigenetic noise. Initially dark DNA is like a tense guitar string but transforms gradually to spaghetti. Basically the reduction of string tension reflects the dissipation accompanying the approach of MB to thermal equilibrium with the ordinary bio-matter.

One could perhaps say that the reduction of string tension of MB flux tubes forces the reduction of electric field strength and the internal consistency (Maxwell equations) requires reduction of the sticky end lengths proportional to the charges generating the electric field along DNA. Note that also charge separations tend to disappear in the approach to thermal equilibrium.

3. An interesting question is whether hyper-methylation accompanying aging [I84, I190, I174] could be seen as an attempt to minimize the effects of DNA damage - analogous to an amputation of a leg to prevent necrosis. Hyper-methylation accompanies also cancer [I53, I147].

Second view is that hypermethylation is due to the loss of control of MB caused by the approach to thermal equilibrium. Hyper-methylation could be seen as the failure of demethylation caused by the low level of demethylase activated by MB and caused by methylation of the genes coding for demethylase! This positive feedback loop would lead to the failure of the control of MB.

Is the shortening of the telomeres a controlled process or due to thermalization? The first option could be argued to be realistic since otherwise the population would end up to fight about metabolic resources. Second law could of course solve the problem without any need for a controlled action. If the length of telomeres correlates with the charges of the sticky ends proportional to its length which in turn would be proportional to the length of the telomere as proposed in [L222], the conclusion would be that the shortening is not a controlled process.

23.5 Epigenesis and aging in TGD framework

In the TGD framework epigenesis would be control of the biological body by MB consisting of ordinary biomatter. The basic control tool would be dark photon 3N-plets coupling resonantly to the dark proton sequences of proteins serving as enzymes and RNAs serving as ribozymes. The coupling would be precise and based on the addresses defined by dark proton 3N-sequences defining emitting dark 3N-photons.

These would in turn catalyze the basic biochemical processes and here TGD suggests a mechanism explaining why the reactants find each other and where the energy needed to overcome the energy barrier to make reaction fast enough come. The reduction of h_{eff} for flux tubes would be the needed mechanism.

Also other catalysts than enzymes and ribozymes can be considered. For these catalysts and organic and non-organic molecules in general, the coupling with MB could be single photon resonant coupling transforming 3N-photon to bio-photon.

23.5.1 How MB could control biochemistry

How does the general biochemistry picture involving biomolecules and reaction pathways relate to the multi-resonance vision about how MB controls ordinary biomatter? Can one reduce this picture to a description in terms of multir-resonance frequencies - that is to the level of MB and MB-BB communications alone.

1. Suppose that MB of DNA, RNA, or protein controls DNA, RNA or protein by signals from dark genes using multi-resonance mechanism allowing to select the target and use modulation of dark photon signal to code control signals. Also the MB of DNA, RNA, or protein can be controlled by a higher level of the hierarchy.

If all control takes place in this manner, epigenetic control would be control of proteins acting as enzymes, of RNA, in particular ribozymes, and of DNA. MB would also activate genes coding for various enzymes, in particular housekeeping enzymes.

The controlled proteins would be naturally enzymes catalyzing various biochemical reactions.

2. Could the MB of DNA just change its geometric conformation inducing change of DNA conformation and changing also the epigenetic patterns determined by methylation, etc...? This would represent something new: in TGD one has a network of molecules connected by flux tubes, in biochemistry approach one has only molecules.

The first basic mechanism for the change of the conformation would be the reduction of h_{eff} leading to the shortening of the flux tubes and liberation of energy and its reversal. The reduction of h_{eff} is crucial in the TGD based model of bio-catalysis. The opposite process would feed metabolic energy to MB. The formation of reconnection would be another key process and allow to change the topology of the flux tube network. This would be the basic mechanism of the immune system and also of biocatalysis in which the U-shaped flux tubes associated with the reacting molecules would reconnect.

For instance, the actions of cells during say catastrophic events mean typically that proteins like Sir2 come in rescue by travelling along flux tubes or pairs of them serving as highways: these highways do not exist in standard biology. The existing pattern of flux tubes determines the road network. MB would control the topology of this network by reconnecting and by controlling the lengths of the flux tubes by h_{eff} changing transitions: motor actions of MB would be in question.

3. TGD leads to a view about emotions as sensory perceptions of MB. The model for genetic code emerging from a model of bio-harmony [L16, L103, L135, L159] based on icosahedral and tetrahedral geometries and the observation that music expresses and induces emotions leads to the proposal that the bio-harmony characterized by 64 allowed 3-chords in one-one correspondence with DNA codons has 3N-resonances assignable to the 3-chords of the harmony as a correlate. These resonant interactions induce transitions of selected bio-molecules and possibly also specific transitions of a given biomolecule characterizing the harmony. Could epigenesis be regarded as expressions of emotions by music of light?

BSFR would create a superposition of deterministic time evolutions leading to the geometric past. It would define an average time evolution described in terms of reaction pathways. Could the final state of MB in BSFR dictate also the epigenetic patterns - say bio-harmony determined by frequencies of cyclotron transitions of protons? They are indeed determined by the strengths of the magnetic fields at flux tubes. This would conform with the proposal that the outcome of volitional action as BSFR dictates what happens in the brain of geometric past explaining the findings of Libet [J4] [L104].

SSFRs give rise to an approximately classical time evolution and generation of entropy, and therefore aging. h_{eff} distribution becomes flatter and MBs of information molecules and ordinary

matter approaches thermal equilibrium. The distribution for the conformations of the magnetic flux tubes thermalizes and cell size increases. Basically string tensions decrease since the electric fields involved weaken and the electric and also magnetic contribution to the tension weakens.

What could be the general mechanism of bio-catalysis? The MB of the enzyme could activate the enzyme when the value of h_{eff} of a flux tube connecting it to other reactants is reduced and induces the shortening of the flux tube and liberation of energy.

Depending in what direction energy flows, one can imagine two scenarios for what happens.

1. The energy could flow from higher levels of hierarchy to lower levels. The flux tube at the highest level would be shortened and liberate energy transferred to a lower level. At the lowest level enzyme would be excited and return to the ground state and liberate the energy needed to overcome the potential wall making reaction slow. Now the shortening of the flux tube of enzyme's MB does not seem to be necessary energetically.

The process would proceed from higher to lower levels in the hierarchy of MBs by this kind of excitations and de-excitations transferring the energy to the lower level, somewhat like in photosynthesis. The flow of money from top towards bottom in a big project serves as a second metaphor for the course of events.

2. If the process is a generalized motor action involving BSFRs and time reversals, the higher levels in the hierarchy of MBs extract energy from shorter scales (very much like higher levels extract work of lower levels in the social hierarchies!). One could also say that negative energy is sent to the lower levels of the hierarchy.

The lower level would provide the energy by reducing its h_{eff} so that its energy is reduced and energy is liberated and taken by the higher level. This would induce the shortening of magnetic flux tubes at all levels. The cascade would proceed down to the level of MBs of proteins and also the U-shaped flux tubes connecting the protein to the other reactants would shorten and bring the reactants together. The reduction of the flux tube length should provide energy to overcome the potential wall, not only the energy going to the higher level of hierarchy.

It is not quite clear which option is realized. Motor actions involve transfer of metabolic energy from short to length scales giving rise to macroscopic coherent motion: time reversal would be natural from this point of view.

Methylation and acetylation

The figures of https://cutt.ly/Qjgrko3 illustrate the effect of methylation and acetylation of DNA or of histone tail.

- 1. The nucleosomes [I26] surround a given gene but nucleosomes can roll along DNA downstream towards the gene to be transcribed and opens the DNA double strand. The modification of the histone tail can prevent or facilitate the opening of the double strand.
- 2. The portion of DNA between the nucleosome and gene corresponds to the promoter part of DNA initiating the gene expression. Proteins initiating the transcription bind to it or alternatively it can be transcribed to RNA.

The methylation [I26] and acetylation [I2] of the histone tail serves as the first example. The binding of the methyl, acetyl, or some other group to the histone tail has an indirect effect on the gene. Histone is positively charged. Since DNA is negatively charged, DNA and histone bind together.

The addition of a modifier can increase or reduce the charge of the histone and tighten or loosen the binding between histone and DNA. Methyl is positively charged and tightens the binding and makes the opening of DNA necessary for transcription more difficult. Acetyl is negatively charged and loosens the binding so that the transcription becomes easier.

Consider next the methylation of a promoter region (https://cutt.ly/3jj8ohZ).
- 1. A promoter is a sequence of DNA to which proteins bind that initiate transcription of a single RNA from the DNA downstream of it. This RNA may encode a protein, or can have a function in and of itself, such as tRNA, mRNA, or rRNA. Promoter region has therefore two it seems alternative functions.
- 2. The methylation of cytosin occurs at CpG islands associated with the promoter region of gene. Promoter region is the region to which proteins initiating the transcription of gene bind. Methylation occurs also for the promoter regions of CpG-islands [I80].
- 3. How methylation silences the gene transcription? Methylation decreases the charge of DNA locally and loosens the binding to histone. This would favor the transcription of the promoter region instead of the transcription of the gene requiring the binding of RNA polymerase to the promoter region.
- 4. If methyl is always positively charged, the direct binding to DNA reduces DNA charge locally and reduces the interaction between histone and help opening of DNA in the promoter region: this would not facilitate the transcription of gene but transcription of non-translated RNA or protein. The binding would also prevent the binding of RNA polymerase to the promoter region. The start codon of the non-protein coding gene could be in the promoter region.

More facts about DNA methylation [I27] (https://cutt.ly/pjj3G45) are needed to develop a TGD based view about the situation.

- 1. DNA methylation reprogramming occurs during gameto-genesis and early embryogenesis. The methylation patterns are erased and regenerated. This requires that the memory about the methylation pattern is stored. In the TGD framework MB could serve as the temporary information storage.
- 2. DNA methylation occurs also in highly transcribed gene bodies and must be distinguished from the methylation of promoter regions. The methylation of gene bodies seems to relate to splicing and could prevent the transcription of intronic portions of the gene.
- 3. In general, the level of DNA methylation is very low. The level of methylation is however high in promoter regions. In particular, in CpG islands [I9] (https://cutt.ly/sjj3STW) accompanying the promoter regions of genes, especially those coding for housekeeping proteins.
- 4. Usually the methylation of C in CpG leads to a mutation replacing C with T. This could have led to CpG loss in DNA except in CpG islands, where some stabilization mechanism should prevent the mutations: presumably an energy barrier somehow caused by CpG is involved.

Hypermethylation accompanies cancer and also aging [I174, I190] and could be seen in the TGD framework as reflecting the approach to epigenetic chaos basically due to the reduction of the scale of quantum coherence in turn caused by the reduction of the values of h_{eff} .

- 5. CpG loss is believed to be induced by transposable elements (TEs) attaching to DNA and hopping around it. TEs are methylated and lose CpG as C transforms to T.
- 6. So called housekeeping proteins [I19] are enzymes crucial for various functions including general gene expression, and the control of various housekeeping functions takes place via the control of the expression of housekeeping genes. Therefore CpG islands, which are stable against mutations and allow both methylation and demethylation are needed. Dynamical and differential methylation is also known to relate to memory recall in the case of hippocampus.

For CpG islands $C \to T$ the mutations induced by methylation are prevented by some mechanism. The loss of CpG makes sense outside CpG islands since this stabilizes the genes against $C \to T$ mutations.

MB uses enzymes and ribozymes as a tool in the control of the basic biochemical processes. DNA methyltransferases [I28] catalyze methylation and MB would control the process by activation of this enzyme. In the case of demethylation the enzymes used are demethylases [I13].

The mechanism of demethylation can be taken as an example since the failure of demethylation might lead to hypermethylation of CpG islands known to accompany aging [I174, I84] and in TGD framework it could be due to the approach of the dark genome and proteome to thermal equilibrium.

1. Oxidative demethylation [I14] (https://cutt.ly/Gjj2Ilz) replaces CH_3 group with hydrogen. This requires the presence of a reactive oxygen species (ROS). ROS include superoxide O_2^- , hydrogen peroxide H_2O_2 and hydroxyl radical OH.(https://cutt.ly/yjj2Ubv).

Superoxide is produced in aerobic metabolism via $O_2 + e^- \rightarrow O_2^-$. This in turn leads to reactions $2H^+ + 2O_2^- \rightarrow H_2O_2 + O_2$ followed by $H_2O_2 + e^- \rightarrow HO^- + OH$ and $2H^+ + 2e^- + H_2O_2 \rightarrow H_2O$.

2. Demethylation is catalyzed by demethylases in presence of O_2 . N-methyl groups are oxidized with oxygen coming from ROS O_2 and CH_2O splits out so that the net reaction is $R_2N - CH_2 \rightarrow R_2N - H + CH_2O$.

Enzymes known as alpha-ketoglutarate-dependent hydroxylases act as DNA demethylases. Also Cytochrome P450 [I10] (https://cutt.ly/ujj20uK) catalyzes demethylation in histones and some forms of DNA (cytocine associated with CpG). "450" refers to "450 nm"", which is the wavelength at which cytochrome P450 has maximum absorption. The wavelength corresponds to blue light near UV range and the photon energy is 2.76 eV. CYPs is a very large class of enzymes catalyzing metabolic processes.

What TGD view could be?

- 1. Suppose that MB controls bio-matter by expressing its moods coded by bio-harmonies in terms of dark photons 3N-plets (say) with the frequency patterns correlating with mood and affecting matter in mood dependent manner via a transformation to bio-photons.
- 2. 60 per cent of promoter regions of human genes contain CpG islands of length about 100-1000 codons and almost all housekeeping genes have CpG islands in their promoter regions. Why?
- 3. MB would induce both methylation and demethylation and other modification using various enzymes which they could activate by dark 3N-photons using as address the dark proton sequence associated with the enzyme. After activation the reaction would proceed by the proposed general mechanism of biocatalysis.
- 4. One can imagine several alternative courses of events after the activation. Even the question whether the energy transfer is from short to long length scales associated with MB or vice versa is not fully settled: this depends on the arrow of time assignable to this process.

In the case of CYP450, one cannot avoid the temptation to ask whether a biophoton with 450 nm wavelength could be formed in a decay of 3N-dark photon to ordinary photon.

Methylation, aging, and memory

According to [?]https://cutt.ly/njAKgFy), the general trends, supported by an increasing body of both in vitro and in vivo work, are the establishment of global hypomethylation (non-CpG islands) and regions of hypermethylation (primarily CpG islands) with age. CpG islands are located in the promoter regions of genes, in particular those of housekeeping genes.

Hypomethylation outside CpG islands could be due to the spontaneous mutation $C \rightarrow T$ but also the failure of the control of the methylation by MB could be involved. Hypermetylation of promoter regions implies that the promoter region transcribing RNA is transcribed instead of gene. This could be due to the failure of demethylation caused by the loss of the control.

In both cases the loss of control could have the same reason. The MBs of the genes coding for housekeeping genes and possibly also the MBs of the housekeeping enzymes approach thermal equilibrium with the ordinary bio-matter.

How methylation could relate to aging in TGD framework?

- 1. Methylation could become irreversible during aging and lead to hypermethylation if MB loses the control of demethylation. If enzymes are the control tools of MB, the reduced transcription of DNAs coding for demethylases would lead to a failure of the control. The approach of MBs of DNA and enzymes to thermal equilibrium with ordinary biomatter could be the basic reason for the failure.
- 2. Housekeeping proteins are an especially important class of proteins since they catalyze basic biological functions necessary for the transcription of genes also the genes coding form them. Their promoter regions are also almost always CpG islands. Therefore one can say that the methylation of their promoter regions would be a natural cause of various problems with housekeeping activities caused by aging.
- 3. CYP450 catalyzes generation of ROS in turn catalyzing demethylation and a large number of metabolic processes crucial for the functioning of the organism. In particular, demethylation could become less effective with aging due to the reduced level of CYP450. CYP450 is a housekeeping protein and the promoter regions of genes coding for CYP450 would be methylated. Methylation slows down transcription of CYP450 and this in turn slows down demethylation. This positive feedback loop eventually leads to a kind of death spiral.
- 4. Differential methylation of the hippocampus is known to be crucial for the memory recall (here memories are understood as learned behaviors rather than episodal memories) [J50]. Differential methylation is not possible without demethylation. If methylation becomes irreversible the formation of recallable memories becomes more difficult. Short term memory recall as also memory recall in longer time scales indeed become less effective during aging.

23.5.2 How epigenetic information is inherited?

There is evidence for the inheritance of epigenetic information.

- 1. Epigenetic inheritance takes place in mitosis and sometimes also in meiosis. The methylation related epigenetic disorder increases with aging.
- 2. How could the epigenetic information be inherited in this picture? It could be represented by the geometry of MB - flux tube network - and at the genetic level by both control genes. Emotional aspects, something new, would have bio-harmony as a correlate, and bio-harmony is determined by cyclotron frequencies determined by the magnetic field strengths of the flux tubes. Not only cell but also MB replicates and the replication of MB induces replication at cell and DNA level.

Both genetic and epigenetic information could be inherited in the replication if MB replicates geometrically like a particle in the decay $A \rightarrow A+A$. Usually particles are regarded as pointlike and Feynman diagram expresses this. The line A decays to two lines A+A. This makes sense also for 3-surfaces, in particular magnetic bodies, replacing the point like particles. That replication occurs at the fundamental physics is a new element in TGD based vision.

At the level of causal diamonds (CDs) $A \rightarrow A+A$ would look like follows. The CD of A in the initial state and the CDS of A+A in the final state would intersect and contain the vertex region. Could the moods of A be inherited by A:s in A+A under some conditions - in other words, are cyclotron frequency spectra of flux tubes of A inherited?: this is true i the flux tubes would replicate as such.

Some methylation patterns are inherited in meiosis but not all. If these patterns are determined by the bio-harmony, magnetic flux tubes are copied faithfully in some cases even in meiosis but not always.

Chapter 24

TGD View about Language

24.1 Introduction

This chapter has been written together with Reza Rastmanesh, who proposed the topics of the article leading to this chapter. Human languages differ dramatically from their analogs for animals. Animal languages consist mainly of simple signals, warnings and threats for instance; emotional expression dominates and grammar is lacking. Birds can have impressive repertoire of different song patterns and monkeys have gesture language.

There is a huge variety of human languages: speech and written language, sign languages based on gestures, the language of mathematics and computer languages in which emotional expression is absent. One can also regard music as a kind language expressing emotions and creating them. Also pictures define linguistic representations. Children and animals learn language by mimicry and also learn the grammar and syntax without conscious efforts. Adults can learn a foreign language by learning the vocabulary and the rules of grammar. Human language is also special in that it involves conceptualization, metaphors, and analogies representing abstract concepts in terms of objects and actions of the external world.

One might understand the semantic aspect of language in terms of association and conditioning. Language acquisition involves showing the object and saying the word describing it. This suggests that conditioning and association happens so that mere word generates an imagined percept of the object. Conditioning and formation of associations is a very general form of learning assumed to relate to the increase of synaptic strengths leading to a generation of association pathways. In computer science pattern recognition and completion models it mathematically. One one can ask whether the learning of language and language understanding is something more than this.

For more detailed approaches of language theories, interested readers may be referred to references [J35, J38, J37, J49]. The article of Kempe and Brooks [J48] and the review article "From Molecule to Metaphor: A neural theory of language" about the language theory of Jerome A. Feldman by Stefan Frank [J45] gives a deeper perspective to language theories. The notion of embodiment is in key role in these theories and will be in a key role also in the proposal to be discussed.

24.1.1 About language genes

Forkhead box protein P2 (FOXP2) encodes a transcription factor involved in language acquisition and speech [J11]. In addition to FOXP2 a limited number of genes are involved in speaking [J19]. All vertebrates possess FOXP2, however it is estimated that some 120,000-200,000 thousand years ago, some mutations occurred only in humans which aided humans to start initial forms of speaking [J35]. Animals have their own primitive language; both voices and gestures with meaning make communications possible. They mainly recognize each other and communicate with pheromones. As for vocabulary, a short review of the Old Testament, cuneiform writings, glossary of old books, and hieroglyphs clearly shows that the number of entries was quite limited in the past. Therefore, a further progression of language could be almost a matter of cultural communications and technological advances. However, today it is clear that crucial mutations occurred in the non-coding part of the genome controlling the expression of genes coding for proteins [J19] which lead to language evolution. Therefore, the evolutionary step was associated with control of existing genes. Humans are also distinguished from animals by their learning abilities.

Language acquisition must rely on conditioning/associations between language expressions and experiences. It seems that embodiment is the mechanism, which associates to a linguistic expression an imagined sensory perceipt and/or motor action making the emergence of meaning. What is needed is long term memory and also some kind of standardization of percepts so that they consist of standardized mental images. Pattern recognition and completion could give this standardization.

Since sensory and motor imagination could be seen as almost sensory experiences and almost motor actions, this suggests that new communications between auditory organs and sensory and motor areas emerged. Even more generally, this kind of communication could have emerged quite generally. This would be essentially a new form of conditioning and the same mechanism could apply to all kinds of conditionings.

24.1.2 How the mutation of only a few genes led to cultural evolution?

Amazingly, only a few mutations for relatively few genes seems so have led to human languages. Why few point mutations of relatively few genes could have transformed biological evolution to cultural evolution? What happened for these genes? In the biochemistry framework it is difficult to imagine an answer to this question. Here TGD could come in rescue.

Number theoretic physics is part of quantum TGD and essential for understanding evolution as an increase of algebraic complexity. Evolutionary hierarchies would correspond to hierarchies of algebraic extensions of rationals. The dimension n of extension defines effective Planck constant $h_{eff}/h_0 = n$, the larger the dimension, the larger the scale of quantum coherence at corresponding level of magnetic body (MB) associated with the system. One can also say that n is analog of IQ. One can assign a value of h_{eff} characterizing their evolutionary level also to genes. The genes with larger h_{eff} would serve as control genes. The increase of h_{eff} for genes would mean an evolutionary step. Perhaps a dramatic increase of h_{eff} occurred to FOXP2 and some other genes as human language emerged.

Second mechanism could be energy resonance in the coupling of the analogs of DNA, RNA, tRNA, and amino acids consisting of dark proton triplet with their chemical counterparts. The coupling would be between the entire gene and its dark analog and codon sequence would play a role of address. In both cases small changes of the gene could spoil or produce an energy resonance. This sensitivity would make genes an ideal control tool but would also serve as a general mechanism also for genetic diseases. The increase of h_{eff} accompanied by a small mutation to guarantee energy resonance could be the mechanism explaining the importance of FOXP2 and similar control genes.

Note: This chapter was prepared in collaboration with Dr Reza Rastmanesh who provided a lot of biological and neurosscientific knowhow and made inspiring questions.

24.2 Number theoretical aspects of quantum biology

The basic ideas about consciousness and life are discussed in Appendix. Here the aspects relevant for the recent work are discussed.

Fig. 24.1 summarises the role of number theory in the TGD inspired vision concerning consciousness, cognition, and quantum biology and Fig. 24.2 the role of dark matter in TGD inspired quantum biology.

24.2.1 Dark proton representation of genetic code

Fig. 24.3 summarizes the TGD based vision about genetic codes.

Codons as dark nucleons?

The model for codons of genetic code emerged from the attempts to understand water memory [?] The outcome was a totally unexpected finding [?] the states of dark nucleons formed from three



Figure 24.1: Adelic physics as physics of sensory experience, cognition and intentionality

quarks connected by color bonds can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAs, 20 amino acids, and tRNA and there is natural mapping of DNA and RNA type states to amino acid type states such that the numbers of DNAs/RNAs mapped to given amino acid are same as for the vertebrate genetic code.

The basic idea is simple. The basic difference from the model of free nucleon is that the nucleons in question - maybe also nuclear nucleons - consist of 3 linearly ordered quarks - just as DNA codons consist of three nucleotides. One might therefore ask whether codons could correspond to dark nucleons obtained as open strings with 3 quarks connected by two color flux tubes or as closed triangles connected by 3 color flux tubes. Only the first option works without additional assumptions. The codons in turn would be connected by color flux tubes having quantum numbers of pion or η .

This representation of the genetic would be based on entanglement rather than letter sequences. Could dark nucleons constructed as a string of 3 quarks using color flux tubes realize 64 DNA codons? Could 20 amino acids be identified as equivalence classes of some equivalence relation between 64 fundamental codons in a natural manner? The codons would not be separable to letters but entangled states of 3 quarks anymore.

Genetic code would be defined by projecting DNA codons with the same total quark and color bond spin projections to the amino acid with the same (or opposite) spin projections. The attractive force between parallel vortices rotating in opposite directions serves as a metaphor for the idea. This hypothesis allows immediately the calculation of the degeneracies of various spin states. The code projects the states in $(4\oplus 2\oplus 2)\otimes(5\oplus 3)$ to the states of 4×5 with the same or opposite spin projection. This would give the degeneracies D(k) as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies D = 1, 2, 3, 4, 6 are predicted. The numbers N(k) of amino acids coded by D codons would be



Figure 24.2: Dark matter in TGD inspired quantum biology

[N(1), N(2), N(3), N(4), N(6)] = [2, 7, 2, 6, 3].

The correct numbers for vertebrate nuclear code are (N(1), N(2), N(3), N(4), N(6)) = (2, 9, 1, 5, 3). Some kind of symmetry breaking must take place and should relate to the emergence of stopping codons. If one codon in the second 3-plet becomes stopping codon, the 3-plet becomes doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result (2, 9, 1, 5, 3)!

Codons as dark proton triplets?

The model of codon as dark nucleon predicts analogs Δ resonances whose masses differ from those of nucleons.

The hint comes from the fact that DNA nucleotides have a negative charge, which is problematic from the point of view of DNA stability. This suggests that dark codons should have a charge of 3 units screening the charge of the ordinary DNA codon. Pollack effect [?]eans formation of negatively charged exclusion zones as protons are transferred to dark protons at magnetic flux tubes. Could DNA be formed by Pollack effect? Could codons be represented as dark proton triplets?

The problem is that protons however have only 2 spin states: 4 states would be needed as in the case of quarks having also color. Where could the counterparts of spin and color come from?

One could consider adding a neural pion-like and/or ρ_0 meson-like bond connecting neighboring protons. Since ρ_0 has spin 1, this would give 1+3=4 states per bond. However, 2 states are enough and one must get rid of 2 states. The string-like structure of the proton triplet



Figure 24.3: Genetic codes in TGD framework

suggests that the rotation group reduces to $SO(2) \subset SO(3)$ so that ρ meson states split into singlets with helicities 0,1,-1. The doublet (-1,1) would serve as the analog of the isospin doublet (u,d) for baryons and enough to achieve a correct effective number N = 4 of states per single DNA codon. Helicity would replace isospin and the tensor product states could be constructed effectively as tensor products of 3 representations $2 \otimes 2$.

There is also an issue related to the fermionic statistics. Protons are fermions and the total wave function for them must be antisymmetric. For baryons color singlet property allows this. Can one require statistics in the ordinary sense also now? Or could the effective 1-dimensionality of the magnetic flux tube allow braid statistics?

The following variant gives good hopes about the ordinary statistics.

- 1. Adelic physics [?]rings in additional discrete degrees of freedom assignable to the group algebra of Galois group of extension of rationals inducing the extensions of p-adic number fields appearing in the adele [?]
- 2. Galois group acts on the space of space-time surfaces, and one can say that one has wave function at the orbit of the Galois group consisting of space-time sheets. At quantum level quantum states correspond to wave functions in the group algebra of Galois group of extension.
- 3. The role of color degrees of freedom in helping to achieve correct statistics in the case of baryon could be taken by Galois degrees of freedom. One can even consider the notion of Galois confinement as a generalization of color confinement [?]inding codons as dark proton triplets to dynamical units. Codons should be antisymmetric under exchange of dark

protons in Galois degrees of freedom. Also genes as sequences of codons could be bound to dynamical units as Galois singlets. Could this allow ordinary statistics.

If this picture is correct, genetic code would be realized already at the level of dark nuclear physics or even at the level of ordinary nuclear physics if the nuclei of ordinary nuclear physics are nuclear strings. Chemical realization of genetic code would be induced from the fundamental realization in terms of dark nucleon sequences and vertebrate code would be the most perfect one. Chemistry would be a kind of shadow of the dynamics of positively charged dark nucleon strings accompanying the DNA strands and this could explain the stability of the DNA strand having 2 units of negative charge per nucleotide. Biochemistry might be controlled by the dark matter at flux tubes.

24.2.2 Bio-harmony as a realization of genetic code

TGD leads to a notion of bio-harmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron [L23, L24, L124]. The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino acid are predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bio-harmony in question corresponds to DNA codons coding for the amino acid assigned with the orbit.

Codon corresponds to 6 bits: this is information in the usual computational sense. Bioharmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bio-harmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it. For emotional expression at RNA level possibly involved with conditioning at synaptic level see [L81].

Does the generation of nerve pulse patterns by a gene mean at the cell membrane from dark DNA to dark protein map to dark protein (it could be also dark RNA or dark DNA even) associated with the cell membrane. What about communications with RNA and enzymes involved with transcription and translation. Do all basic biocatalytic processes involve them.

What about a generalization of Josephson currents? Dark ions certainly define them but could also dark proton triplets and their sequences associated with proteins give rise to oscillating Josephson currents through cell membrane and therefore to dark Josephson radiation with 3N dark photon units! Proteins themselves need not move much!

The universal language could be restricted to the genetic code which would be realized by dark proton triplets. The 64 codons are formed from 3 20-chord harmonies associated with icosahedron and the unique 4-chord harmony associated with tetrahedron. Bio-harmonies are associated with the so-called Hamiltonian cycles ,which go through every vertex of Platonic solid once. For icosahedron the number of vertices is 12, the number of notes in 12-note scale.

Also tetrahedron, cube, octahedron and dodecahedron are possible and one can consider the possibility that they also define harmonies in terms of Hamiltonian cycles. Dodecahedron would have 5-chords (pentagons as faces) as basic chords and there is only single harmony. Same mood always, very eastern and enlightened as also the fact that scale would have 20 notes.

Also octahedron gives 3-chords (triangular faces) whereas cube gives 4-chords (squares as faces). One can of course speculate with the idea that DNA could also represent this kind of harmonies: sometimes the 3N rule is indeed broken, for instance for introns.

Galois confinement [L139] allows the possibility to interpret dark genes as sequences of N dark proton triplets as higher level structures behaving like a single quantal unit. This would be true also for the corresponding dark photon sequences consisting of 3N dark photons representing the gene in bio-harmony as an analog of a music piece consisting of 3-chords and played by transcribing it to mRNA.

The picture can be viewed even more generally. Any discrete structure, defining graph, in particular cognitive representation providing a unique finite discretization of space-time surface as points with the coordinates of the 8-D embedding space coordinates in the extension of rationals, defines harmonies in terms of Hamiltonian cycles. Could also these harmonies make sense? The restrictions of the cognitive representations to 2-D partonic 2-surfaces would define something analogous to bio-harmony as Hamiltonian cycle of 2-D graph (Platonic surfaces solids can be regarded as 2-D graphs). The interpretation as representations of Galois groups and the notion of Galois confinement is possible although one loses the symmetries of the Platonic solids allowing to identify genetic code.

About the details of the genetic code based on bio-harmony

TGD suggests several realizations of music harmonies in terms of Hamiltonian cycles representing the notes of music scale, most naturally 12-note scale represented as vertices of the graph used. The most plausible realization of the harmony is as icosahedral harmony [L16] (see http://tinyurl.com/yad4tqwl and http://tinyurl.com/yyjpm25r).

- 1. Icosahedron (see http://tinyurl.com/l5sphzz) has 12 vertices and Hamiltonian cycle as a representation of 12-note scale would go through all vertices such that two nearest vertices along the cycle would differ by quint (frequency scaling by factor 3/2 modulo octave equivalence). Icosahedron allows a large number of inequivalent Hamiltonian cycles and thus harmonies characterized by the subgroup of the icosahedral group leaving the cycle invariant. This group can be Z_6 , Z_4 , or Z_2 which acts either as a reflection group or corresponds to a rotation by π .
- 2. The fusion of 3 icosahedral harmonies with symmetry groups Z_6 , Z_4 and Z_2 gives 20+20+20=603-chords and 3+1+5+10=19 orbits of these under symmetry group and almost vertebrate genetic code when 3-chords are identified as analogs of DNA codons and their orbits as amino acids. One obtains counterparts of 60 DNA codons and 3+1+5+10=19 amino acids so that 4 DNA codons and 1 amino acid are missing.
- 3. The problem disappears if one adds tetrahedral harmony with 4 codons as faces of tetrahedron and 1 amino acid as the orbit of the face of tetrahedron. One obtains 64 analogs of DNA codons and 20 analogs of amino acids: this harmony was coined as bio-harmony in [L23, L24]. The predicted number of DNA codons coding for given amino acid is the number of triangles at the orbit of a given triangle and the numbers are those for genetic code.
- 4. How to realize the fusion of harmonies? Perhaps the simplest realization found hitherto is based on the union of a tetrahedron of 3 icosahedrons obtained by gluing tetrahedron to icosahedron along its face which is a triangle. The precise geometric interpretation of this realization has been however missing and some possibilities have been considered. The model could explain the two additional amino acids Pyl and Sec appearing in Nature [L23, L24] as being related to different variant for the chemical counterparts of the bio-harmony.

There is also a slight breaking of symmetries: ile 4-plet breaks into ile triplet and met singlet and trp double breaks into stop and trp also leu 4-plet can break in leu triplet and ser singlet (see http://tinyurl.com/puw82x8). This symmetry breaking should be understood.

Cell membrane and microtubules as a higher level representation of genetic code?

Also the representation of genetic code at the level of cell membrane can be considered [L97]. This kind of proposal have been made with different motivations by Okecukwu Nwamba [I157]. The motivation for the current proposal is that the lipids have at their ends negatively charged phosphates just as DNA nucleotides have. The generalization of DNA as a 1-D lattice like structure to a 2-D cylindrical lattice containing nucleotide like units - letters - possibly assignable to lipids and realized as dark protons. Single lipid could be in the role of ribose+nucleotide unit and accompanied by a neutralizing and stabilizing dark proton. For axons one would have cylindrical lattice. The two lipid layers could correspond to two DNA strands: the analogs of the passive and active strand.

The finding is that membrane affects protein's behavior. This would be understandable in the proposed pictures 2-D analog of 1-D nucleotides sequences with codons replaced with counterparts of genes as basic units. That lipids are accompanied by phosphates with charge -1 gives the hint. Phosphate charge is neutralized by a dark proton as an analog of a nucleotide.

The notion of Galois confinement identifying genes as units consisting of N dark proton triplets representing genetic codons suggests that genes possibly assignable to the lipid layers of

the cell membrane could communicate using dark 3N-photon sequences with the proteins, genome, RNA and DNA. Dark variants of the control genes could initiate a nerve pulse pattern. An interesting possibility is that ganglions, nucleus like structures assignable to sensory organs and appearing as basal ganglia in brain [I99] (https://cutt.ly/zfWoBFt) could communicate with genes.

Also microtubules have GTPs with charge -3 bound to tubulins. In dynamical instability known as treadmilling the transformation of $\text{GTP} \rightarrow \text{GDP}$ bound to β tubulin by hydrolysis induces the shortening of the microtubule at minus end whereas the addition of tubulins bound to GTP induces the growth at plus end. Also actin molecules bound to ATP show a similar behavior. Could they be accompanied by dark DNA codons? Are all codons allowed or does the absence of XTP, X= T,C,G mean that only codons of type GGG would be present?

For the dark codons for the cell membrane the p-adic length scale $L(151) \simeq 10^{-8}$ m would correspond to the lipid's transversal size scale and would be the distance between the dark protons. The scale of dark nuclear energy would be proportional to 1/L(151) and scaled down by factor ~ 10^{-3} from that for DNA. The energy scale should be above the thermal energy at room temperature about .025 eV. If the energy scale is 2.5 eV (energy of visible photon) for DNA, the condition is satisfied. Note that 2.5 eV is in the bio-photon energy range. For p-adic large scales longer than L(151) thermal instability becomes a problem.

It is interesting to compare the number of codons per unit length for ordinary genetic code (and its dark variant) and for various membranes and microtubules.

- For the ordinary genetic code there are 10 codons per 10 nm defining p-adic length scale L(151). This gives a codon density $dn/dl = 10^3/\mu m$ in absence of coiling. The total number of codons in human DNA with a total length $L \sim 1$ meter is of order $N \sim 10^9$ codons. The packing fraction of DNA due to coiling is therefore huge: of order 10^6 .
- If each lipid phosphate is accompanied by a dark proton and if lipid correspond to square at axonal cylinder with side of length d = L(151) and the radius R of axon corresponds to the p-adic length scale $L(167) = 2.5\mu$ m (also of the same order as nucleus size), there are about $dn/dl = 2\pi (R/d)^2 \sim (2\pi/3) \times 10^4 \sim 1.3 \times 10^5/\mu m$. Axon should have length $L \sim 1$ cm to contain the entire genome.

The same rough estimate applies to microtubules except that there would be one codon per GTP so that the estimate would be 3 times higher if GTP corresponds to length scale L(151) of tubulin molecule. It has been proposed that genetic code is realized at the microtubular level.

• The nuclear membrane assumed to have a radius about $L(167) = 2.5\mu$ m could represent $N \sim (4/3)R^2/d^2 \sim .8 \times 10^5$ codons. This is a fraction 10^{-5} about the total number of codons. For a neuronal membrane with radius $R \sim 10^{-4}$ meters assignable to a large neuron the fraction would be roughly 10^{-1} . The fraction of dark codons associated with membranes could correspond to genes involved with the control and communication with genome and other cell membranes. Note that the non-coding intronic portion dominates in the genome of higher vertebrates. One can ask whether the chromosome structure is somehow visible in the membrane genome and microtubular genome.

24.2.3 Galois group of space-time surface as new discrete degrees of freedom

Galois confinemenent

The problem is to understand how dark photon triplets occur as asymptotic states - one would expect many-photon states with a single photon as a basic unit. The explanation would be completely analogous to that for the appearance of 3-quark states as asymptotic states in hadron physics - the analog of color confinement [L142]. Dark photons would form Z_3 triplets under the Z_3 subgroup of the Galois group associated with corresponding space-time surface, and only Z_3 singlets realized as 3-photon states would be possible. The invariance under Gal(F) would correspond to a special case of Galois confinement, a notion introduced in [L137] with physical motivations coming partially from the TGD based model of genetic code based on dark photon triplets.

Cognitive measurement cascades

Quantum states form Galois group algebra - wave functions in Galois group of extension E. E has in general decomposition of extension E_1 as extension of E_2 as extension of ... to a series . Galois group of E has decomposition to product of $Gal(E) = Gal(E/E_1)Gal(E_1)$ and same decomposition holds true for $Gal(E_1)$ so that one has hierarchy of normal subgroups corresponding extension of extension of...hierarchy defined by a composite polynomial $P(x) == P_1(P_2(x))$ with P_2 having similar representation. P defines in M^8 picture the space-time surface. This maps a tensor product composition for group algebra and the factors of group algebra entangle. SSFR corresponds to a quantum measurement cascade: SSFR in $Gal(E/E_1)$, SSFR in $Gal(E_1/E_2)$ etc.

Could this cascade relate to the parsing of a linguistic expression? It would certainly correspond to a sentence S_1 about a sentence S_2 about ... such that one substitutes a concrete sentence for S_1 first, then to S_2 , etc.... The sentences in the sequence indeed have h_{eff} which decreases. This is the case in the cascade of SSFRs since $h_{eff}/h_0 = n$ is the dimension of E_n .

I also mentioned the number theoretic measurement cascades for purely number theoretic Galois degrees of freedom. http://tgdtheory.fi/public_html/articles/SSFRGalois.pdf.

Could cascade of flux tubes decaying to smaller flux tubes with smaller value of h_{eff} should correspond to this hierarchy. Certainly this is linguistics but the sentence as argument could correspond to several sub-sentences - different flux tubes. Could a neural pathway defined by the branching axon correspond to a concretization of this kind statement about statement (or multistatement, perhaps nerve pulse pattern generated by nerve pulse patterns arriving to a given neuron) about...

24.2.4 Energy and frequency resonance as basic elements of dark photon communications

Dark photon realization of genetic code leads to a view about fundamental linguistic communication based on resonance and we will write a separate paper connecting TGD with language soon. Two systems can be in communication when there is resonance. $E = h_{eff} f$ and energy conservation implies

$$h_{eff,1}f_1 = h_{eff,2}f_2$$
.

For $h_{eff,1} = h_{eff,2}$, energy conservation implies that both energies and frequencies are identical: $E_1 = E_2$ and $f_2 = f_2$. Both energy and frequency resonances in question.

In the general case one has $f_1/f_2 = h_{eff,2}/h_{eff,1}$ and frequency scaling takes place. The studies of water memory lead to the observation that this kind of phenomenon indeed occurs [I52]. The communications of dark matter with ordinary matter and those between different values of h_{eff} involve only energy resonance. Frequency and wavelength scaling makes it possible for long scales to control short scales. Dark photons with EEG frequencies associated with the big part of MB transform to bio photons with a wavelength of say cell size scale and control dynamics in these short scales: for instance, induce molecular transitions. This is impossible in standard physics.

The resonance condition becomes even stronger if it is required there is a large number of biomolecules in resonance with dark matter realized as dark variants of biomolecules and dark ions. Cyclotron resonance energies are proportional to \hbar_{eff} characterizing magnetic flux tubes and to the valued of the magnetic field strength dictated by the quantization of the monopole flux quantization by the thickness of the flux tube which can be do some degree varied by varying the thickness of the flux tube giving rise to frequency modulation.

The findings of Blackman *et al* [J7] suggest that $B_{end} = 0.2$ Gauss defines an important value in the spectrum of B_{end} values. It could correspond to the field strength for the monopole flux part of the Earth's magnetic field: besides this there would be a non-monopole flux part allowed also in the Maxwellian theory.

There are however indications that the value B_{end} is quantized and is proportional to the inverse of a biologically important p-adic length scale and thus would be quantized in octaves.

This could relate directly to the octave equivalence phenomenon in music experience. The model of bio-harmony [L23, L24, L124] suggests a further quantization of the octave to Pythagorean 12-note scale of music. This would not be only essential for the music experience but communications of emotions and molecular level using the music of light.

Selection of basic biomolecules by energy resonance

The dark particles must have energy resonance with bio-molecules in order to induce their transitions. This seems to pose extremely strong conditions possibly selecting the bio-molecules able to form interacting networks with dark matter and with each other. One expects that only some amino acids and DNA type molecules survive.

Nottale's hypothesis provides a partial solution to these conditions. Nottale proposed the notion of gravitational Planck constant

$$\hbar_{ar} = GMm/v_0$$

assignable in TGD to gravitational flux tubes connecting large mass M and small mass m and v_0 is velocity parameter. The gravitational flux tube presumably carries no monopole flux. The TGD based additional hypothesis that one has equals to

$$hbar_{qr} = h_{eff} = nh_0$$
.

This implies that the cyclotron energy spectrum

$$E_c = n\hbar_{gr}\frac{eB}{m} = n\frac{GM}{v_0}eB$$

of the charged particle does not depend at all on its m. Therefore in a given magnetic field, say B_{end} , the cyclotron resonance spectrum is independent of the particle.

The energy resonance condition reduces to the condition that the charged ion or molecule has some cyclotron energy coming as a multiple of fundamental in its spectrum in the spectrum of its transition energies. Even this condition is very strong since the energy scale for cyclotron energy in B_{end} is in the bio-photon energy range containing energies in visible and UV. The fact that bio-photons have a quasi-continuous spectrum strongly suggests that B_{end} has a spectrum. The model of bio-harmony [L16, L103] suggests that the values of B_{end} correspond to Pythagorean scaling constructible by quint cycle.

The above simplified picture is formulated for single dark photon communications. The dark proton and dark photon realizations of the genetic code requires 3-resonance that is a simultaneous energy resonance for the 3 members of dark photon triplet. In dark-dark pairing also frequency resonance is possible. In dark-ordinary pairing frequency increases and couples long scales with short scales. Also resonant communications between genes with N codons involving 3N dark photon frequencies must be possible. This requires new physics provided by number theoretical vision.

What happens in the cyclotron resonance?

3 cyclotron energies for flux tubes characterize dark 3-proton triplet and Nottale's hypothesis predicts that they depend on the values of B_{end} for the flux tubes only. Bio-harmony suggests that the spectrum of frequencies and thus B_{end} corresponds to Pythagorean 12-note scale for a given octave. The allowed chords of bioharmy would characterize the emotional state at the molecular level and correspond to the holistic emotional aspects of the communication beside the binary information.

The resonance would require that the dark cyclotron energy changes are equal to corresponding energies in molecular transitions. Galois confinement [L137] makes possible also 3-N resonance. The resonance condition would select basic biomolecules and the ability of dark analogs of biomolecules to simultaneously resonate with several biomolecules would give additional conditions. In particular this would select DNAs and amino acids.

An open question is whether the coupling to ordinary biomolecules involves a transformation of a dark photon triplet or an N-plet to a single ordinary photon. For instance, does the sum of the 3 cyclotron excitation energies appear in the coupling of dark 3-proton state to amino acid in protein? This would have an analog as 4-wave coupling in laser physics allowing in biology the transformation of dark photon triplet to single biophoton/or 3 bio-photons or vice versa. 6-wave coupling of laser physics would be analogous to the coupling of ordinary 3-photon state to dark 3-photon and back to ordinary 3-photon state.

The resonance itself would mean a process in which dark 3-proton cyclotron excitation returns to the ground state and generates dark 3-photon transforming transforming to ordinary photon (or 3-photon) and absorbed by the ordinary codon or amino acid excitation to hither energy state. This state would in turn emit an ordinary photon transforming to dark 3-photon absorbed by dark codon. This mechanism generalizes to 3N-proton states representing genes or dark proteins.

24.3 TGD based view about brain

24.3.1 A new view about the role of nerve pulses in sensory perception

Sensory perception would in TGD generate sensory mental images at sensory organs: this would solve a basic problem of neuroscience due to the similarity of neural tissue in various sensory areas. The new view about time and memory implied by ZEO solves the problem caused by the phantom limb. The pain in the phantom limb is a sensory memory of pain.

The stimulation of temporal lobes indeed generates sensory memories, and people with a cognitive impairment are known for memory feats such as being able to draw a building seen in the past with every detail or to learn music pieces with single listening. These feats can be understood if the memories correspond to "seeing" in time direction with a beam of dark photons travelling to the past reflected back. ZEO allows this.

Since perception involves a lot of processing this would require forth-and back signaling between brain and sensory organs. There would be virtual sensory input from the brain or via the brain. Sensory percept would be an artwork, standardized mental image, resulting as pattern recognition assigning to sensory input standardized mental image nearest to the input.

1. Nerve pulses would not mediate information inside the brain. They would only build short connections between existing flux tube connections parallel to axons. Same happens in an old fashioned telephone network by relays: it would be energy consuming to keep the connections on all the time.

The velocity of nerve pulse conduction is quite too slow to realize the iteration leading to a standardized sensory mental image. If the signal velocity is light velocity, duration of order 1 ms for nerve pulse also for 10 cm neural pathway about 10^6 forth and back travels between sensory cortex and retina.

Communications would occur by dark photons signals with $h_{eff}/h = n$ and with maximal signal velocity allowing for an iteration leading to standardized perceptions as near as possible to the sensory input and representing only the essential features. Dark photons could transform in an energy conserving manner to biophotons with energies in visible and UV range (at least) and thus above thermal energy and therefore having effects not masked by thermal radiation. Brain is known to emit biophotons and they are also associated with axons [K31, K20].

2. All information molecules (neural transmitters, hormones, messengers) would be connection builders so that the view of neuroscience would be badly wrong here. I have discussed this idea earlier but in a slightly different form: the proposal was that information molecules are attached to the end of a flux tube getting longer as the molecule travels to its target. This is possible but unnecessary since it is enough to build just the bridge between existing connections. **Remark:** The view of neuroscience might be very different if information technologies would have been known for a century ago. Same applies to homeopathy and water memory [K62], which still remains curse words in mainstream science, although a lot about the mechanisms involved is known.

The standard view about learning as strengthening of synaptic connections would translate to a gradual build-up of permanent flux tube connections so that communications with dark photon signals would be possible all the time. This would lead to fusion of sender and receiver to a single quantum entangled system.

If the meridians of acupuncture network correspond to this kind of permanent network, they would not require nerve pulses, transmitters, nor information molecules.

3. Nerve pulse patterns would however generate Josephson radiation at EEG frequencies propagating from the brain to its MB from axonal membranes serving as Josephson junctions. EEG would code the nerve pulse patterns as frequency modulated Josephson radiation [K45].

The view about sensory perception and function of nerve pulse transmission differs from the standard view. Nerve pulse transition would not be communication between parts of CNS but building of the communication line for dark photons making possible communications with maximal signal velocity [L57] [K92].

- 1. This would allow generation of sensory mental images at sensory organs by an iteration involving virtual sensory input from brain to sensory organs. Pattern recognition would be realized as a build-up of an artwork representing standardized mental image as near as possible to the original sensory input.
- 2. Neurotransmitters and all information molecules would be bridges needed to construct connected communication lines. Learning as formation of permanent synaptic connections would be generation of permanent bridges of this kind.
- 3. Cell membrane and perhaps also other structures serve as generalized Josephson junctions [K45]. The (generalized) Josephson radiation generated by nerve pulses would give rise to EEG (and perhaps also to its fractal counterparts) as communication of neural information from brain to MB via Josephson frequency modulation. The size scale of the layer of MB would be rather large, of the order $1/f_c$, of the order Earth size in alpha band ($f_c \simeq 10$ Hz).

This view allows to understand imagination as virtual sensory inputs *resp.* motor actions from MB via brain which do not reach actual sensory organs . muscles but virtual sensory organs inside brain for which a good candidates are basal ganglia - ganglions are also associated a with sensory receptors. Dreams (REM), hallucinations, and psychedelic experiences (motor activities during sleep) could be understood as virtual sensory input reaching the sensory organs (muscles).

Also memory recall could involve virtual (real in the case of sensory memories) sensory input from MB at which memory mental images are realized [L148] [L110].

24.3.2 Binaural beat as a support for TGD view about brain

The phenomenon known as binaural beat [J17] provides support for the TGD view about the brain. Binaural beat occurs when sound waves with slightly different frequencies arrive in both ears. The beat can be understood as interference due to the time-varying phase difference of the waves. What is heard is the difference frequency, even when it is below 20 Hz - for instance 10 Hz-, and therefore not audible. The amplitude modulation with 10 Hz would be perceived, not the 10 Hz frequency. Strangely, the binaural beat occurs also when the signals arrive only to separated ears so that interference is not possible.

The TGD based explanation could be that the sound waves generate dark photon signals propagating along flux tubes and having classical em waves as correlates. The waves from different ears would interfere if the flux tubes meet at some point in the brain located at auditory areas perhaps. The first option is that this interference gives rise to the experience of the binaural beat and superposes with the sensory input assigned to ears (one cannot exclude the possibility that the sensory qualia are assigned to virtual sensory organs in the brain). Second option is that the virtual sensory input as feedback sent back to ears as dark photons superpose to the sensory input from ears.

24.3.3 The roles of nerve pulses and oscillations of neuronal membrane in the TGD picture

1. Nerve pulses - or more precisely, the transmitters emitted at synaptics contacts - connect flux tubes to longer pathways along which dark photons signals travel. Biophotons are dark photons transformed to ordinary so that there is empirical basis for this. Dark photons are an optimal tool for communications: light velocity and coherence.

This allows the build of percepts as standardized sensory mental images by feedback. Nanosecond is the time scale for a single feedback loop so that there is a lot of time for this. This also explains dreams as virtual sensory input from the brain of MB to sensory organs in particular eyes (REM).

Imagination can be understood as virtual sensory input which does not reach sensory organs or muscles but stops before it. Imagination is almost sensory experience with input from MB or brain. The notion of virtual sensory input is central for understanding speech comprehension and also inner speech.

2. Nerve pulses patterns modulate generalized Josephson frequencies for the membrane proteins (ion channels and pumps, etc...) and Josephson radiation to big bart of MB codes for the sensory input.

Motor output is from MB in reverse time direction induced by BSFRs. A good guess is that it is via genes and induces gene expression by producing proteins but possible are also other forms of gene expression such as as dark photon signals to cell/neuronal membrane inducing nerve pulse patterns building connected wave guides for motor output as dark photons signals to propagate

24.3.4 Memories

To understand what memories and memory recall could be in ZEO one must specify what the geometrical correlate of subjective "Now" have?

1. The first proposal was that it corresponds to the active boundary of causal diamond (CD). It however turned out that the subjective "Now" could more naturally correspond to the t = T slice of CD with maximal size located in the middle of the CD. Here t corresponds to a linear Minkowski time axis connecting the tips of the CD. If one accepts $M^8 - H$ duality [L126], this picture can be made precise.

The moments "Now" would correspond to "special moments in the life of self" [L126, L147] identifiable as intersections of 6-spheres, which are brane-like entities (branes are encountered in M-theory) appearing as universal special solutions of algebraic equations determining the space-time surfaces in M_c^8 . The values of T correspond to the roots of the real polynomial defining the space-time surface so that the values of "Now" are quantized.

2. During the sequence of state function reductions the active boundary of CD would shift towards the geometric future and the size of CD would increase (in statistical sense). The sub-CDs accompanying sensory and other mental images would shift to the direction of geometric future as CD increases and become potential memory mental images suffering BSFRs in a shorter time scale.

The self would experience a memory mental image as a sub-self in memory recall to be discussed below. The time=constant snap-shots at the upper half of CD assignable to the memory mental images are ordered with respect to the Minkowski time t but the order is opposite to that for the subjective experiences. This was a great surprise to me. They would correspond to subselves to which memory recall builds a connection by entanglement quantally or by sending a signal, which is reflected back in BSFR for the memory mental images.

What about recall of episodic memories in ZEO?

- 1. Spontaneous memory recall could correspond to a death of a memory mental image with an opposite arrow of time and re-incarnation with the same arrow of time as self. This could be accompanied by emission of a past directed "negative energy" signal received by self associated with the moment "Now". The interpretation would be in terms of extraction of metabolic energy: memory recall indeed requires metabolic energy. Active memory recall could correspond to a receival of future directed "positive energy" signal coming from "Now" having interpretation as metabolic energy feed. Energy conservation would force the memory mental image to change the arrow of time.
- 2. The prediction would be that in active memory recall by a "positive energy" signal received by the memory sub-CDs, the order of recalled memories is opposite to that for the real experiences. There is evidence for this kind of change [J34] (see also the popular article "*The human brain works backwards to retrieve memories*" at http://tinyurl.com/y7hbqmug).

24.3.5 Associations at quantum level

How associations could be formed at quantum level? Certainly memories and memory recall are involved and ZEO provides a universal model of memories.

1. In contrast to the naïve expectations, in ZEO the memory mental images would be subselves and would comove with the active boundary of causal diamond (CD identified as an intersection of future and past directed light-cones) and shift to the direction of the geometric future after their creation at t = T hyper-plane of CD at which upper and lower light-cones of CD are glued to together. This is the largest time slice of CD and assumed to define the geometric correlate for the subjective moment "Now".

Memory mental image (associated with sub-CD) continues its Karma's cycle having as basic unit a birth in BSFR, a life consisting of a sequence of analogs of unitary time evolutions followed by SSFRs, death in BSFR and living a life with opposite arrow of time. Memory mental images can live in the brain of the geometry future being connected to the brain "Now" by long flux tubes.

- 2. Memory recall wakes up the memory mental images by sending a message using dark photons received by the memory mental image. The universal model of language suggests that the signal is biological system coded genes serving also as addresses.
- 3. Conditioning in its simplest form should associate two mental images. The classical example about conditioning is a dog, which learns to expect food after it hears the sound of a bell. The primary experience involves both the sound of the bell and getting the food. After the conditioning the mere sound of the bell stimulates activities like salivation. Positive or negative emotions facilitate conditioning. In ZEO framework the learning of the conditioned response would involve two mental images: imagined experience about obtaining the food and the sound of a bell.

They should fuse to a composite mental image, perhaps by entanglement. These primary memory mental images and their almost copies produced later and involving only the bell and the imagined food would form a population of memory mental images in the geometric future shifting farther away. As the dog hears the sound of the bell, a message to the memory mental images in the geometric future is sent. It is realized as frequency modulated dark Josephson radiation from say basal ganglia of sensory organs.

4. A naïve guess is that the modulated Josephson frequencies correspond to a period larger than the temporal distance of the memory mental image from "Now" and defining its age. Rather low frequencies are involved for long term memories and the values of h_{eff} must be scaled correspondingly. The longer the time span of the memory, the larger the value of h_{eff} . The emergence of language is therefore accompanied by the emergence of long term memory. The memory mental images about expectation of food +sound of bell have however a shorter time span. These signals wake-up the memory mental images but they are however not conscious to self - and as they die they send a signal back to the brain inducing an imagined mental image involving also the promise of food. 5. In some cases the signal can reach the sensory organs and a sensory memory mental image is generated. This picture applies also to the acquisition of the language. The larger value of h_{eff} associated with language genes (the value of h_{eff} could vary for a given language gene) meaning larger layers of MBs and a possible fusion of MBs of he communicators, and therefore the ability to remember the associations of the words to sensory mental images for a long time. Hearing of the linguistic expression would also generate internal speech as a particular virtual motor action.

24.4 A TGD inspired vision about language

24.4.1 The role of MB

The proposal is that new layer of MB assignable to larger part of MB outside body was involved with the emergence of language. There are several arguments in favor of this proposal.

- 1. The model for how mutation of few genes like FOXP2 lead the evolution of human languages to be discussed relies on the idea that the value of h_{eff} assignable to dark variants of language genes increases. This means the emergence of new layer of MB having onion-like structure. What emerged was grammatics and syntax as hierarchical structures represented as manysheeted space-time structures distinguishing humans from other animals could have emerged: these tructures can be assigned to MB and they have also interpretaton in terms of extension of rationals leading to n-sheeted structures. The new level of hierarchy would have emerged at the level of the MB including also dark gene first: flux tubes inside flux tubes inside labelled by values of h_{eff} .
- 2. The development of language led to a cultural evolution and could have been a quantum leap in the evolution of collective levels of consciousness: emergence of new levels in the hierarchy of extensions of rationals. Maybe the emergence of gene with large h_{eff} meant that it receives control commands from this collective level of consciousness possibly assgnable to communications, social group, or even larger structure. Recall that the size scale of MB assignable to EEG frequencies is of order Earth size. The basic structure of language are indeed very "social". Subjects, objects, verbs expressing what they do to each other, relations between these entities, attributes (adjectives) characterizing their states. Also the notions of plural and singular.
- 3. One can also ask how it is possible to distinguish between sensory input created by living beings and having meaning from that produced to dead matter. Also humans give emotional meaning to bird's song and vocal signals and gestures of animals but not to the sounds of dead Nature. For autists this ability might be very weakly developed. The natural answer to the queston is that all communications are also communications between magnetic bodies, quite concrete touching, makes it possible to distinguish natural sounds from speech and signals with represent communications. Communications require attention and the flux tube connections between communicators would be correlates for the attention.

Mere mimicry does not require interpretation of the signal as communications. Some birds can mimic the sound of even a car. I remember my astonishment when finnish bird "talitiainen" mimicked the fate motif of Beethoven's symphony No. 5. My neighbours listened to classical music!

There should be also a fundamental difference between the communications of ordinary sounds and speech to brain. The communications of speech could be via the large part of MB outside body whereas ordinary sensory data would be communicated via small part of MB to brain.

4. In language acquisition the role of parents, in particular mother, is crucial. One might of course argue that just mimicry and rewards are enough. But how the child knows that mother is trying to teach her that the word "apple" corresponds to the object that the mother is holding at ther hand. Is the fusion and entanglement of MBs needed?

The acquisition of language by child might also involve the MBs of child and Mother at least fusing to a larger structure. This might help the child to understand that the purpose is to learn to reproduce the word associated with the object that word describes. It could also make possible to learn the grammatics and syntax by becoming a part of larger self already learned these notions.

5. Speech communications happen magically in a good company when people are friendly and benevolent. As a young man I was extremely shy in a company of people who were not my friends. When I had intention to say something, I tried to form sentences in my mind as internal speech before possibly getting courage to talk but found it extremely difficult and I remained usually silent. In a company of good friends I realized that it was not so difficult at all: someone talked through me using me as an instrument.

24.4.2 Genes and language

What is the role of FOXP2 and other control genes?

The question that led to the writing of this article was whether the mutation of the genome leading to FOXP2 gene and other similar genes responsible for control of the genome did lead to the evolution of human language. How? The above mechanism does not distinguish in no manner between linguistic and ordinary associations. What happened?

Evolution in TGD framework means the increase of number the increase of the complexity of extension of rationals and thus increase of its dimension $h_{eff}/h_0 = n$ defining a universal measure of intelligence and also a measure for the temporal and spatial scale of quantum coherence. A possibly dramatic increase of h_{eff} for FOXP2 gene and other key genes is a natural hypothesis explaining why the complexity of the language evolved and led from signals to sentences requiring longer time scale of quantum coherence and also the emergence of complex hierarchical structures naturally assignable to the new extension as extension of the original one.

The larger the value of h_{eff} , the larger the scale of the layer of MB. This suggests that a new level of collective consciousness essential for communications emerged. This layer would be associated with the system formed by the systems communicating using language. This would explain the ability to distinguish between sounds produced by inanimate systems and sounds produced by living systems and having meaning.

The emergence of this new level would have meant emergence of many new things: of speech, of longer time scales of memory and planned action, of a new level of cognition, of imagination in longer time scales, and of cultural evolution.

Second mechanism related to the emergence of FOXP2 and other similar control genes could be energy resonance in the coupling of the analogs of DNA, RNA, tRNA, and amino acids. The coupling would be between the entire gene and its dark analog. Whether the energy resonance occurs for all cyclotron energies of codons separately or for their sum remains an open question. For both scenarios small changes of the gene can spoil or produce an energy resonance. This sensitivity would make genes an ideal control tool but would also serve as a general mechanism also for genetic diseases. The increase of h_{eff} accompanied by a small mutation to guarantee energy resonance could be the mechanism explaining the importance of FOXP2 and similar genes.

What about the development of speech organs and brain areas related to speech?

The development of speech required development of speech organs and brain areas for understanding of language and language production. How important was their role or was the mutation of certain genes responsible for language control enough to initiate the evolution leading to the development of speech organs and needed brain areas?

One can consider the emerge of a layer of MB with a considerably longer scale perhaps assignable to some collective level of consciousness - perhaps even the entire species. MB as a TGD counterpart for magnetic fields in Maxwellian theory indeed has layers or order of Earth size and even much larger. The proposed emergence of a big layer of MB with a large value of h_{eff} could relate closely to Sheldrake's proposal [I165] about learning at the level of species. How this new layer could have affected the evolution of speech organs and new brain regions.

- 1. MB is the key player in TGD. The TGD Universe allows conscious entities and they tend to have ideas as we know. Did MB at some level of hierarchy get an idea about expression of information using temporal sound patterns coupling to dark photons with specific frequencies? That would be a representation of bio-harmony in a new much longer spatial and time scale: did this evolutionary step correspond to the emergence of a new even larger value of h_{eff} to the dark matter hierarchy. Maybe the realization of this new faculty would have been a fractally scaled up variant of earlier realizations making this easier. Did MB make a plan which was eventually realized after a lot of trials and errors?
- 2. What this plan could correspond to? Here p-adic physics enters into the game. p-Adic dynamics for p-adic variants of space-time sheets obeys the same field equations as real space-time sheets. It however allows breaking of a strict determinism of real number based field equations: this non-determinism would correspond to the freedom of imagination.

p-Adic data could give rise to full space-time surface as dynamical patterns but they could correspond only to a piece of its real counterpart. Imagination would be non-realistic. Imagined motor actions and sensory inputs would correspond to this kind of partially fulfilled entions: signals would not reach sensory organs or muscles.

3. How this would apply to MB's plan to create sound producing organs? This plan could proceed by trial and error to become more realistic and gradually find a complete realization. The reduction of the planning to trial and error at dark gene level - would be an enormous simplification and could have meant mutations increasing the value of h_{eff} bringing in larger layers of MB related to the brain areas and speech organs.

24.4.3 Meaning from embodiment in the TGD framework

The notion of embodiment is central for the understanding of how speech gets its meaning. The simplest sentences represent sensory inputs or motor actions. But also very abstract expressions have metaphoric representations in terms of subject and objects and verbs representing actions. Embodiment means that language expressions are transformed to virtual sensory inputs and virtual motor actions creating imaginations of the real ones. This requires formation of associations as generation of sensory and motor mental images.

For instance, the sentence "A does something to B" creates virtual sensory and motor mental images in which A indeed does something to B. Mental images representing A and B and "does something" are generated and could correspond to interaction between two mental images. Basically remembering sensory percept in which A does something to B is enough to provide the meaning and the linguistic decomposition is a model. For instance, the heard speech generates internal speech helping in understanding.

The experience or imagined experience as virtual almost experience with input from MB rather than environment is associated with the expression of language. When the language has been learned, a mere language expression generates memory mental images about the experience associated with the expression. The mechanism is naturally pattern recognition and completion as a general mechanism of association and conditioning also in neuroscience and artificial pattern recognition.

Questions

In the TGD framework the questions are the following ones.

1. How memories are represented and how they give rise to conscious memory mental images? ZEO leads to a general proposal for how memory mental images are represented. First communication of sensory input to the part of MB containing a subself representing memory mental image, call it M. M receives the signals and experiences BSFR analogous to motor action involving a signal to the direction of geometric past to subself representing "Me Now". This signal is transformed to a nerve pulse pattern generating a virtual almost sensory mental image. The general proposal is that in biology at cellular level motor actions are generated as time reversed signals from MB to dark genome inducing neural activity by a signal to cell membrane. The signal from MB to genome would take place by dark photon representation of genetic code and induce BSFR. This mechanism would be quite general.

Genes with N codons must be represented as a dark 3N-photon signal behaving like a single particle like entity. This is not possible in standard physics but adelic physics relying on number theory makes this possible. The notion of Galois confinement [L142] allows dark photon 3N-plets representing genes as sequences of N 3-chords of bio-harmony - kind of music pieces - serving as dynamical units analogous to baryons as color confined units formed from 3 quarks and thus behaving as dynamical units.

The signal would generate a sequence cyclotron resonance peaks at the genome giving rise to a sequence of ticks at dark genome. They must in turn generate a signal to the cell membrane received as a sequence of ticks inducing the sequence of nerve pulses. This seems to require realization of genetic code at the level of the cell membrane level proposed [L77]. The general principle would be the same as in computer language LISP manipulating lists: only identical genes serving as addresses can be in communications by cyclotron resonance. Not only the notion of cyclotrotron radiation but also the notion of generalized Josephson radiation [L22] must be further generalized: dark Josephson photons are replaced with dark 3N-photons.

- 2. Where the sensory signal to MB is generated? Its generation at neuronal or cell membranes as generalized Josephson radiation is not plausible since the time scales do not fit together. The modulation of Josephson radiation by nerve pulses patterns produces ripples rather than slow frequency modulation. A more plausible proposal is that the sensory signal to MB is generated at the basal ganglia of sensory organs as a generalized Josephson radiation with frequency modulation generated by the sensory input.
- 3. What is the basic quantum mechanism of association of the memory mental image B to a sensory input A? In the neuroscience framework it would happen in the associative regions of the brain by new pulse patterns and by learning based on changes in synaptic contacts. Now this would take place at analogous regions of MB to which sensory input is sent as a signal and induced cyclotron resonance for 3N-chords.

A pattern recognition at the level of MB would be in question. This involves a completion of the sinput pattern - sensory mental image - to a pattern representing memory mental image associated with it. This requires a generalization of the existing view about pattern recognition to quantum level. Also this step could involve resonance leading to a fusion of the associated mental images by entanglement. This fused pair of mental images would generate a dark 3N-photon signal propagating to the brain as a generalized cyclotron radiation.

Association to memory mental images gives meaning to linguistic expressions

Association of the auditory input to memory mental images would provide linguistic expressions with meaning.

1. Association is a way to assign meaning to linguistic expressions by embodiment. Language expression is associated with an imagined sensory experience or motor activity. Also internal speech is imagined speech as imagined motor activity and generated by written text.

Association requires wake-up of memory mental image by the speech signal, which in turn generates a virtual sensory brain or lower level of layers of MB. In ZEO memory mental images are in the geometric future of "me Now" so that BSFR must take place: the memory self "dies" when it sends the message as a dark photon signal. The signal eventually arrives in the brain and generates a nerve pulse pattern needed by dark photon communications generating the virtual sensory to virtual sensory organs.

Memory mental images at MB are woken up in ordinary memory recall presumably taking place at the hippocampus [J8]. The frequencies involved are theta frequencies suggesting that the layers involved of MB have the size scale of Earth. In the case of speech the frequencies are in the range 150-300 Hz which suggests that layers corresponding to these frequencies are involved. Also longer time scales such as minute time scale are involved and much bigger layers of MB could be involved.

- 2. The signals could be sent to the MB from sensory organs:
 - (a) Ganglions associated with sensory organs are analogous to brain nuclei and would be the primary receivers of the sensory input. Nerve pulses are generated by neurons above then. Ganglions must play an important role in the generation of sensory experience and motor activities. Ganglions in the brain are called basal ganglia. They could serve as receivers of virtual sensory input and motor output from the brain.

The neuron structures above ganglions also generate nerve pulses and these give rise to communications to the brain along flux tubes associated with neural pathways by dark photons signals. These communications would represent ordinary sensory communications, in particular sounds as mere sounds without meaning. They would also give rise to language acquisition via association.

(b) The view about communications to MB as Josephson radiation modulated by membrane voltage variations suggests that the frequency modulations of membrane potential at frequencies of speech are involved. The earlier proposal that nerve pulse patterns could induce this modulation. They however would correspond to ripples of long wavelength waves. Of course, also axonal membranes involve oscillations of the membrane potential inducing the modulation but this modulation of generalized Josephson energy involving also difference of cyclotron energies is much smaller than that caused by nerve pulses.

The oscillations ganglion membrane potential induced by sound waves could be involved. Frequency modulated Josephson radiation modulated by sounds would propagate to some part of MB. One can consider even the possibility that dark genes such as FOXP2 generate dark 3N-photon radiation. These dark genes could be also realized at the level of cell membrane.

What could be the radiation in the case of dark genes. Could it be generalized Josephson radiation assignable to an array of Josephson junctions defined by dark genes and their conjugates. Sound waves could induce frequency modulations of oscillations of the voltage between the dark genes just by putting them into motion. Does the distance matter.

- (c) The signals would be received by frequency resonance by some layer of MB responsible for memories representing word-sensory/motor associations. What this layer of MB is and where it is located? The flux tubes should allow 3-N dark photon sequences. Their realization outside the biological body does not look realistic. This suggests that the part of MB can be assigned with the brain of the geometric future. Magnetic loops would return back to the brain of the geometric future. The longer the time scale of the memory, the longer the loop. The realization of sensory or in part of MB analogous to associative cortex. What happens in the part of the MB of the future brain representing the memory about association. The analogy of pattern completion of incoming sound signal to sensory input should take place and generate a virtual sensory input to the geometric past as a response along flux loops arriving at the virtual basal ganglia defining virtual sensory organs. Two long loops would be involved. From sensory basal ganglia to the highest motor and sensory areas? And from these to virtual sensory and motor organs.
- (d) The branching of axons suggests a branching of corresponding flux tubes. What could happen in this process? In branching the value of h_{eff} could be reduced for dark photons for instance by frequency doubling. Frequency doubling would transform audible frequencies to patterns of nerve pulses with much higher frequencies. From long to short scales. h_{eff} hierarchy would be essential.

A possible interpretation as a cognitive quantum measurement is possible. Cognitive quantum measurement as a cascade of measurements in the group algebra of the Galois group of extension would give rise to a gradual reduction of effective Planck constants for the factors of the tensor product.

This cascade could correspond to the branching of axons leading to the reduction of biophoton energy in visible or UV to energy above thermal energy and assignable to cell membrane. What happens in branching of the flux tube? Is energy shared to that of n dark photons with the same frequency and smaller h_{eff} . Or does a localization to a single branch occur. h_{eff} would be reduced and f would increase. E would be conserved. Also both processes can occur. Division into n dark photons with $h_{eff} - - > h_{eff}/n$ with f preserved plus a reduction $h_{eff}/n \to h_{eff}/nm$ and increase $f \to mf$ increasing by factor m.

(e) The communication via long flux loops to the small part of MB at the brain cannot correspond to this kind of process since the value of h_{eff} assignable to FOXP2 genes should be preserved. The communication could be to dark control genes such as dark FOXP2 generating signal to neuronal membrane - perhaps dark control gene also there - giving rise to nerve pulse pattern generating virtual almost sensory experience at the virtual sensory organs defined by basal ganglia.

This feedback should have been present already before the emergence of language but in shorter scales and leading to lower layers in the hierarchical structure of the brain ordered by evolution. They would correspond to a hierarchy of increasing values of h_{eff} realized at the level of genome.

These long feedback loops could end also at lower layers inside the brain and also the hierarchy of cortical layers could relate to this kind of feedback hierarchy. The virtual sensory input to the basal ganglia inside the brain would give rise to imagined sensory perceptions and motor actions.

(f) The interpretation as analog of Fourier transform [A4] is suggestive. The cyclotron resonance peaks would generate a sequence of ticks analogous to a Fourier transform of the incoming waves. Music-speech dichotomy suggests itself strongly. Speech could be analogous to a sequence of SFRs - ticks - and singing to superpositions of classical time evolutions connecting them. It is said that the right brain sings and the left brain talks. Could some brain regions sing in the sense that they receive or send the signal as dark cyclotron radiation and could some brain regions talk in the sense that this radiation would induce or be induced by internal speech as virtual motor action.

A holistic representation in terms of frequencies would be transformed to "reductionistic" representation as time series. The correlation function for ticks would have the frequencies in its Fourier transform: stochastic resonance or its analog. Eventually this association to a sequence of ticks could generate a nerve pulse pattern creating a neural pathway making possible virtual sensory input in various sensory areas.

Given language expression corresponds to a huge number sensory percepts and one could argue that this requires a huge number of associations. In the computationalistic framework this would mean a huge amount of computer storage. The model for the generation of mental images predicts that the sensory mental images are standardized mental images generated by a feedback loop giving rise to a pattern recognition. Standard mental images allow also abstraction and conceptualization. One can even consider a quantum counterpart of the classical notion of concept. Concept as the set of its instances would be replaced by wave function in the set of instances giving a large number of different views about the concept.

24.4.4 Bio-harmony as a universal language

Bio-harmony [L16, L103] realizing genetic code for communications is an ideal candidate for a universal language: codon would represent 6 bits and the allowed 64 chords would represent mood at molecular level. There is quite a large number of fundamental moods. Both dark codons and 3-chords bound to units by Galois confinement [L137] can be combined to dark genes by Galois confinement. This language would be minimal. The contents of the message would be minimal - the

address of the receiver same as that of sender - so that LISP like language would be in question. The communications would be based on 3N-resonance. U-shaped flux tubes from receiver and sender forming bridges by reconnection would be the topological aspect of the communications.

The space-time surface associated with n:th order polynomial in M^8 defining the extension of rationals has n sheets corresponding to the roots of the polynomial [L112, L110]. These manysheeted structures would give rise to a geometric representation of hierarchical linguistic structures.

There is also an abstraction hierarchy defined by the functional composition of polynomials giving rise to representation of the Galois group of extension in terms of inclusion hierarchy of normal subgroups. Flux tubes within flux tubes within.... are possible. For extension of extension of ... with extensions having dimensions $n_1, n_2, ...$ one would have n_1 -sheeted structure with sheets replaced with n_2 sheeted structures replaced with..... Substitution of x in $P_{n_1}(x)$ with $P_{n_2}(x)$ with x replaced with....would correspond to this replacement.

Cascades of quantum measurements for the states of the Galois group algebra to a product state in the tensor product of Galois group algebras of the hierarchy of normal subgroups would define cognitive measurements which could be crucial for understanding of language by analysis [L139].

Speech is only one form of communication of binary and emotional information

Concerning production and understanding of speech, one must see the situation more generally in TGD framework.

- 1. Speech is only one form to communicate information and emotions. Also gestures define a language being based on motor expression. An interesting test is how complex gestures developed before speech and whether FoxP2 has anything to do with sign language. Does sign language have grammatics and syntax characterizing formal languages?
- 2. Music and singing is the second form of language and expresses emotions rather than bits. Here harmony is an essential notion. Some basic chords define the harmony expressing the mood. Bits/words do not matter, only the chords used.

This leads in TGD to the model of bioharmony in terms of icosahedral and tetrahedral geometries and 3-chords made of light assigned to the triangular faces of icosahedron and tetrahedron. The surprise was that vertebrate genetic code emerged as a prediction: the numbers of DNA codons coding for a given amino-acid is predicted correctly. DNA codons correspond to triangular faces and the orbit of a given triangle under the symmetries of the bioharmony in question corresponds to DNA codons coding for the amino-acid assigned with the orbit.

Codon corresponds to 6 bits: this is information in the usual computational sense. Bioharmony codes for mood: emotional information related to emotional intelligence as ability to get to the same mood allowing to receive this information. Bioharmony would be a fundamental representation of information realized already at molecular level and speech, hearing and other expressions of information would be based on it.

The surprising findings that RNA is central in conditioning [?]uggest that RNA somehow represents emotions crucial for conditioning [?] Dark DNA and bioharmony for which emotions would be realized at molecular level would make it possible.

What does Universality mean?

There are two views about language: Universality (or computationalism involving only grammar and syntax) concentrates on the formal aspects whereas connectionism concentrates language as a conditioning. For the first option one speaks of language learning as learning of formal rules and this applies to written language and language of mathematics. For the latter option one speaks of language acquisition as an almost unconscious process of imitation. These two views would be fused together in TGD view.

1. There would be only one universal language at the fundamental level. For communications it would be defined by genetic code realized as 3-chords of dark photons forming in turn

3N-frequency composites serving also as units. This code has both the bitty aspect: codon corresponds to 6 bits and the emotional aspect defined by given bio-harmony characterizing that is by the 3-chords defining the bio-harmony and in this manner mood. Genome would define genotype of language and specific languages would be phenotypes.

This code is used in communications between various levels of the hierarchy. At least in control commands arriving from MB to genome. The analog of Josephson radiation from cell membrane mediating sensory data to MB would consist of a sequence of notes but if cell membrane realizes genetic code, also Josephson radiation could consist of 3N-frequency dark photon composites representing genes. Note that the notion of tick makes sense also for 3N-chords. The message would be sent as Josephson radiation or cyclotron radiation and received as ticks corresponding to state function reductions.

Of course, one cannot exclude the single note option - mere temporal pattern of ticks with varying time separations - for the messages to the genome could be the case of speech having constant pitch. For singing and speech mediating emotions the situation melody or sequence of 3-chords would be needed.

Since the language would be realized at DNA level, even plants could communicate using it. Plants are known to communicate and there is evidence that plants can cognize and even count [I64](https://cutt.ly/ffRYXH8). In TGD framework also hormonal communications thought to be chemical would take place by biophotons: the hormones connected by flux tube to molecule in say hypothalamus would build the waveguides to second molecule in body for dark photons to propagate.

The basic new physics building bricks in this picture would be 3N-frequency cyclotron resonance transforming the oscillating signal from basal ganglia membranes to a sequence of ticks in turn inducing a sequence of nerve pulses generating the virtual sensory experience using stochastic resonance coding the frequencies of original signal to peaks in the frequency spectrum of the correlation function for the sequences of nerve pulses. Also dark 3N-photon Josephson radiation assignable to genes represented also at cell membrane level would emerge as a new concept.

2. The universal aspects of the language would be realized as a basic expression of dark genes realized in terms of 3N dark photon composites propagating along flux tubes. The content of the packet is the address to which it sent! This would be just like in computer language LISP. This would be the genotype of language, the universal language based on 3N-frequency-resonance between sender and receiver genes.

This would completely separate the meaning of language expressions from the basic communication mechanism. This is of course true also for kinds of communications. The sender and receiver provide the meaning for language expressions by sensory perceiving them. Understanding of how the meaning is generated is the key problem. This requires theory of consciousness and a new view about the conscious brain.

3. TGD view is based on dark 3N-photon resonance communications between genomes and possibly also the genomes associated with the cell membranes and microtubules realizing the genetic code. The sensory input together with the language expression would provide the primary sensory percept - just as in learning by example. When communicated to the brain and even MB a secondary virtual almost sensory percept and virtual almost motor action would be generated as imagined sensory inputs.

This would be the fundamental association giving meaning to the language. Conditioning would occur and when the mere linguistic input is received, the virtual sensory precept and motor output are generated. Does this require anything new: for instance, does it require that the associations are remembered in some sense or are the associations realized as in neuroscience in terms of synaptic strengths? One would have memory as a learned behavior.

First the sensory input generated by linguistic expression is communicated from the basal ganglia of sensory organ or virtual sensory organ to the sensory and motor cortices by using dark 3N-photon resonance. After this the virtual sensory input and almost imagined) perception is generated. How?: as dark 3N-photon signals propagating in opposite spatial

direction to sensory organs. The fact that nerve pulse conduction is in a single direction only suggests that also time reversal occurs in BSFR.

4. This general picture applies to the formation of associations and conditioning quite generally. This would be also the mechanism of imagination, which also sharply distinguishes humans from animals. The special ability of the humans to imagine would have emerged at the same time as the complex language. This could be due to the mutations of certain language genes like FOXP2 acting as genes for which the 3N-photon resonance is realized and one must understand how this could be the case.

The proposed notion of universality is not in conflict with the fact there exist large number of languages. The development of different languages is actually easy to understand as reflecting the fact that there is underlying universal language which is minimal in the sense that the content of the message is the address of the receiver. Language acquisition is a conditioning process associating sensory inputs and motor outputs to language expressions at a more fundamental level and the words are just labels for them. This is like general coordinate invariance in general relativity. Points of space-time can have infinite manner of different labelings in terms of numbers (now words).

24.4.5 Geometrization and topologization of the grammar and syntax in terms of many-sheeted space-time

These aspects of speech make understanding of speech acquisition possible but what about intentional learning of speech involving learning of grammar and syntax, which have nothing to do with contents of speech? In computer languages and mathematics as language this aspect would dominate.

Fractal flux tubes networks and structures of language

The TGD proposal is that magnetic flux tube networks - possibly trees in case of speech and associated with nerve pulse patterns are in an essential role. Flux tubes are effectively 1-D and have orientation which corresponds to temporal direction of speech and spatial direction of written language. There are flux tubes inside flux tubes flux tubes giving rise to hierarchical structures corresponding to the parsing of language expressions. MB would as many-sheeted structure would geometrize/topologize grammar and syntax.

There are aso 2-D and even 3-D flux tube networks but not accompanied by neural networks. These would be essential for the geometric and holistic aspects of cognition: visual cognition in particular. The meridian system of Eastern medicine could be associated with the MB. These flux tube networks would have been present before the emergence of the neural system and would be possessed even by plants. TGD could reduce the structures of language to purely geometric structures. Sentences would correspond to many-sheeted space-time surfaces with their topology representing the parsing structure. Basic space-time sheets would represent words, and the gluing of them to larger space-time sheets by topological sum operation would build sentences. Topological sum of surfaces A and A_0 essentially means that A is inside A_0 . Also the ordering of the words matters: AB and BA are not the same thing. When A and B are inside an effectively 1-D magnetic flux tube A_0 , the ordering of the positions inside the flux tube makes it possible to tell whether Ais before B or vice versa.

Non-associativity forcing use of brackets in mathematical expressions would be also important $((A + B)C \neq A + BC)$. For instance, (AB)C would correspond to the structure formed from a pair A_0C of flux tubes by putting AB inside flux tube A_0 . A(BC) would be obtained from the AA_0 by putting BC inside A_0 . Putting inside brackets means gluing at a larger space-time sheet. The reader is encouraged to imagine what these examples look like when represented in terms of flux tubes within flux tubes.

The hierarchy of extensions of rationals realized in terms of functional composition of polynomials defining space-time surfaces in M^8 as *n*-sheeted structures provides a number theoretical view about linguistic structures [L126]. The functional decomposition $P_1 \rightarrow P_1 \circ P_2(x)$ replaces each space-time sheet of the n_1 -sheeted structure with an n_2 -sheeted structure associated with P_2 . This is like fractal zoom each sheet to n_2 sheets. This is due to the fundamental theorem of algebra stating that a polynomial P_n of complex argument with degree n obtains all its values n times. The argument $y = P_{n_2}(x)$ of $z = P_{n_1}(y)$ has the same value for n_2 points x_k . This gives n_2 sheets at y. The value z in turned obtained for n_1 points. Therefore n_1 sheets decompose to n_2 sheets.

How the structural elements of language can be understood?

One must understand what is behind the notions of subject, object, verb. How tense, case, singular and plural, pronouns, adverbs, etc. are expressed: at the level of genetic code or of conscious experience as contents of imagined sensory experience and motor activity associated with the experience? Are they coded already by the oscillation pattern of the basal ganglia membrane giving rise to imagined experience beside genuine sensory experience? This would be the most elegant option.

The same FoxP2 gene or its analogs could be involved. Consider tense as an example. How the tense would be coded to the oscillations of the ganglia membrane or to the position of these membranes in the brain - to what subself they represent. Who is talking and about what and when!

- "I see" would correspond to a real sensory perception.
- "I saw" corresponds to immediate personal memory: could this be a virtual almost percept produced by a memory and realized at different places as virtual sensory percept. Basal ganglia associated with a level higher than sensory organs responsible for imaginations and inner speech.
- "I will see" would correspond to sensory percept, precognitions in reversed arrow of time.
- "I have done" seems to refer to a remote past: different time scale and perhaps different value of h_{eff} .
- "I had done" is talk of another self above or parallel me in self hierarchy about me as sub-self as an outsider. Now the basal ganglia would be at some part of the brain containing mental images representing some outsiders, say community as sub-self.

One should also understand what makes the sentence a question or command. In written language formal tools to express whether the sentence represents a question, command or something else have emerged. The many-sheeted structure of space-time should express these aspects of language using fixed words as vocabulary at the basic level. For instance, the building bricks for "Did you do this?" and "Do this!" should have the same "genotype" but different "phenotypes" if the reduction to dark genetic code makes sense. The context represented by a mental image containing the standard mental images representing the words of the sentence would determine "phenotype" allowing to differentiate between the two cases. The geometric representation would be based on flux tubes. Context - the larger flux tube - would be associated with the mental image "I do not know" for "Did you do this?" and "I am the boss" for "Do this!": this context would determine the phenotype just like the environment affects the phenotype in ordinary genetics.

24.5 Appendix: Living matter, biochemistry, and consciousness

The model for living matter relies heavily on the notions of MB carrying $h_{eff} > h$ phases behaving like dark matter and ZEO.

24.5.1 ZEO based quantum measurement theory extends to a theory of consciousness

ZEO based quantum measurement theory [L148] leads to a quantum theory of consciousness (see **Fig. 24.4**)by lifting the observer from an outsider to part of physical system. In particular, the theory predicts that the arrow of time changes in "big" (ordinary) state function reductions

(BSFRs) as opposed to "small" SFRs (SSFRs) as the counterparts of weak measurements (see Fig. 24.5).

This suggests that self-organization in all scales reduces to dissipation with reversed arrow of time. The energies of states increase with h_{eff} and h_{eff} tends to be reduced spontaneously. This means that energy feed is needed to preserved the distribution for h_{eff} : in biology this corresponds to metabolic energy feed. The energy feed necessary for self-organization would reduce to dissipation of self-organizing system in reversed time direction. Dark matter at MB of the system would serve as a master controlling the ordinary matter serving in the role of slave. Note that there would be master-slave hierarchy of MBs ordered by h_{eff} .

This would happen at magnetic and have dramatic implications. Time reversed dissipation looks like energy feed from the environment to system. Self-organization involves always energy feed and generation of structures rather than their disappearance in apparent conflict with second law. Self-organization would correspond to dissipation in reversed time direction implied by generalized second law. No specific mechanisms would be required and only metabolic energy storages- systems able to receive the energy dissipated in reversed time direction - are enough. Obviously this provides a totally new vision about energy technology.



Figure 24.4: Consciousness theory from quantum measurement theory

24.5.2 p-Adic physics as a correlate of intention and cognition

One of the earlier ideas about the arrow of subjective time was that it corresponds to a phase transition front representing a transformation of intentions to actions and propagating towards the geometric future quantum jump by quantum jump. The assumption about this front is unnecessary in the recent view inspired by ZEO. Intentions should relate to active aspects of conscious



Figure 24.5: Time reversal occurs in BSFR

experience. The question is what the quantum physical correlates of intentions are and what happens in the transformation of intention to action.

- 1. The old proposal is that p-adic-to-real transition could correspond to a realization of intention as action. One can even consider the possibility that the sequence of state function reductions decomposes to pairs real-to-padic and p-adic-to-real transitions. This picture does not explain why and how intention gradually evolves increasingly stronger, and is finally realized. The identification of p-adic space-time sheets as correlates of cognition is however natural.
- 2. The newer proposal, which might be called adelic, is that real and p-adic space-time sheets form a larger sensory-cognitive structure: cognitive and sensory aspects would be simultaneously present. Real and p-adic space- time surfaces would form a single coherent whole which could be called adelic space-time. All p-adic manifolds could be present and define kind of chart maps about real preferred extremals so that they would not be independent entities as for the first option. The first objection is that the separate assignment of fermions to every Cartesian factor of the adelic space-time does not make sense. This objection is circumvented if fermions belong to the intersection of realities and p-adicities.

This makes sense if string world sheets carrying the induced spinor fields- define seats of cognitive representations in the intersection of reality and p-adicities. Cognition would be still associated with the p-adic space- time sheets and sensory experience with real ones. What can be sensed and cognized would be represented by the intersection.

Intention would be however something different for the adelic option. The intention to perform quantum jump at the opposite boundary would develop during the sequence of state function reductions at fixed boundary and eventually Negentropy Maximization Principle (NMP) [K73] [L54] (stating that in given state function reduction negentropy gain is in some sense maximized) would force the transformation of intention to action as first state function reduction at opposite boundary. NMP would guarantee that the urge to do something develops so strong that eventually something is done.

Intention involves two aspects: The plan for achieving something which corresponds to cognition and the will to achieve something which corresponds to emotional state. These aspects could correspond to p-adic andreal aspects of intentionality.

The recent view relying strongly on $M^8 - H$ duality lead to ask whether the picture could be made more precise. This picture forces also to challenge the above picture.

- 1. The basic idea is that p-adic integration constants of the differential equation are pseudoconstants having a vanishing derivative but depending on finite number of pinary digitsrational numbers satisfy this condition. In M^8 picture a real polynomial with rational (or possibly algebraic) coefficients determines the space-time surface. The roots of this polynomial as a function of radial light-coordinate r at light-like boundary of CD determine this polynomial. When pseudo constant are allowed, the coefficients become pseudo constants, which are constants at the interval [0; T] divided to sub-intervals $I_1 = [0; t_1], I_2 = [t_1; t_2],$ $\dots, I_N = [t_{N-1}; t_N]$ by the division $0 < t_1 < t_2 < \dots t_N = T$.
- 2. Could the division to the intervals be unique by some argument? The roots of P are identified as moments for which SSFRs occur. Could tk correspond to a root of the polynomial P_k defined in the interva II_k . Could the "very special moments in the life of self" as roots of a polynomial correspond to introduction of new pseudo constants as a p-adic correlate for the state function reduction? Each interval has it own polynomial P_k and the allowed roots r_{k_i} become to the interval $[t_k; t_{k+1}]$ and their number is usually smaller than the degree n of the polynomial. Assume that each polynomial restricted to its own range defines a 4-surface inside the same CD. One would have m separate p-adic space-time surfaces. These surfaces would serve as correlates for intentions or dreams.

How could the real space-time surface as a realized intention relate to these surfaces?

- 1. Each of the 4-surfaces with genuinely constant coefficients of P_k has its own cognitive representation as points common to real and all p-adic variants. If the number of points t_k is finite one indeed has p-adic pseudo-constants for any prime p.
- 2. The realization of intention should be a quantum jump, state function reduction, or action of free will. Does this state function reduction have the selection of one of the polynomials P_k as a real polynomial defining the real space-time surface as a geometric correlate.
- 3. Could one generalize this to fermionic degrees of freedom. In [L119] its is proposed that one could super-symmetrize TGD and quark spinors as embedding space spinors by replacing embedding space coordinates with super fields with components expressible as hermitian composites of second quantized quark and antiquark oscillator operators. Analogous generalization would be made for the second quantized quark field.

In the M^8 picture the real polynomial would be replaced with a polynomial of super coordinate algebraically continued to super-octonionic coordinate. Solutions of the algebraic equations defining space-time surface would be now super-space-time surfaces which are unions of components assignable with the fermionic super coefficients of the super-polynomial.

The rational coefficients of this polynomial could be replaced with pseudo- constants and the above picture seems to generalize. The spinor super-field would be a restriction of the M^8 spinor super-field to the p-adic branches of the p-adic space-time surface. Could the above picture about intentional act as a choice of the real branch generalize.

The next important step is to understand intentional action at quantum level.

- 1. The most general vision is that intention corresponds to a superposition of p-adic spacetime surfaces with coefficients of polynomials which are genuine pseudo constants and by number theoretic universality same in all p-adic sectors. These superpositions would represent intentions and dreams. One could also speak of a dreamy CD containing a dreamy quantum Universe. Since cognitive representations are considered, everything would reduce to an extension of rationals, and the quantum dynamics by SSFRs and BSFRs would not formally differ from that for the real space-time surface and one could speak about transition amplitudes between dreams.
- 2. The realization of an intentional action would correspond to an SFR in which the pseudo constants become genuine constants. The simplest model is that one of the polynomials P_k is selected and be extended to a polynomial in the entire CD associated with P. The origin of CD is in a unique role in M^8 picture and P(0) = 0 makes possible hierarchies of extensions and conservation of number theoretical data as roots of P in the composition of polynomials realized for space-time surfaces.

If $P_k(0)$ is required also for k > 1, any P_k can be selected. One can however challenge the idea that intentional action involves a selection. If $P_k(0) = 0$ for k > 1 is not assumed, P_1 associated with the interval $[0, t_1]$ must be chosen and CD corresponds to its size cale. One can talk about a partial realization of the intention in accordance with the intuitive expectations. For instance, imagined sensory percepts and motor actions could correspond to this kind of partial realizations.

- 3. If motor action corresponds to BSFR, intentional action can be realized only for BSFR. SSFR could not allow a realization of intention if the sequence of SSFRs corresponds to a functional composition of polynomials or even iteration of a single polynomial: I have considered these options for the sequence of SSFRs in [?].
- 4. This picture is in accordance with the conservation laws in ZEO and allows the creation of Universes as from nothing. CDs do not pop up from vacuum but dream-CDs transform to real ones.

It is difficult to avoid the question of whether the notion of state function reduction could be reduced to a classical choice selecting one P_k : quantum jump as choice between dreams to be realized. This option would lead to purely classical probability theory and it would be however very difficult to understand what determines the transition probabilities.

24.5.3 The notion of magnetic body

Magnetic body (MB) would carrying dark matter would serve as the boss controlling ordinary matter at flux tubes.

- 1. MB has as building bricks magnetic flux quanta. Typically flux tubes and flux sheets. It consists of two kinds of flux quanta. Flux can be vanishing, which corresponds to Maxwellian case. The flux can be also non-vanishing and quantized and corresponds to monopole flux. In monopole case magnetic field requires no current to create it. This option is not possible in Maxwellian world. These flux tubes play a key role in TGD Universe in all scales.
- 2. Also Earth's magnetic field with nominal value $B_E = .5$ Gauss would have these two parts. Monopole part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss explaining strange effects of ELF em radiation to the physiology and behavior of vertebrates [J7]. The presence of this part identifiable as monopole flux explains why Earth has magnetic field: this field should have decayed long time ago in Maxwellian world since it requires currents to generate it and they disappear. Magnetic fields of permanent magnets could have a monopole part consisting of flux quanta. Electromagnets would not have it.
- 3. MB would carry dark matter as $h_{eff} = n \times h_0$ phases and act as a "boss" controlling ordinary matter [L125]. Communication to and control of biological body (ordinary matter) would be based on dark photons, which can transform to ordinary photons and vice versa. Molecular transitions would be one form of control.

- 4. Dark photons with large h_{eff} serve as as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to biophotons [L11, L10] with energies covering visible and UV associated with the transitions of bio-molecules. The control by MB which layers having size even larger than that of Earth means that remote mental interactions are routine in living matter. EEG would be a particular example of these communications: without MB it is difficult to understand why brain would use such large amounts of energy to send signals to outer space.
- 5. The experiments of Blackman and others led originally to the notion of h_{eff} hierarchy. The large effects of radiation at ELF frequencies could be understood in terms of cyclotron transitions in $B_{end} = .2$ Gauss if the value of h in E = hf is replaced with h_{eff} , which would be rather large and possibly assignable to gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$.

MB would control BB by cyclotron radiation - possibly via genome accompanied by dark genome at flux tubes parallel to the DNA strands. Cyclotron Bose-Einstein condensates of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear in living matter and $h_{eff} = h_{gr}$ hypothesis predicts universal energy spectrum in the range of bio-photon energies.

Cell membrane could act as generalized Josephson junction generating dark Jophson radiation with energies given by the sum for ordinary Josephson energy and of the difference of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential would induce variation of the Josephson frequency and code the sensory information at cell membrane to a dark photon signal sent to MB.

6. In ZEO field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSRs. Motor action would correspond to BSRs.

24.5.4 Life is not mere chemistry

The dogma about biology as mere bio-chemistry is given up in TGD framework.

1. Bio-catalysis remains a mystery in bio-chemical approach. MB carrying dark matter could provide the needed mechanisms.

According to TGD view about catalysis, the U-shaped flux tubes associated with the MBs of reactants reconnect to a pair of flux tubes connecting the molecules [L100]. This happens if there is cyclotron resonance for dark cyclotron radiation assignable to massless extremals (MEs) associated with U-shaped flux tubes. This requires that the flux tubes have same strength of magnetic field and therefore same thickness by flux quantization. The same value of h_{eff} guarantees resonance. The next step is the shortening of the flux tubes by a reduction of h_{eff} and liberating energy kicking the reactants over the potential wall making the process extremely slow otherwise.

- 2. Also valence bonds and hydrogen bonds could correspond to magnetic flux tubes characterized by $h_{eff} = h_{em} = n \times h_0$, where n is now rather small number $(h = 6h_0)$. This leads to a model for valence bond energies of atom with n increasing as one moves to right along the row of the periodic table providing insights to the biological roles of various molecules in biology [L74]. For instance, the molecules involving atoms towards right end of the periodic table would be natural carriers of metabolic energy whereas at the left end of row would be naturally involved with biocontrol via cyclotron frequencies.
- 3. The physics of water is full of anomalies [I186]. TGD suggests an explanation [L75] in terms of flux tubes assignable to hydrogen bonds [L75, L99]. These flux tubes could correspond

also to values of $h_{eff} > h$ so that these flux tube could be long and give rise to long range quantal correlations. Water could be seen as a manyphase system. The MBs assignable to water molecule clusters could mimick the cyclotron frequency spectrum of invader molecules and make possible water memory and primitive immune system based on reconnections of U-shaped flux tubes of water cluster and invader molecule [L142]. In this framework water would represent a primitive life form.

In Pollack effect [I162] exclusion zones (EZs) are induced at the boundary between gel phase and water by energy feed such as IR radiation. The negative charge of EZs is explained as a formation of flux tubes carrying dark protons having interpretation as dark nuclei. A simple model for linear dark proton triplets predicts their states to be in 1-1 correspondence with DNA, RNA, tRNA, and amino-acids and the numbers of codons coding for given amino-acid are predicted to be same as for vertebrate genetic code [L97, L124]. The model thus predicts deep connections between nuclear physics, condensed matter physics, chemistry, and biology usually thought to be rather disjoin disciplines.

EZs are able remove impurities from interior in conflict with second law. TGD based explanation of the mystery is change of the arrow of time induced by TGD counterpart of ordinary state function reduction in ZEO) [L148]: self-organization would be dissipation with reversed arrow of time at at the magnetic body (MB) of system acting as master and forcing time reversed evolution at the level of ordinary bio-matter serving as a slave.

DNA has one negative charge per nucleotide, microtubules are negatively charged, also cell is negatively charged, ATP carries 3 units of negative charge. This together with ZEO suggests that Pollack effect plays a key role in bio-control and macroscopic SFRs play a key role in living matter.

Chapter 25

Horizontal Gene Transfer by Remote Replication?

25.1 Introduction

This article was inspired by a Quantamagazine article "DNA Jumps Between Animal Species. No One Knows How Often" (https://cutt.ly/7UKasRp), which described the findings of Laurie Graham and Pete Davies published in the article "Horizontal Gene Transfer in Vertebrates: A Fishy Tale" in Trends in Genetics [I44] (https://cutt.ly/SUKamqP).

1. Marine life around the Arctic and Antarctica has evolved many defense mechanisms against the lethal cold. One common adaptation is the ability to make anti-freezing proteins (AFPs) that prevent ice crystals from growing in blood, tissues and cells. This solution has emerged repeatedly and independently, not just in fish but in plants, fungi and bacteria. AFPs make possible survival at water temperature, which is by 1 degree C colder than the *unprotected* freezing point of fish blood and this offers an evolutionary advantage.

Remark: TGD based general mechanisms possibly associated with heat and cold shock, involving zero energy ontology (ZEO) [L118] [K132] in an essential way, have been considered in the model for the effects of various shock proteins in [L225]. The key idea is that the macroscopic counterparts of ordinary state function reduction changing the direction of time change the arrow of time at the level of the magnetic body of the system so that, from the point of view of observer with the standard arrow of time, the system seems to extract energy from the environment instead of dissipating it.

- 2. Herrings and smelts are two groups of fish, which have learned to make AFP. The story began when Graham discovered that smelt had a protein gene very similar to one of the AFG genes of herring. The gene's introns, stretches of non-coding DNA involved also with TEs, which in general mutate rather fast, are more than 95 % identical. That both have exactly the same gene coding for AFP proteins, is surprising since their ancestors diverged more than 250 million years ago and the AFP gene is absent from all species relating to them. Somehow the AFP gene must have found its way to the genome of smelt.
- 3. Cross breeding of herring and smelt is not possible so that direct horizontal gene transfer (HGT) should have occurred. HGT is known to be possible between prokaryotes (monocellulars) and also between prokaryotes and eukaryotes (multi-cellulars). Herring and smelt are not rare exceptions: recent studies demonstrate that HGT occurs also in other fish, reptiles, birds and mammals.
- 4. However, the belief has been that HGT is not possible for eukaryotes (multicellulars) and there are several good arguments in favor of this belief. In the case of bacteria, it is enough for the gene to get through the cell membrane since there is no nucleus and HGT occurs quite generally. The DNA of eukaryotic cells is however isolated inside the nuclei and most of the time the DNA is tightly bound in chromosomes. Gene should also find its way to germ

cells in order to have a lasting effect. The transferred gene of the donor should also integrate to the genome of the host.

5. In 2019, the full genome of herring was published. It turned out that the genome contains several AFP genes with associated transposable elements (TEs). The herring genome contains several copies of these TEs but they are absent from other fish with a single exception: the genome of smelt contains only a single AFP gene and this gene with similar transposable elements occurs also in the genome of herring. Therefore there is little doubt that the HGT has taken place.

Somehow HGT must be possible.

- 1. 94 % HGTs occur between fishes and only 3 per percent between birds and mammals. Therefore the water environment must be part of the explanation.
- 2. What comes first in mind is spawning. In a situation in which one has sperms and eggs in water, germ cells which are effectively monocellulars apart from the presence of cell nuclei. Most of the cells degrade and could produce fragments of DNA, say TE+AFP gene.

If the spawning of two species occurs at the same time at the same location, HGT might have taken place from the sperm or egg cells of herring or of their degradation products to the sperm cells of smelt. These would have naturally found their way to the eggs of smelt. The amount of spawn in the sea water is so high that it changes the color of water white: this would increase the probability of HGT.

3. Maybe the AFP gene of herring has somehow attached to the DNA of the smelt sperm cells during spawning. Sperm mediated gene transfer is indeed a standard technique of genetic engineering. The challenge is to understand how the AFP genes were transported from herring cells to the smelt sperm cells. AFP gene is not able to make the travel between cells alone. In standard biology, some vector should have transported the gene between the two cells and one can make only guesses about the mechanism.

25.1.1 The notions of transposon and horizontal gene transfer

The notions of transposon or transposable element (TE) and horizontal gene transfer (HGT) will be needed in the sequel.

Transposons

Transposable elements or simply transposons (TEs) (https://cutt.ly/HUZIItW) were discovered by Barbara McClintock. TEs are jumping genes, which involve introns were once regarded as "junk". The basic operation is cut and paste operation.

TEs are now known to have several important functions: they make the genome dynamic and affect its identity and size, induce mutations or their reversals, and can also lead to a duplication of pieces of the genome. TEs are also involved with the control of gene expression and epigenesis (amusingly, they are still regarded as selfish genes!).

TEs are abundant in eukaryotic cells. TEs make approximately 64 % of the maize genome, 44 % of the human genome, and almost half of the mouse genome.

TEs serve as a kind of text editing tool. The TE (https://cutt.ly/HUZIItW) consists of inverted repeats (TEs in my terminology) at its beginning and end, and the structural genes between them.

There are at least two kinds of TEs: class I and class II. In the human genome 98 per cent of TEs class I and the rest are of type II.

1. Class I TEs or retrotransposons are first transcribed to RNA, and reverse transcriptase often encoded by the TE itself catalyzes the reverse transcription of RNA to DNA, which is then pasted to DNA sequence. The text processing analog is copy and paste.

Retrotransposons are classified into 3 types:

- Retrotransposons with long terminal repeats (LTRs), which encode reverse transcriptase producing DNA from the RNA transcribed from TE, which is then glued to a DNA. Retrotransposons are similar to retroviruses.
- Retroposons, long interspersed nuclear elements (LINEs). Also they encode reverse transcriptase but lack LTRs and are transcribed by DNA polymerase II to RNA.
- Short interspersed nuclear elements (SINEs) do not encode reverse transcriptase and are transcribed by DNA polymerase II.

Also retroviruses can be regarded as TEs. They can transfer genes between eukaryotic target and host cell. The integrated gene in the host cell is called produces and this transfer can be seen as an eukaryotic analog of the transfer of bacterial TEs.

2. Class II TEs or DNA transposons encode for protein transposase, which they require for excision and insertion. No intermediate RNA is produced. The text processing analog is cut and paste.

The figure https://en.wikipedia.org/wiki/File:DNA_Transposon.png of the Wikipedia article illustrates the situation. The structure of TE is : TSD+TIR+gene+TIR+TSD. Two inverted tandem repeats (TIR) flank the transposase gene. Two tandem site duplications (TSD) are present on both sides of the insert.

Transposase makes a staggered cut at the target site with sticky ends and the complex TIR+gene+TIR is transferred to the new site. Gene itself is not duplicated as in the copy and paste process for retrotransposons. TSDs are left at the target site. DNA polymerase fills in the gaps at the target site leading gradually to long repeating sequences. The insertion sites can be identified by short direct repeats followed by inverted TIRs.

3. TEs can also replicate.

TEs can be also classified as autonomous and non-autonomous. Autonomous TEs can move by themselves whereas non-autonomous TEs require other TEs to move.

Horizontal gene transfer

Horizontal gene transfer (HGT) (https://cutt.ly/zUKTED5) occurs mostly in prokaryotes but also in some eukaryotes. HGT tends to occur in extreme environments.

Diatoms and algae have received genes from bacteria. For eukaryotes HGT to germ cells is required, which makes the process difficult to realize. Donor and host tend to be closely associated organisms. HGT from bacteria to chordates occurred shortly after this lineage arose.

There are several mechanisms of bacterial HGT.

- 1. Transformation involves three steps: introduction, uptake and expression.
- 2. Transduction: DNA is transferred by virus
- 3. Bacterial conjugation. DNA is transformed in cell-to-cell contact.
- 4. Gene transfer agents are viruslike elements coded by the host.

Transposable elements (TE) are often involved with HGT. One speaks of the transfer of horizontal TE (HTT). TE transfer occurs also for eukaryotes. This suggests that TEs, which distinguish between prokaryotes and eukaryotes, involve a new transfer mechanism. The mechanism of TE transportation requiring a vector carrying the TE, has not been identified and this allows us to wonder whether only information could be transferred?
25.1.2 General constraints on the model

Consider first general constraints on the model.

- 1. For eukaryotes, cell and nuclear membranes make HGT difficult if not impossible. The transfer should also occur to germ cells.
- 2. Water must be essential since in other species than fish the process is much rarer.
- 3. Sperm cells are analogous to monocellulars, and the HGT occurs for monocellulars. Note however that sperm cells and eggs have a nucleus and chromosomes, which are obstacles for HGT.
- 4. That HGT would occur during spawning looks a highly plausible hypothesis. This increases the probability of HGT, whatever the mechanism is. Sperm mediated transfer would allow to overcome the basic obstacles and the basic properties of TEs involved would make possible the integration to the host genome.
- 5. Most of the cells and their DNA degrades during the spawning and the resulting DNA fragments would also contain AFG+TE, which could be transferred to the smelt sperm cells.

How the TE involving the AFG from the sperm of herring could be transported to the sperm of smelt? This is not known.

According to Wikipedia:

Though the actual mechanism for the transportation of TEs from donor cells to host cells is unknown, it is established that naked DNA and RNA can circulate in bodily fluids. Many proposed vectors include arthropods, viruses, freshwater snails, endosymbiotic bacteria and intracellular parasitic bacteria. In some cases, even TEs facilitate the transport for other TEs.

This justifies a heretic question. Could it be only the genetic information, which is transferred and used to construct DNA in the host as a kind of remote replication analogous to quantum transportation?

25.2 Some key ideas of TGD inspired quantum biology

In this section basic notions of TGD inspired quantum biology relevant to the recent article are discussed. The ideas discussed the notion of magnetic body (MB) as a controller of ordinary matter; the hierarchy of effective Planck constants assigned to the hierarchy of extensions of rationals defining a hierarchy of phases of ordinary matter behaving like dark matter; Galois confinement as a universal mechanism for the formation of bound states; dark realizations of genetic code; communications and control in TGD inspired quantum biology. Zero energy ontology (ZEO) [L118] [K132] plays a central role in TGD inspired quantum biology but is not discussed in the sequel.

25.2.1 MB carrying dark matter as controller of ordinary biomatter

MB contains dark matter identified, as phases of ordinary matter characterized by EQ with a dimension $n = h_{eff}/h_0$ serving as a measure of the algebraic complexity of a given space-time region [L143, L144], and interpreted as a universal IQ. The scales of quantum coherence increase with h_{eff} . The layers of MB characterized by the value of n naturally form a master-slave hierarchy in which ordinary matter with the smallest Planck constant is at the bottom, and controlled by higher levels. The energies of systems increase with h_{eff} and since h_{eff} tends to be spontaneously reduced, an energy feed is needed to preserve the distribution of h_{eff} : the interpretation is as an analog of a metabolic energy feed.

MB acts as a "boss" controlling ordinary matter and induces self-organization [L113].

Anatomy of MB

MB has, as its body parts, magnetic flux quanta: flux tubes and flux sheets. There are two kinds of flux quanta. Flux can be vanishing, which corresponds to a Maxwellian regime. Flux can also be non-vanishing and quantized corresponding to a monopole flux. In the monopole case, the magnetic field requires no current for its creation. This option is not possible in the Maxwellian world. By fractality of the TGD Universe, these flux tubes play a key role at all scales [L105].

Also the Earth's magnetic field with nominal value of $B_E = .5$ Gauss has two parts.

1. The monopole flux part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss and explains the strange effects of ELF EM radiation on the physiology and behavior of vertebrates [J7].

The presence of this part explains the stability of the Earth's magnetic field. This field should have decayed long ago in a Maxwellian world since it is generated by currents which disappear. The contribution of the molten iron in the Earth's core to B_E decays but the changes of the orientation of B_{end} regenerate it [L30]. Also, magnetic fields that penetrate super-conductors as quantized fluxes and even those of permanent magnets (as opposed to electromagnets) may have a monopole part consisting of flux quanta.

2. The interaction of MB with the gravitational field of Earth is discussed in [L172]. Intriguingly, the metabolic energy currency with the nominal value of .5 eV is rather close to the energy for the escape velocity of a proton. Could the transfer of ions from the surface of the Earth to MB be a standard process?

Communications to and control by MB

Communication from the biological body (BB) to MB and its control by MB would rely on dark photons, which can transform to ordinary photons with a large h_{eff} and vice versa. Molecular transitions would represent one form of control.

- 1. Cell membranes could act as generalized Josephson junctions generating dark Josephson radiation with energies given by the sum $E_J + \Delta E_c$ of ordinary Josephson energy E_J and the difference ΔE_c of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential modulates the Josephson frequency and codes the sensory information at the cell membrane to a dark photon signal sent to MB.
- 2. The large effects of radiation at ELF frequencies observed by Blackman and others [J7] could be understood in terms of the cyclotron transitions in $B_{end} = .2$ Gauss if "h" in E = hf is replaced with h_{eff} . h_{eff} should be rather large and possibly assignable to the gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. For the simplest model, M represents the Earth's mass coupling to the small mass m, and v_0 is a parameter with dimensions of velocity expected to have discrete spectrum. The energies $E = h_{eff}f$ of dark photons should be in the biophoton energy range (visible and UV) characterizing molecular transitions [K20, K31].
- 3. For the value $v_0/c \simeq 2^{-11}$, suggested by the Nottale's model for planetary orbits [E1], the predicted cyclotron energy scale is 3 orders of magnitude higher than the energy scale of visible photons. Several solutions of this problem were considered [L171]. The most plausible solution [L171, L155] is $\beta_0 = v_0/c = 1/2$ for living matter so that gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ equals to Schwartschild radius at the surface of Earth. and brings nothing new to the original Nottale hypothesis.

By its higher level of "IQ", MB would naturally be the master controlling BB by cyclotron radiation - possibly via a genome accompanied by dark genome at flux tubes parallel to the DNA strands.

1. Cyclotron Bose-Einstein condensates (BECs) of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear as dark matter in living systems and the $h_{eff} = h_{gr}$ hypothesis predicts a universal cyclotron energy spectrum in the range of bio-photon energies.

- 2. Dark photons may transform to bio-photons [L11, L10] with energies covering the visible and UV energies associated with the transitions of bio-molecules. This control of biomolecules implies that remote mental interactions are routine in living matter. EEG signals would represent a particular instance of these communications: without the presence of MB it is difficult to understand why the brain would use such large amounts of energy to send signals to outer space.
- 3. In ZEO, the field body (FB) and MB correspond to 4-D rather than 3-D field patterns and quantum states correspond to quantum counterparts of behaviors and biological functions. Conscious holograms could be generated as a result of interference of a dark photon reference beam from MB and a dark photon beam carrying the sensory information. This hologram would be read by MB using the conjugate of the reference beam.

In ZEO time reversals of these processes also take place. This makes it possible to understand memory as a result of communications with memory mental images.

25.2.2 Galois confinement

Galois confinement is a universal number theoretical mechanism for the formation of all bound states [L169, L167]. Galois confinement emerged originally in TGD inspired quantum biology but has become a central theme of also the TGD view about condensed matter. Galois confinement provides a purely number-theoretic mechanism for the formation of hierarchies of bound states.

- 1. Galois confinement involves $M^8 H$ duality and requires $h_{eff} > nh_0 > h$. M^8 has an interpretation as an analog of momentum space and the points of $X^4 \subset M^8$ assignable to polynomial P with rational coefficients have interpretation as 4-momentum. Monic polynomials P are physically especially interesting [L150]. P defines an algebraic extension of rationals with dimension $n = h_{eff}/h_0$. The physical interpretation is as a hierarchy of phases of ordinary matter with an increasing value of effective Planck constant behaving like dark matter.
- 2. The roots r_n of P correspond to 3-D mass shells $m^2 = r_n$ in fixed $M^4 \subset M^8$ and X^4 itself contains these mass shells and is determined as a deformation of M^4 which corresponds to an element of local group $SU(3) \subset G_2$, where G_2 is automorphism group of M_c^8 having interpretation as complexified octonions. The condition that $U(2) \subset SU(3)$ leaves the point g(x) invariant implies that one has local CP_2 element defining the $M^8 - H$ duality.SU(3)corresponds to color group physically.
- 3. Quark states as solutions of algebraic octonionic Dirac equation (all equations are algebraic at M^8 side of $M^8 H$ duality while everything is differential geometric at H side) correspond to points of M^8 assume to correspond to algebraic integers in the extensions of rationals defined by P so that the points carrying quark define what I have called cognitive representation playing a key role in adelic physics [L66, L67]. For instance, p-adic variants of the cognitive representations make sense.
- 4. Periodic boundary conditions allow only many-quark states assignable to mass shells for which the total M^4 momentum is an ordinary integer (in suitable units defined by the size scale of CD considered) are possible [L169, L167]. This is the simplest realization of Galois singlet property/confinement. The integer valued total momenta emerge also in the twistorial construction of scattering amplitudes [L150]. This is the simplest realization of Galois singlet property/confinement.
- 5. This gives rise to an infinite hierarchy of bound states. One can also consider composite polynomials and if they vanish at origin, the roots of composite polynomials contain also the roots of the functional factors of the composite. This is analogous to conservation of genes. All kinds of states: nucleons, nuclei, photons, etc..., can form Galois bound states. It is enough that one deforms the states so that they are not Galois singlets with the original Galois group or to increase the extension so that they are not Galois singlets in the larger extension. From these kinds of states one can form Galois singlets.

25.2.3 Dark realizations of genetic code

The model of bio-harmony [L16] [L103, L136, L157, L159] is essential for the TGD based understanding of what might be called emotional intelligence (whose reality is accepted) and its relations with ordinary intelligence. The surprising outcomes are the connection with genetic code and the key role of bioharmony in quantum information processing in living matter.

- 1. The notion of bioharmony relies on icosahedral and tetrahedral geometries. The representation of the 12-note scale as a sequence of quints, reduced by an octave equivalence (notes differing by octave are experienced as equivalent) to the basic octave, defines the harmony for a given Hamiltonian cycle: the 20 allowed 3-chords of the icosahedral harmony correspond to the 20 triangular faces. The symmetries of the harmony are defined by some subgroup $(Z_6, Z_4, \text{ or } Z_2)$ of the icosahedral group.
- 2. Genetic codons correspond to dark photon triplets (3-chords of light) defined by the triangular faces of an icosahedron and tetrahedron. The counterparts of amino-acids are identified as orbits of 3-chords under the symmetries of a given harmony.

Any combination of 3 icosahedral harmonies with 20 chords with symmetries Z_6 , Z_4 and Z_2 and of the tetrahedral harmony with 4 chords gives a particular bioharmony with 20+20+20+4=64chords assignable to DNA codons. DNA codons coding for a given amino acid correspond to the chords at the orbit of the symmetry group. Rather remarkably, the numbers of DNA codons coding for a given amino acid come out correctly.

3. Music expresses and creates emotions. Musical harmony codes for moods and emotions as holistic aspects of music. Bio-harmony with 64 3-chords, would assign the binary, local, aspects of information to the 6 bits of the codon and its holistic, emotional aspects to the bio-harmony. A chemical representation of the genetic code can thus correspond to several moods represented by bioharmony. In contrast with physicalism, emotions would appear already at the molecular level, and would have physical effects that are not reducible to bio-chemistry. This understanding is not possible without using the notion of MB.

The model of bio-harmony requires that the values of B_{end} correspond to those associated with the Pythagorean scale definable by the quint cycle. These frequencies correspond to energies that a molecule must have in order to serve as a basic biomolecule. This criterion could select DNA, RNA, tRNA, and amino-acids.

In the second model of genetic code [L77, L36, L103], codons are represented as dark proton triplets assignable to flux tubes parallel to DNA strands.

- 1. The numbers of dark proton triplets turn out to correspond to numbers of DNA, RNA, tRNA codons, and amino acids. The numbers of DNA and RNA codons assignable to a given amino-acid in the vertebrate genetic code are correctly predicted. Genes would correspond to sequences of dark proton triplets [L124].
- 2. Dark proton triplet dark codon would be analogous to baryon and Galois confinement [L142] behaving like a single quantum unit. The N dark codons of a dark gene would, in turn, bind to Galois confined states of the Galois group of an EQ associated with the sequence of codons. An entire hierarchy of confinements is possible.
- 3. Galois confinement can be realized also for dark photon triplets and the sequences of N darkphoton triplets representing genes as dark 3N-photon states. Genes could serve as addresses for communications based on dark 3N-photon resonances.

For communications between levels with the same value of h_{eff} there would be both energy and frequency resonance and for levels with different values of h_{eff} only the energy resonance. It is an open question whether dark 3N-photons transform to a single ordinary photon or 3N ordinary photons (biophotons) in dark-ordinary communications.

4. The basic hypothesis is that both DNA, RNA, tRNA, and amino acids are paired with their dark analogs, and that energy resonance mediates the interaction between the members of pairs.

How could the icosahedra and tetrahedra be realized? Why must one glue them together? This looks aesthetically unappealing. However, surprisingly, both icosahedrons and tetrahedrons appear in, perhaps the simplest honeycomb of the hyperbolic 3-space H^3 (cosmic time = constant hyperboloid). H^3 is also central to special relativity and cosmology [L159]. Dark genetic code can be realized in terms of both dark protons and photons using this particular tessellation and would be universal. This master tessellation would induce sub-tessellations at the space-time surface, in particular representations of genetic code at magnetic flux tubes. Also 2-D and even 3-D representations of genetic code can be considered (i.e. cell membrane and microtubules) [L161].

25.2.4 Communication and control in living matter

The TGD inspired model for bioharmony suggests a universal communication and control mechanism based on frequency modulation of dark photon radiation and its resonant receival producing a sequence of pulses. The signal sent by the DNA sequence would be resonantly received by a similar DNA sequence as a temporal sequence of resonance peaks determined by the modulation.

An interesting hypothesis is that nerve pulse patterns are basically produced by this mechanism transforming membrane potential oscillations producing Josephson radiation sent to MB and producing pulse sequences initiating nerve pulse pattern at the level of cell membrane.

U-shaped flux tubes serve as the basic tools of communication. Their reconnection replaces U-shaped flux tubes with pairs of flux tubes between two objects and occurs when a resonant dark photon communication between objects is possible. This requires the same cyclotron energy implying identical cyclotron frequencies if the values of h_{eff} are the same: this implies the value of magnetic field and by flux quantization the same thickness of flux tubes.

Galois confinement allows a generalization replacing U-shaped flux tubes with N-flux tubes along which dark N-photons can propagate and to replace dark photon resonance with M-resonance. This communication and control mechanism would be realized at the level of DNA and other biomolecules. The generalization of the notion of genetic code allowing higher dimensional realization of DNA generalizes this communication mechanism further.

Some applications

The proposed general model of communications and control has an impressive number of applications to living matter.

- 1. The model of water memory involves dark DNA [K62] [L6, L17] assignable to the ordinary DNA and also the dark variants of other biomolecules can be involved. The MBs of water clusters can vary the thickness of their U-shaped flux tubes and therefore their cyclotron frequencies. This makes possible recognition of bio-active molecules with MB involving flux tubes with cyclotron frequencies shared by living matter. When the U-shaped flux tube meets a similar flux tube of a bio-active molecule, reconnection takes place and if it leads to dark photon resonance, a long-lived flux tube pair is formed. The bioactive molecule is "caught".
- 2. The MB of water clusters can mimic the MBs of invader molecules and this could give justification for the claimed homeopathic effects. Resonant reconnection could be behind water memory, immune system, the claim about homeopathic healing [K62], and the bio-catalysis involving the mysterious looking ability of reactants to find each other in dense molecular soup.
- 3. The most general option is that every polar molecule in living matter is accompanied by a dark nucleon sequence or several of them (as in the case of amino-acids) serving as its "name". This would also associate a unique dark nucleon sequence with the MB of DNA so that DNA-dark DNA association would be automatic. The same applies to mRNA and tRNA and amino-acids.

The model for the communications also leads to a model for the emergence of language [L226, L227]. Amazingly, only a few point mutations for relatively few genes seem to have led to human languages and transformed biological evolution to cultural evolution? What happened to

these genes? In the biochemistry framework it is difficult to imagine an answer to this question. Here TGD could come to the rescue.

One can assign a value of h_{eff} characterizing the evolutionary level also to genes. The genes with larger h_{eff} would serve as control genes and the increase of h_{eff} would mean an evolutionary step. Perhaps a dramatic increase of h_{eff} occurred to FOXP2 and some other genes as human language emerged.

The fundamental language would be defined by genetic code realized in terms of dark 3N-photons and h_{eff} as a measure of algebraic complexity and a universal "IQ" would characterize the realizations of this language.

What is the role of introns and TEs?

Interesting questions relate to the role of introns and transposons (TEs), which involve introns besides genes.

- 1. Introns do not express themselves as proteins and their fraction is highest in humans so that the interpretation as junk DNA does not look realistic. TGD inspired quantum biology motivates the proposal that the dark genes could express themselves electromagnetically and that remote replication (and the remote variants of transcription and even translation) could rely on this. This leads to a general model for communications and control.
- 2. The simplest assumption is that all DNA related structures and also RNA proteins and tRNA, can "talk" by applying these communication mechanisms.

The difference between TEs and genes not belonging to TEs brings to mind the difference between animals and plants. TEs can move and actively control their environment. TEs are also involved with epigenesis, that is control of gene expression, and modifications of genes.

Animals and plants differ also in that animals have a nervous system. Could also TEs and ordinary genes have an analogous difference? Animals are thought to represent a level of evolution higher than plants. Could this be true also for TEs? A higher value of h_{eff} for the MBs of TEs would concretize this idea. Nervous system in TGD inspired quantum biology means communications to MB by Josephson radiation. Could one think something like this also now?

The relation of TEs to genes looks like the relation of a programmer to the program modules of a software. This suggests that the MBs of TEs represent a higher level in the h_{eff} hierarchy than the MBs of genes. The higher value of h_{eff} means also a longer scale of quantum coherence so that TEs might be involved also between communications of even different organisms of the same species.

25.3 Is remote replication of DNA involved with HGT?

In remote replication only the information about TE would be transferred and one would have a biological analog of teleportation.

25.3.1 Is replication of the magnetic body behind biological replication?

The vision [L20] about exclusion zone (EZ) like regions discovered by Gerald Pollack [I110, L20, I197, I162] as primordial life forms and facts about water memory and homeopathy [K62] lead to a vision about how a primitive immune system might have developed and how the recent genetic code might have emerged.

Magnetic bodies and dark analogs of bio-polymers should still play a key role in living matter. The basic idea is that the time evolution of the MB is the template for the time evolution of the biological body. In [K88] [L18] various pieces of evidence for the role of the MB as "morphogenetic field" is discussed. For instance, the replication of DNA and cell would reduce basically to that for corresponding magnetic bodies.

Replication of the MB is analogous to what happens in the 3-vertex of a Feynman diagram. This occurs on several scales. This would make possible dark DNA (dDNA) replication and copying of dDNA to dDNA+dRNA as well as copying of dRNA to dRNA+dark protein.

Replication process should start from the higher levels of dark matter hierarchy and proceed to shorter scales. The basic constraint from ZEO is that the time evolutions of magnetic bodies at various levels of the hierarchy are highly unique as preferred extremals connecting initial and final 3-surfaces. For the maxima of vacuum functional only preferred pairs of 3-surfaces are possible. This gives rise to what might be called "standard behaviors". Also the replication would be this kind of behavioral pattern. In the context of the positive energy ontology it is extremely difficult to understand the predictability of cell replication or the development of the organism from a single cell by repeated cell divisions.

Remote gene replication [K136] might be one application: the model described was actually developed before the idea that the replication of the MB could be the fundamental mechanism. Its reversal could be a basic mechanism of bio-catalysis and induce the attachment of the bio-molecules together. Also ordinary DNA replication could be induced by the same electromagnetic signal as remote replication.

TGD based model for ordinary DNA replication

Consider first a TGD based model for the ordinary replication of DNA.

- 1. Assume that the portion of DNA promoting DNA replication is activated by dark radiation at some frequency and that the promoter region emits radiation with the same frequency. This activates further promoter regions -also in other cell nuclei. The replication process is amplified exponentially. The negative feedback is necessary in the general case and is provided by attachment of the produced proteins (basically dark proteins) to the genes making them inactive.
- 2. This might occur during cell division which might involve irradiation by dark analog of white noise exciting all promoter regions. Certainly the coherence of this process is essential and here the higher levels of the dark matter hierarchy would be essential.

Remote replication in weak sense

Gariaev has reported a phenomenon suggesting remote replication in the sense that the DNA strands exist in B and the irradiation of the DNA at A induces the remote replication in B. In the sequel I will speak about the weak form of remote replication (WRR). We have written together with Peter Gariaev an article discussing a possible TGD based model for the findings [L220].

The work of Gariaev [I74, I73] [I75, I113] provides the experimental guidelines.

- 1. The phantom DNA [I74] identified as dark nucleon sequences in TGD framework and the evidence for remote activation of DNA transcription [I73] both discovered by Gariaev's group are assumed as the first two key elements of the model.
- 2. The notion of wave DNA introduced suggests that genes express themselves by em radiation and that genetic code is involved. Wave DNA should provide a mechanism of information transfer. Somehow DNA should be encoded to spatial or temporal patterns in turn decoded somehow to DNA. Gariaev has suggested that the modulation of polarization direction for the radiation propagating along the DNA strand could encode for the DNA to a temporal pattern.

The TGD based model for WRR using existing DNA in both A and B is discussed in the article [L220] written together with Peter Gariaev. This discussion and also later developments can be found in [K136, K88].

WRR would use existing DNA strands in B accompanied by dark DNA strands realizing the genetic codons as dark proton triplets. The replication would be remotely induced by the dark radiation from DNA at A possibly arriving to B via the MB having contacts with both A and B. This would be a general mechanism of remote mental interactions in the TGD Universe.

1. WRR becomes possible if the dark radiation exciting promoter region can leak to other cells or even other organisms. Large h_{eff} might make this possible.

- 2. Also remote transcription is possible by the same mechanism. Actually remote variants of very many basic processes seem to be possible.
- 3. The observations of Peter Gariaev's group about effects of laser light on genes [I75, I113] could be interpreted as remote replication in this sense.

The analog of this mechanism could make remote transcription and even remote translation at the dark level possible. These processes would induce these processes at the level of biochemistry in accordance with the proposal that biochemistry is quite generally shadow dynamics induced from the level of the MB.

TGD based model for the remote replication in strong sense

For the strong form of remote replication (SRR) only DNA codons are available at B, and under some conditions the presence of DNA at A induces the remote replication at B.

The findings of the group of HIV Nobelist Montagnier [I91, I92] could be interpreted in terms of SRR. In this case the information about DNA at A must be transferred from A to B. Peter Gariaev has reported replication in this sense for years after Montagnier' findings [I158].

- 1. Montangier's experiment involves two chambers A and B. A contains water plus genes and B contains water plus DNA nucleotides. There were channels between the chambers but so thin that DNA could not get through. Also an em field with 7 Hz frequency was present. Same genes as in A appeared also in B. As if remote replication of genes in A had happened in B. In the TGD framework the presence of 7 Hz frequency suggests that MB was present: the identification either as Schumann frequency or the cyclotron frequency of K ion in the endogenous magnetic field of .2 Tesla is suggestive.
- 2. Polymerase chain reaction (PCR) [I32] (see http://tinyurl.com/ybv6mn51) is the technique used in the experiments of Montagnier's group and in somewhat modified experiment by Gariaev's group involving irradiation of the second test tube by laser light.

The findings of Montagnier *et al* [I91, I92] can be described in terms of SRR. The model for SRR has developed gradually and the latest version was discussed in 2020 [L137]: this discussion is included also in [K136, K88]. The following describes the definition and development of the model for SRR.

- 1. Consider two positions A and B. A could be a chamber containing DNA strands and B a chamber containing DNA codons. Assume that DNA to be remote-replicated is in A and the codons producing the replica are in B. The dark flux tubes parallel to ordinary DNA in A and carrying dark codons would be accompanied by dark planar flux tube bundles transverse to them and leading to B. Each flux tube would be analogous to a wave guide for dark photons. In Gariaev's model photons polarized orthogonally to DNA would propagate along these.
- 2. The planar flux tube bundles extending from A to B would have $h_{eff} > h$. The associated space-time surface which could be seen as a many-valued map from CP_2 or its lower-D surface to M^4 giving rise to a planar bundle of parallel U-shaped flux tubes in M^4 as a quantum coherent structure. DNA codons floating in water in B would reconnect to the ends of these U-shaped flux tubes by resonance mechanism and the resulting DNA strand in B would be the same as in A.
- 3. The dark photon signal representing DNA sequence could catalyze the formation of conjugate DNA in chamber B from existing DNA sequences in chamber A serving as a template. Since the catalytic interaction of DNA polymerase takes place with already existing DNA sequence, the simplest possibility is that first some conjugate DNA sequences are generated by WRR after which DNA polymerase utilizes these sequences as templates to amplify them to original DNA sequences. Whether the product consists of original DNA or its conjugate can be tested. I have also commented on Montagnier's findings from the TGD point of view [L6, L17].

4. The crucial assumption, which is in conflict with the standard picture, is that the dark DNA nucleotides (dark protons) serving as building bricks of DNA strands do not float freely in water but are already loosely bound to form dark codons.

The motivation for this assumption is that one cannot assign the frequencies of the 3-chord with different nucleotides of the codon but only to the entire codon. The difference between ordinary codon and dark codon is like that between spoken and written language: in spoken language word is basically a single entity but in written language it decomposes to letters. Interestingly, in written Chinese the words decompose to syllables but not to letters.

The assumption of effective independence of codons makes sense if the magnetic flux tubes connecting the codons have either value of string tension or larger value of h_{eff} than in the dark codon accompanying the ordinary codon.

Galois confinement allows to generalize the model and gives a justification for the formation of units with increasing complexity and size and behaving quantum coherently.

1. Triplets of dark codons can bind to a single dynamical unit by Galois confinement [L169, L167]. Dark codons can in turn bind to dark genes and even to DNA strands with a larger Galois group. Strands can in turn bind to double strands and double strands to chromosomes. Even larger structures are possible since Galois confinement is hierarchical and new levels correspond to the increase of algebraic complexity associated with the polynomials P defing 4-surfaces in M^8 and by $M^8 - H$ duality in H [L127, L128, L169].

Biological evolution could be seen as a number theoretical evolution of Galois singlets with increasing size as the algebraic extension and the Galois group associated with space-time regions defined by polynomials would increase and become more complex.

2. Dark codons represented by 3 dark photons would be Galois singlets. From these dark photon genes and even larger dark photon structures can be formed as analogs of dark Bose-Einstein condensates. Photons as particles would be replaced by dark 3N photons. Also the planar flux tube bundles would be particle-like entities: 3N-flux tubes forming quantum coherent structures. The entire gene would use this 3N-tentacle to build resonant connections to other similar genes or to build similar genes from dark codons to which ordinary codons would be attached.

The communications between dark proton genes with N codons would be by using dark photon genes involving 3N-fold cyclotron resonance selecting the receiver. In communications, the simultaneous frequency modulation would yield the message transformed to a sequence of resonance pulses with temporal durations between pulses determined by the modulation.

25.3.2 Could HGT rely on remote replication in strong sense?

Transposons are abundant in eukaryotic cells unlike in prokaryotic cells. This suggests that TEs could make possible SRR and thus allow to circumvent the problems posed by the presence of nuclear membrane and chromosome structure. The reason for this could be simply that the value of h_{eff} is so large for the TEs (or rather, for their MBs) that it makes coherent activities possible in longer length scales and therefore also the control by MB. MB would have a larger size scale and higher "IQ".

Perhaps TE is one particular structure behaving like a unit expressing itself in terms of codons realized as dark photon triplets. TE would be moving gene as an analog of animal. This structure could be essential for SRR. If TE has MB with large h_{eff} , it (or its MB) would be able to behave autonomously: this is what jumping genes are. Genes not associated with TEs would be like plants coding for structure and TEs would be like animals making the structure dynamical.

Therefore the question in the concrete example considered is the following: Could SRR take place and yield a copy of a TE involving the AFG of herring inside the sperm cell or egg of smelt? The TE complex could belong to the sperm cell or egg of herring or their degradation products.

25.3.3 Some reckless speculations

It is interesting to try to see this proposal in a more general context.

1. Introns were for a long time regarded as "junk DNA". Junk interpretation does not resonate with the fact that human genome has the highest portion of introns and humans have also developed culture and language [L226, L227], which in TGD framework would correspond to an evolution of collective consciousness. The reasons for the junk interpretation might have been the repetitive nature of introns and the belief that genes can be expressed only as proteins or RNA.

TEs as jumping genes are now known to have many important functions: they make the genome dynamic and affect its identity and size and can lead to a duplication of pieces of the genome. They are involved with the control of gene expression and epigenesis (amusingly they are still regarded as selfish genes!).

DNA is interpreted as information theoretically and one can wonder whether TEs might play an essential role in the communications at molecular level. Magnetic body (MB) and the hierarchy $h_{eff} = nh_0$ of effective Planck constants are a central element in TGD inspired quantum biology. The larger the value of h_{eff} , the longer the quantum coherence length and time scales are and genes could be classified using the value of h_{eff} for their MB as a criterion, a kind of universal IQ.

2. TEs dominate also in the genomes of crops (see https://cutt.ly/5UZGvbY and https: //cutt.ly/QUZG8qa) and trees. It has become clear that trees are not isolated entities but know each other and take this into account in their behavior. Forest is not a collection of isolated trees, but a highly refined self-organizing social structure. For instance, conifers have a high amount of TEs, which suggests that forest is a conscious entity, which has MB controlling the forest at the level of the ordinary biomatter.

Concerning crops, at least 35 % of the rice genome % of the sorghum genome [3], and nearly 85 % of the maize genome is made up of transposable elements (TEs). It is difficult to avoid seeing an analogy between human community and crop field or forest. Could TEs make possible communications in the scale of the crop field and forest and make it, or rather, its MB, a conscious intelligent creature?

3. I know that I should overcome the temptation of mentioning crop circles although most mainstream biologists certainly regard crop circles as human made. I cannot. It is also better to immediately confess that I have even written two articles about crop circles about a quarter century ago [K42, K43]. I of course know that there is no statute of limitations for this kind of science crimes so that this is not intended to be a defense for what I have done.

Are the crop circles really human made? Some biologists have risked their career by studying them and have found that the folded straws of crops of the crop circle have the appearance of being affected by microwave radiation (think of a tomato, which has exploded in a microwave oven). Also light balls have been reported around crop circles as well as glass balls resulting from molten quartz.

Microwave photons are known to induce "burning" of water, an effect which is poorly understood. If microwave photons are dark with energy $E == h_{eff} f$, say in biophoton range, this might be understood. One can also create in a microwave oven small light balls consisting of plasma.

This raises questions: Could TEs make possible communications between individual plants of the crop field? Could TEs make it possible for the MB of the crop field to control the field? Could MB of the crop field of some other conscious entity use dark microwave photons to induce the formation of crop circles. Could the crop circles be interpreted as an expression of an intelligent conscious entity (not necessarily the MB of crop field) and analogs of patterns of neural activity as I proposed years ago [K42, K43]?

4. Cannabis is one of humanity's oldest crops and has a high proportion of TEs https://cutt. ly/8UZW5v1. Could this relate to its dramatic effects on human consciousness?

Usually these effects are interpreted as being due to the biochemistry of cannabis (https: //cutt.ly/8UZET6t). In the TGD framework, the idea that the binding of various psychoactive molecules on synaptic contacts activates flux tubes to MBs, even those in outer space, is attractive. The book "Inner paths to Outer Space" [J23] by Rick Strassman, Slawek Wojtowicz, Luis Eduardo Luna and Ede Frecska inspired an model [K114] for the possible mechanism of the action of psychedelics.

Could also the TEs in the DNA of cannabis play some role? Could they have MBs with especially high h_{eff} ? Could it make sense to speak of co-evolution of the human consciousness and cannabis-consciousness (or crop-consciousness in general) based on interactions not directly conscious to us?

Chapter 26

Gene tectonics and TGD

26.1 Introduction

Quantamaganize articles are often highly inspiring. At this time the article "Secrets of Early Animal Evolution Revealed by Chromosome 'Tectonics'" (https://cutt.ly/OOJbxUz) provide food for TGD inspired thoughts about genetics.

This led to a little intellectual adventure leading to a proposal for a general answer to two questions. What is the physical counterpart of biological function at fundamental level? How do genes code for biological functions?

26.1.1 Gene tectonics

Due to the technical restrictions, the research of evolutionary history is strongly concentrated on point mutations so that one has not learned much about the evolution in the scale of the entire genome. This kind of research tries to understand what differentiation to new species and lineages involves at the. level of genes.

In a paper appearing in Science Advances [?] (https://cutt.ly/L0JbaH0), an international team of researchers led by Daniel Rokhsar has tracked changes in chromosomes that occurred as 800 million years ago. They identified 29 big blocks of genes that remained recognizable as they passed into three of the earliest subdivisions of multicellular animal life. Using those blocks as markers, the scientists deduced how the chromosomes fused and recombined as those early groups of animals became distinct.

The researchers call this approach "genome tectonics". What Rokhsar intuited was that blocks of genes in a given lineage were in good approximation conserved apart from the reshuffling of the genes inside the blocks. One can speak of conservation of chromosomes. This intuition could be tested recently, when enough chromosome-scale genomic information about diverse animal groups became available.

What causes the blocks of genes to stay together? One explanation for the conservation of the blocks is that physical nearness facilitates co-operation in the basic genetic processes such as transcription. This functional explanation applies to Hox genes, which is however a small part of the genome.

An alternative explanation is in terms of genomic inertia. There are only very few mechanisms of genetic reorganization.

- 1. Remixing occurs within chromosomes so that genes remain linked over the time.
- 2. In the terminal fusion chromosomes A and B are fused along their ends but genes remain linked with their original fragment.
- 3. Chromosome A is inserted inside chromosome B.
- 4. Fusion with mixing involves blending of genomes of the chromosomes A and B. The simultaneous fusion and mixing does not sound plausible whereas fusion followed by mixing is natural and this is what is meant as one learns from the original article [I101]. One speaks

about mixing as inversion mutations in this case. If so, only the first three mechanisms serve as basic mechanisms.

Interestingly, the second and third mechanism correspond to basic topological reactions for strings involving reconnection. The mixing within a chromosome corresponds to a permutation of genes within the genome, and the question is whether it could have some natural mathematical description.

Genomic rearrangements are not easy to spread in the population. During meiosis and the formation of gametes all chromosomes must pair with a matching partner. In absence of a partner, odd-sized chromosomes cannot pass to the next generation. Hence broken and fused chromosomes tend to be dead ends. The reshuffling of genes within chromosomes is however possible. There is also a competition with the existing genomes so that the rearrangements have small changes except in small populations.

This picture allows us to make conclusions about genetic evolution. If two species share a similar mixture of two gene blocks, the mixing very probably occurred in the common ancestor. It is also possible to make testable predictions.

Simakov, Rokhsar and their colleagues [?] (https://cutt.ly/70JbE8U) used genetic tectonics to learn more about the emergence of some of the earliest animal groups about 800 million years ago. Chromosome fusions in early evolution were studied. How conserved genes passed into early animal lineages during the animals evolution from a common ancestor. Three early lineages represented by demosponges (21 chromosomes), cnidarians (23 chromosomes) cnidarians, bilaterians (24 chromosomes). The researchers found 29 blocks of genes that were highly conserved among their chromosomes.

Using the rules of chromosome fusing and gene mixing that they had identified, the researchers reconstructed the chromosome-level events that accompanied the evolution of these three lineages from a common ancestor. They showed that the chromosomes of sponges, cnidarians and bilaterians all represent distinctive way of combining elements from the ancestral genome.

26.1.2 How does gene tectonics relate to the TGD view about genome and its evolution?

Key notions of TGD inspired quantum biology

For several reasons, the proposed mechanisms of evolution at the level of chromosomes are highly interesting from the point of view of TGD.

TGD inspired quantum biology relies on the following key ideas.

- 1. The view about space-time as 4-surface in $H = M^4 \times CP_2$ leading to the notion of magnetic cody (MB).
- 2. Number theoretical (adelic) physics predicting the hierarchy of phases of ordinary labelled by the effective Planck constant h_{eff} and behaving like dark matter, p-adic physics as correlates for cognition, and $M^8 - H$ duality predicting that space-time regions are coded by polynomials.

Number theoretic vision associates evolutionary hierarchies to the inclusion hierarchies of extensions of rationals associated with polynomials P, which at the fundamental level determine space-time via holography. The degree of the polynomial defines effective Planck constant $h_{eff} = nh_0$ serving as a kind of universal IQ characterizing the system.

MB has large value of h_{eff} serving as a universal IQ, and serves the master and controls the biological body in the role of slave. This leads to the proposal that genetic code has fundamental realization at the level of dark matter in terms of dark proton and dark photon triplets and biochemical realization is a secondary realization.

3. Quite generally, biochemistry emerges as a kind of shadow dynamics. The controlling dynamics of MB is much simpler and control and communications is based on dark photon signalling. Biophotons can be identified as ordinary photons produced from dark photons. Resonance is the general communication mechanism. The frequencies associated with the signal select the receiver via resonance condition and the signal itself represented as a frequency modulation is transformed to a sequence of resonance peaks.

Genetic codons are realized as dark proton and dark photon triplets, which correspond to Galois singlets in a number theoretic picture. Quite generally, bound states correspond to Galois singlets and codons could combine to form genes and larger quantum coherent structures by Galois confinement somewhat analogous to Bose-Einstein condensates.

4. Zero energy ontology (ZEO) in which the quantum state is identified as a superposition of deterministic time evolutions analogous to biological functions or computer programs.

Polynomials determine space-time surfaces, which in turn are correlates for biological functions so that the notion of biological function reduces to a function as a polynomial with rational coefficients. Functional composition is analogous to a composition of a computer program from modules or of a biological function from simpler ones. The natural proposal is that genes correspond to compositions of polynomials with codons and letters perhaps identifiable as generating functions.

ZEO provides a new view about quantum measurement theory and predicts that the arrow of time changes in ordinary, "big", state function reductions (BSFRs) and predicts also the occurrence of "small" SFRs (SSFRs) as counterparts of "weak" measurements. This leads to a generalization of thermodynamics and time reversal provides a general mechanism of self-organization and of homeostasis.

Questions

This picture allows us to consider answers to several questions inspired by the article.

What could be the mathematical description for the mixing of genes inside the chromosomes? Why does it have no dramatic effects unlike the recombinations of chromosomes? What does the mixing mean for the biological functions associated with the genes?

What is the fundamental mathematical counterpart for the biological function of a gene? What does construction of chromosomes from genes and various recombinations of chromosomes correspond to in terms of biological functions?

In meiosis chromosomes re-arrange in a new way. What does this mean at the level of the biological functions?

26.2 Key ideas of TGD and TGD inspired quantum biology

To consider the questions posed above, one must first introduce some key ideas and notions of TGD.

26.2.1 Duality between geometric and number theoretic physics

The TGD based view of fundamental physics and also of quantum biology involves in an essential manner the duality of the two visions about physics behind TGD. The geometrization of physics involves generalization of Einstein's program from the geometrization of classical physics to that for the entire quantum physics. Number theoretical vision about physics, which I call adelic physics, brings in number theoretical notions [L66, L67, L127, L128, L169].

1. In the physics as geometry vision [L169], space-time at the fundamental level is identified as a 4-surface in $H = M^4 \times CP_2$, in a loose sense an orbit of 3-surface.

General Coordinate Invariance (GCI) requires that the dynamics associates to a given 3surface a highly unique 4-surface at which the 4-D general coordinate transformations act.

This 4-surface is a preferred extremal of the action principle determing space-time surfaces in H and analogous to Bohr orbit. GCI gives Bohr orbitology as an exact part of quantum theory and also holography. The space-time surfaces turn out to be minimal surfaces with singularities analogous to the frames spanning the soap film [L174]. 2. In the physics as number theory vision, one considers 4-surfaces in complexified octonionic M^8 determined by octonionic continuations of real polynomials P with rational coefficients. The dynamics reduces to the condition that the normal space of 4-surface is associative (quaternionic). M^8 is analogous to momentum space so that a generalization of momentum-position duality of wave mechanics is in question.

26.2.2 Space-time surfaces are coded by roots of polynomials

The roots of an irreducible polynomial P continued to a complexified octonionic polynomial, code for a 4-surface in M^8 in turn mapped by $M^8 - H$ by duality to a space-time surface in H [L175, L176, L127, L128].

- 1. The algebraic roots of P (having rational coefficients) define mass shells $H^3 \subset M^4 \subset M^8$ and these mass shells serve as holographic data defining $M^8 - H$ duality. The duality is defined in terms of a deformation of the real projection M_c^4 defining 4-D surface connecting the real projections of the mass shells.
- 2. The deformation is local SU(3) element g for the subgroup $SU(3) \subset G_2$ of octonionic automorphisms satisfying the condition that the image points g(m) are invariant under U(2). This deformation maps M^4 to CP_2 and defines $M^8 - H$ duality explicitly. An alternative, purely geometric manner to define the duality is by assigning to the normal space of X^4 containing a preferred plane E^2 a point of CP_2 characterizing it.
- 3. The construction of scattering amplitudes [L175, L176] based on this picture leads to the proposal that by the conservation property the interaction many-particle systems with external particles characterized by polynomials P_i corresponds to a functional decomposition of P_i . The permutations of P_i give rise to different compositions but conserve the roots. There are good reasons to assume that only cyclic permutations can appear in the quantum superposition to which cognitive measurements [?] producing as a final state a collection of disjoint surfaces as external particles of the reaction and described by the product of polynomials can be applied.

Scattering amplitudes are assumed to be dictated by a number theoretic dynamics defined by re-combinations of Galois singlets of many quark states consisting of free quarks with total momenta, which are ordinary integers (quarks have momenta which are algebraic integers) in a unit defined by p-adic length scale associated with the largests ramified prime of P.

26.2.3 Space-time surfaces and quantum computer programs

The interaction by the formulation of the functional composite has also cognitive interpretation [?]: Nature would be doing quantum computations by performing functional compositions.

- 1. In zero energy ontology (ZEO) [L118] [K132, K135], quantum states are quantum superpositions of deterministic time evolutions analogous to computer programs, biological functions or behaviors.
- 2. The functional composite would correspond to a decomposition of a computer program to sub-modules, and for rational or even integer coefficients one has a quantum analog of the Turing machine.

The hierarchy of algebraic extensions of rationals however extends the Turing paradigm. Physical states are however Galois singlets with momentum components, which are integers in suitable scale.

- 3. The state function reduction (SFR) cascade process reducing the entanglement between different relative Galois groups in the hierarchy of Galois groups defined by the polynomials can be identified as a physical correlate of cognitive analysis [L139]. SFR cascade would be analogous to a halting of a quantum computer program.
- 4. Biological functions are analogous to (quantum) computer programs. They could be realized as topological quantum computations [K7, K122]. The braids connecting DNA and nuclear membrane or microtubules could code for these programs.

26.3 The new findings about genes and TGD

In this section the findings of [I101] and their possible implications are considered in the conceptual framework discussed above.

26.3.1 Dark realizations of the genetic code

The realization of the genetic codons in terms of dark proton - and dark photon triplets [L16, L103] leads to a profound generalization of the notion of the genetic code suggesting a new realization as which could be 2- and even 3-D (the MB of the cell membrane could realize genetic code). Dark DNA codons coding for the same amino-acids differ and the proposal is that dark photons realizations are responsible for what could be called emotional intelligence realized as bioharmony [L16, L103, L159]. The realization in terms of codons and frequencies would be behind the reductionistic "bit" intelligence and holistic and intuitive, emotional intelligence [L57].

The vision about biological control and communications using genetic code realized as 3chords brings to mind computer language LISP [L159]. Dark codons represented as 3-chords serve as addresses and the message would be coded as frequency and amplitude modulations. The cyclotron resonance sequence at the receiving end transforms the message to a sequence of pulses and also nerve pulse patterns could be produced in this manner.

Codons would correspond to either dark 3-protons or 3-photons identifiable as Galois singlets. Also genes, gene pairs in double DNA strand, and even to chromosomes could be Galois singlets behaving like a single quantum unit having dark proton and perhaps even dark photons counterparts.

Quite generally, these realizations of the genetic code would be induced from the socalled icosa-tetrahedral tessellation of the hyperbolic space H^3 (mass shell) [L159]. The chemical realization of the genetic code would be only a secondary realization. The dynamics of the MB would induce biochemistry as a shadow dynamics of the MB serving as the "boss".

26.3.2 Genes as composite functions?

There is an intriguing analogy with genetics inspired by the idea that functional compositions define analogs of quantum computer programs.

- 1. One might say that the roots of P determine the genome of the 4-surface since they fix the boundary data as 3-D mass shells specifying the holographic data fixing $X^4 \subset M^8$ and its image as a minimal surface in H.
- 2. If the polynomials P of a real variable with rational coefficients (possibly monic polynomials with integer coefficients) satisfy the condition P(0) = 0, the compositions of polynomials inherit the roots of the factors in the composition. One can speak of analogs of conserved genes.
- 3. These analogies inspire the question whether genes or their MBs could indeed correspond to functional composites of polynomials characterizing the 4-surfaces determining the spacetime surfaces assignable to genes or their magnetic bodies carrying dark genes as dark matter in TGD sense and controlling the genes. A stronger condition would be that the genes correspond to polynomials and the linear sequence of n genes to the composition $P = P_n \circ$ $\dots \circ P_n$. In principle, this would provide a solution to the fundamental question of how genes code for biological functions.
- 4. The remixings of genes within chromosomes would correspond to permutations of the polynomials P_i in their functional composite. In this picture the mixtures of genes inside the chromosome would correspond to the permutations of polynomials P_i representing genes in the functional composite: $P = P_n \circ ... \circ P_n$ representing chromosomes. The fusion of two chromosomes would in term correspond to the functional composite of $P \circ Q$ of composites of this kind. The simplest genes would correspond to a functional composites of polynomials representing codons, which in turn would correspond to functional composites of 4 polynomials.

5. Suppose that the 64 codons correspond to functional composites of 4 polynomials P_i allowing all permutations. One cannot however assume that the functional composites differing by a cyclic symmetry are equivalent so that the Z^3 equivalence class for the functional composites corresponds to the same amino-acid. One would have N = 24 non-equivalent composites corresponding to 24 codons of 3 different polynomials coding for 8 amino-acids, 36 codons with 2 different polynomials coding for 12 amino-acids, and 4 codons containing only a single polynomial coding for 4 amino-acids. The prediction would be unrealistic.

The letters of codon could however correspond to 4 basic functions and their functional decomposition having codon as its counterpart indeed implies that their order in the composition matters. It is interesting to interpret the symmetries of the genome in terms of functional compositions. The most notable symmetry is almost perfect doublet symmetry with respect to the last letter.

This symmetry suggests that the basic functions correspond to 2 doublets $D_1 = (f_1, f_2) and D_2 = (f_3, f_4)$ and that the members of the doublet $D_1 \circ f \circ g$ are almost equivalent as also the members of the doublet $D_2 \circ f \circ g$ at the biochemical level (protein transcription).

26.3.3 Why the reshuffling of genes need not have dramatic effects?

What is the effect of a permitatopm on a general composite polynomial $P_n \circ ... P_1$ at the fundamental level? The functional composite changes in the permutation of the composing functions. In particular, the root spectra of two composites with different order differ. They correspond to inverses of the roots of composites P^k under $(P_k \circ ... P_1)^{-1}$, k = 1, ..., n so that the spectra are not identical although they can be mapped to each other in 1-1 manner. The permutation of genes in chromosomes or codons in genes would correspond to this kind of change for the root spectrum.

At the fundamental quark level this kind of permutation would affect the discrete virtual quark spectrum given by the roots of P appearing as virtual masses in the scattering amplitudes defining zero energy states, and also in the spectrum of Galois singlets [L175, L176] since the sum of quark momenta would be ordinary integer by Galois confinement.

Also the reshuffling of genes could corresponds to permutation of polynomials. Unless the 4 polynomials are commutative, this need not cause too dramatic effects.

This could have an interesting interpretation inspired by the TGD based view of the brain. The sensory data, in very general sense, from the biological body, in particular the brain, are communicated to MB. There is evidence that the brain obeys effective hyperbolic geometry in statistical sense [J13]. Neurons close to each other functionally, but not necessarily physically, are near to each other in this effective geometry.

The TGD inspired explanation [L131] is that these neurons correspond to nearby points at the magnetic body (MB) assignable to mass shell H^3 in H, which indeed obeys hyperbolic geometry. H^3 plays a fundamental role in the number theoretical physics at the level of M^8 . This would explain the mysterious looking fact that salamander survives in reshuffling of its neutrons [J39] since this reshuffling does nothing for the image points at MB.

Could the situation be almost similar at the level of genes? Could the reshuffling of genes alter the situation at the level of chemical realization of chromosomes but not at the level of MB. Could this be tested?

26.3.4 How do the findings relate to Cambrian Explosion

The evolution of chromosomes was studied in a time scale of 500 million years. Interestingly, Cambrian Explosion (CE) took place roughly 500 million years ago and plays a key role in the TGD based view about biological evolution [L85, L173]. The TGD based view about pre-Cambrian evolution proposes that multicellular life evolved in underground oceans and bursted on the surface of Earth in CE about 500 million years ago.

Amusingly, the plate tectonics would have emerged at that time if TGD is right. Before that the surface of Earth would have been like the surface of Mars now.

The finding that multicellulars have started to evolve already 800 million years ago does not conflict with the TGD picture. The evolution would have occurred underground and its outcome would have bursted to the surface of Earth 500 million years ago.

Monocellulars could have drifted to the surface of Earth much before CE, say 800 million years ago, and managed to survive. For the multi-cellulars, the Earth's surface was however too harsh a place. Their sudden appearance in the CE would have brought to surface genomes, which had experienced fusions followed by mixing. Unless one is ready to believe that the fossils of the intermediaries have disappeared, the interpretation would be that fusion and almost simultaneous mixing must have occurred.

Chapter i

Appendix

A-1 Introduction

Originally this appendix was meant to be a purely technical summary of basic facts but in its recent form it tries to briefly summarize those basic visions about TGD which I dare to regarded stabilized. I have added illustrations making it easier to build mental images about what is involved and represented briefly the key arguments. This chapter is hoped to help the reader to get fast grasp about the concepts of TGD.

The basic properties of embedding space and related spaces are discussed and the relationship of CP_2 to the standard model is summarized. The basic vision is simple: the geometry of the embedding space $H = M^4 \times CP_2$ geometrizes standard model symmetries and quantum numbers. The assumption that space-time surfaces are basic objects, brings in dynamics as dynamics of 3-D surfaces based on the induced geometry. Second quantization of free spinor fields of H induces quantization at the level of H, which means a dramatic simplification.

The notions of induction of metric and spinor connection, and of spinor structure are discussed. Many-sheeted space-time and related notions such as topological field quantization and the relationship many-sheeted space-time to that of GRT space-time are discussed as well as the recent view about induced spinor fields and the emergence of fermionic strings. Also the relationship to string models is discussed briefly.

Various topics related to p-adic numbers are summarized with a brief definition of p-adic manifold and the idea about generalization of the number concept by gluing real and p-adic number fields to a larger book like structure analogous to adele [L66, L67]. In the recent view of quantum TGD [L197], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L127, L128] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L118] [K132] has become a central part of quantum TGD and leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory having quantum biology as an application. Also these aspects of TGD are briefly discussed.

A-2 Embedding space $M^4 \times CP_2$

Space-times are regarded as 4-surfaces in $H = M^4 \times CP_2$ the Cartesian product of empty Minkowski space - the space-time of special relativity - and compact 4-D space CP_2 with size scale of order 10^4 Planck lengths. One can say that embedding space is obtained by replacing each point m of empty Minkowski space with 4-D tiny CP_2 . The space-time of general relativity is replaced by a 4-D surface in H which has very complex topology. The notion of many-sheeted space-time gives an idea about what is involved.

Fig. 1. Embedding space $H = M^4 \times CP_2$ as Cartesian product of Minkowski space M^4 and complex projective space CP_2 . http://tgdtheory.fi/appfigures/Hoo.jpg

Denote by M^4_+ and M^4_- the future and past directed lightcones of M^4 . Denote their intersection, which is not unique, by CD. In zero energy ontology (ZEO) [L118, L165] [K132] 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 [A36] so that $H = M^4 \times CP_2$ is twistorially unique.

One can loosely say that quantum states in a given sector of "world of classical worlds" (WCW) are superpositions of space-time surfaces inside CDs and that positive and negative energy parts of zero energy states are localized and past and future boundaries of CDs. CDs form a hierarchy. One can have CDs within CDs and CDs can also overlap. The size of CD is characterized by the proper time distance between its two tips. One can perform both translations and also Lorentz boosts of CD leaving either boundary invariant. Therefore one can assign to CDs a moduli space and speak about wave function in this moduli space.

In number theoretic approach it is natural to restrict the allowed Lorentz boosts to some discrete subgroup of Lorentz group and also the distances between the tips of CDs to multiples of CP_2 radius defined by the length of its geodesic. Therefore the moduli space of CDs discretizes. The quantization of cosmic recession velocities for which there are indications, could relate to this quantization.

A-2.1 Basic facts about CP_2

 CP_2 as a four-manifold is very special. The following arguments demonstrate that it codes for the symmetries of standard models via its isometries and holonomies.

CP_2 as a manifold

 CP_2 , the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \quad . \tag{A-2.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space SU(3)/U(2). The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2 . As j runs from 1 to 3 one obtains an atlas of three coordinate charts covering CP_2 , the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2 . Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^{4*} ".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, i = 1, 2 the coordinates of Eguchi and Freund [A31] will be used and their relation to the complex coordinates is given by

$$\xi^1 = z + it$$
,
 $\xi^2 = x + iy$. (A-2.2)

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) ,\\ \xi^2 &= rexp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) . \end{aligned}$$
(A-2.3)

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second b = 1.

Fig. 4. CP₂ as manifold. http://tgdtheory.fi/appfigures/cp2.jpg

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2 , observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \to exp(i\alpha)z^i$ 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

$$ds^2 = g_{a\bar{b}}d\xi^a d\bar{\xi}^b , \qquad (A-2.4)$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \quad (A-2.5)$$

where the function K, Kähler function, is defined as

$$K = log(F) ,$$

$$F = 1 + r^2 .$$
(A-2.6)

The Kähler function for S^2 has the same form. It gives the S^2 metric $dz d\overline{z}/(1+r^2)^2$ 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

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} , \qquad (A-2.7)$$

where the quantities σ_i are defined as

$$r^{2}\sigma_{1} = Im(\xi^{1}d\xi^{2} - \xi^{2}d\xi^{1}) ,$$

$$r^{2}\sigma_{2} = -Re(\xi^{1}d\xi^{2} - \xi^{2}d\xi^{1}) ,$$

$$r^{2}\sigma_{3} = -Im(\xi^{1}d\bar{\xi}^{1} + \xi^{2}d\bar{\xi}^{2}) .$$
(A-2.8)

R denotes the radius of the geodesic circle of CP_2 . The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A , \qquad (A-2.9)$$

are given by

$$e^{0} = \frac{dr}{F} , \quad e^{1} = \frac{r\sigma_{1}}{\sqrt{F}} ,
 e^{2} = \frac{r\sigma_{2}}{\sqrt{F}} , \quad e^{3} = \frac{r\sigma_{3}}{r\sigma_{3}} .$$
(A-2.10)

The explicit representations of vierbein vectors are given by

$$e^{0} = \frac{dr}{F}, \qquad e^{1} = \frac{r(\sin\Theta\cos\Psi d\Phi + \sin\Psi d\Theta)}{2\sqrt{F}},$$

$$e^{2} = \frac{r(\sin\Theta\sin\Psi d\Phi - \cos\Psi d\Theta)}{2\sqrt{F}}, \quad e^{3} = \frac{r(d\Psi + \cos\Theta d\Phi)}{2F}.$$
(A-2.11)

The explicit representation of the line element is given by the expression

$$ds^{2}/R^{2} = \frac{dr^{2}}{F^{2}} + \frac{r^{2}}{4F^{2}}(d\Psi + \cos\Theta d\Phi)^{2} + \frac{r^{2}}{4F}(d\Theta^{2} + \sin^{2}\Theta d\Phi^{2}) .$$
(A-2.12)

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B , \qquad (A-2.13)$$

is given by

$$\begin{aligned}
V_{01} &= -\frac{e^1}{r} , & V_{23} &= \frac{e^1}{r_2} , \\
V_{02} &= -\frac{e^2}{r} , & V_{31} &= \frac{e^2}{r} , \\
V_{03} &= (r - \frac{1}{r})e^3 , & V_{12} &= (2r + \frac{1}{r})e^3 .
\end{aligned}$$
(A-2.14)

The representation of the covariantly constant curvature tensor is given by

$$\begin{array}{rcl}
R_{01} &=& e^{0} \wedge e^{1} - e^{2} \wedge e^{3} &, & R_{23} &=& e^{0} \wedge e^{1} - e^{2} \wedge e^{3} &, \\
R_{02} &=& e^{0} \wedge e^{2} - e^{3} \wedge e^{1} &, & R_{31} &=& -e^{0} \wedge e^{2} + e^{3} \wedge e^{1} &, \\
R_{03} &=& 4e^{0} \wedge e^{3} + 2e^{1} \wedge e^{2} &, & R_{12} &=& 2e^{0} \wedge e^{3} + 4e^{1} \wedge e^{2} &. \\
\end{array} \tag{A-2.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -is_{a\bar{b}}d\xi^a d\bar{\xi}^b , \qquad (A-2.16)$$

the so called Kähler form. Kähler form J defines in \mathbb{CP}_2 a symplectic structure because it satisfies the condition

$$J_{r}^{k}J^{rl} = -s^{kl} {.} {(A-2.17)}$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$J = dB , \qquad (A-2.18)$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

dJ = ddB = 0 gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality *J = J reduces the remaining equations to dJ = 0. Hence the Kähler form can be regarded as a curvature form of a U(1) gauge potential B carrying a magnetic charge of unit 1/2g (g denotes the gauge coupling). The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$B = 2re^{3} ,$$

$$J = 2(e^{0} \wedge e^{3} + e^{1} \wedge e^{2}) = \frac{r}{F^{2}}dr \wedge (d\Psi + \cos\Theta d\Phi) + \frac{r^{2}}{2F}\sin\Theta d\Theta \wedge d\Phi .$$
(A-2.19)

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$B = \sum_{k=1,2} P_k dQ_k ,$$

$$J = \sum_{k=1,2} dP_k \wedge dQ_k .$$
(A-2.20)

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$P_{1} = -\frac{1}{1+r^{2}},$$

$$P_{2} = -\frac{r^{2}cos\Theta}{2(1+r^{2})},$$

$$Q_{1} = \Psi,$$

$$Q_{2} = \Phi.$$
(A-2.21)

Spinors In CP₂

 CP_2 doesn't allow spinor structure in the conventional sense [A25]. 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 Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2 . Now, however this path corresponds to a lift of the corresponding SO(4) path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1-factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a U(1) gauge potential this factor is given by the exponential

 $exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the U(1) potential carries half odd multiple of Dirac charge 1/2g. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of B/2.

Geodesic sub-manifolds of CP₂

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the embedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h_{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 [A50] 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

$$[X, [Y, Z]] \in t \text{ for } X, Y, Z \in t .$$
(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

$$\begin{split} S_I^2 &: \ \xi^1 = \bar{\xi}^2 \ \text{or equivalently} \ (\Theta = \pi/2, \Psi = 0) \ , \\ S_{II}^2 &: \ \xi^1 = \xi^2 \ \text{or equivalently} \ (\Theta = \pi/2, \Phi = 0) \ . \end{split}$$

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-2.2 *CP*₂ geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the U(1) gauge potential defined by the Kähler structure provides the missing U(1) factor in the gauge group. Secondly, it is possible to couple different *H*-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [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

$$\Gamma \Psi = e \Psi ,$$

$$e = \pm 1 ,
 (A-2.23)$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed *H*-chirality CP_2 - and M^4 -chiralities are correlated.

The spinors with *H*-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite *H*-chirality one can identify the vielbein group of CP_2 as the electro-weak group: SO(4)having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_{+}1_{+} + n_{-}1_{-}) . \qquad (A-2.24)$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality +(-). The integers n_{\pm} are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{aligned}
 V_{01} &= -\frac{e^1}{r} , & V_{23} &= \frac{e^1}{r} , \\
 V_{02} &= -\frac{e^2}{r} , & V_{31} &= \frac{e^2}{r} , \\
 V_{03} &= (r - \frac{1}{r})e^3 , & V_{12} &= (2r + \frac{1}{r})e^3 ,
 \end{aligned}$$
(A-2.25)

and

$$B = 2re^3 , \qquad (A-2.26)$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of SO(4), one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 , \qquad (A-2.27)$$

where one have defined

$$I_L^1 = \frac{(\Sigma_{01} - \Sigma_{23})}{2} ,$$

$$I_L^2 = \frac{(\Sigma_{02} - \Sigma_{13})}{2} .$$
(A-2.28)

 A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^{\pm} = \frac{2(e^1 \pm ie^2)}{r} , \qquad (A-2.29)$$

where W^{\pm} denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$R_{01} = -R_{23} = e^{0} \wedge e^{1} - e^{2} \wedge e^{3} ,$$

$$R_{02} = -R_{31} = e^{0} \wedge e^{2} - e^{3} \wedge e^{1} ,$$

$$R_{03} = 4e^{0} \wedge e^{3} + 2e^{1} \wedge e^{2} ,$$

$$R_{12} = 2e^{0} \wedge e^{3} + 4e^{1} \wedge e^{2} .$$
(A-2.30)

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) ,$$

$$W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 ,$$

$$W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 .$$

(A-2.31)

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$X = re^{3} ,$$

$$Y = \frac{e^{3}}{r} ,$$
(A-2.32)

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\bar{\gamma} = aX + bY ,$$

$$\bar{Z}^0 = cX + dY ,$$
(A-2.33)

where the normalization condition

$$ad - bc = 1$$
,

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and \bar{Z}^0 by simple normalization factors. Expressing the neutral part of the spinor connection in term of these fields one obtains

$$A_{nc} = [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_{+}1_{+} + n_{-}1_{-})]\bar{\gamma} + [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_{+}1_{+} + n_{-}1_{-})]\bar{Z}^{0} .$$
(A-2.34)

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5 \Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d . (A-2.35)$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0 (I_L^3 - \sin^2 \theta_W Q_{em}) .$$
 (A-2.36)

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$Q_{em} = \Sigma^{12} + \frac{(n_{+}1_{+} + n_{-}1_{-})}{6} ,$$

$$I_{L}^{3} = \frac{(\Sigma^{12} - \Sigma^{03})}{2} .$$
(A-2.37)

The fields γ and Z^0 are defined via the relations

$$\gamma = 6d\bar{\gamma} = \frac{6}{(a+b)}(aX+bY) ,$$

$$Z^{0} = 4(a+b)\bar{Z}^{0} = 4(X-Y) .$$
(A-2.38)

The value of the Weinberg angle is given by

$$\sin^2 \theta_W = \frac{3b}{2(a+b)} , \qquad (A-2.39)$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0 . This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_{+}1_{+} + n_{-}1_{-}) , \qquad (A-2.40)$$

where one has

$$R_{03} = 2(2e^{0} \wedge e^{3} + e^{1} \wedge e^{2}) ,$$

$$R_{12} = 2(e^{0} \wedge e^{3} + 2e^{1} \wedge e^{2}) ,$$

$$J = 2(e^{0} \wedge e^{3} + e^{1} \wedge e^{2}) ,$$
(A-2.41)

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

$$F_{nc} = \gamma Q_{em} + Z^0 (I_L^3 - \sin^2 \theta_W Q_{em}) . \qquad (A-2.42)$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\gamma = 3J - \sin^2 \theta_W R_{12} ,
Z^0 = 2R_{03} .$$
(A-2.43)

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + \sin^2\theta_W Z^0) .$$
 (A-2.44)

Expressing the neutral part of the symmetry broken YM action

$$L_{ew} = L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} ,$$

$$L_{sym} = \frac{1}{4g^2} Tr(F^{\alpha\beta} F_{\alpha\beta}) ,$$
(A-2.45)

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$X = -\frac{K}{2g^2} + \frac{fp}{18} ,$$

$$K = Tr \left[Q_{em} (I_L^3 - sin^2 \theta_W Q_{em}) \right] , \qquad (A-2.46)$$

This parameter can be calculated by substituting the values of quark and lepton charges and weak isospins.

In the general case the value of the coefficient K is given by

$$K = \sum_{i} \left[-\frac{(18+2n_{i}^{2})sin^{2}\theta_{W}}{9} \right] , \qquad (A-2.47)$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$\sin^2 \theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i (18 + n_i^2))}$$
 (A-2.48)

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$\sin^2 \theta_W = \frac{9}{\left(\frac{fg^2}{2} + 28\right)} . \tag{A-2.49}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is not far from the typical value 9/24 of GUTs at high energies [B4]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $\sin^2\theta_W = 1 - (m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \to 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $\sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \to 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

- 1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).
- 2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.
- 3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0 , the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L214] contains, besides the induced Kähler form, also the induced curvature form R_{12} , which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$R_{03} = 2(2e^{0} \wedge e^{3} + e^{1} \wedge e^{2}) = J + 2e^{0} \wedge e^{3} ,$$

$$J = 2(e^{0} \wedge e^{3} + e^{1} \wedge e^{2}) ,$$

$$R_{12} = 2(e^{0} \wedge e^{3} + 2e^{1} \wedge e^{2}) = 3J - 2e^{0} \wedge e^{3} ,$$

(A-2.50)

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\gamma = 3J - \sin^2 \theta_W R_{12} ,$$

$$Z^0 = 2R_{03} = 2(J + 2e^0 \wedge e^3)$$
(A-2.51)
per. (A-2.52)

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2 \theta_W) J$$
.

For $sin^2\theta_W = 3/4 \ langle\gamma$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron. 2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

- 1. Symmetries must be realized as purely geometric transformations.
- 2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B5] .

The action of the reflection P on spinors of is given by

$$\Psi \quad \to \quad P\Psi = \gamma^0 \otimes \gamma^0 \Psi \quad . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{array}{lll} m^k & \to & T(M^k) \ , \\ \xi^k & \to & \bar{\xi}^k \ , \\ \Psi & \to & \gamma^1 \gamma^3 \otimes 1\Psi \ . \end{array}$$
 (A-2.54)

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2 :

$$\begin{aligned} \xi^k &\to \quad \bar{\xi}^k \ , \\ \Psi &\to \quad \Psi^{\dagger} \gamma^2 \gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has U(1) holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see http://tgdtheory.fi/appfigures/induct.jpg).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. http://tgdtheory.fi/appfigures/induct.jpg.

A-3.2 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP₂ projection, only vacuum extremals and space-time surfaces for which CP₂ 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 CP₂ projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{\sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8}$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by SU(3) rotation.

 $Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0 , and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP₂ projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. http://tgdtheory.fi/appfigures/manysheeted.jpg

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields. This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. http://tgdtheory.fi/appfigures/wormholecontact.jpg

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. http://tgdtheory.fi/appfigures/fieldsuperpose.jpg

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating

with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. http://tgdtheory.fi/appfigures/field.jpg

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

 CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an n = 1 (n = 3) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

- 1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of SU(3) Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.
- 2. Spinor harmonics of embedding space correspond to triality t = 1 (t = 0) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

- 1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.
- 2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

- 3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.
- 4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.
- 5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0 , or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2 , the expression of Kähler form reads as

$$J = \frac{r}{F^2} dr \wedge (d\Psi + \cos(\Theta)d\Phi) + \frac{r^2}{2F} \sin(\Theta)d\Theta \wedge d\Phi ,$$

$$F = 1 + r^2 .$$
(A-3.1)

The general expression of electromagnetic field reads as

$$F_{em} = (3+2p)\frac{r}{F^2}dr \wedge (d\Psi + \cos(\Theta)d\Phi) + (3+p)\frac{r^2}{2F}\sin(\Theta)d\Theta \wedge d\Phi ,$$

$$p = \sin^2(\Theta_W) , \qquad (A-3.2)$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\Psi = k\Phi ,$$

(3+2p) $\frac{1}{r^2 F} (d(r^2)/d\Theta)(k + \cos(\Theta)) + (3+p)\sin(\Theta) = 0 ,$ (A-3.3)

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$r = \sqrt{\frac{X}{1-X}} ,$$

$$X = D \left[\left| \frac{k+u}{C} \right| \right]^{\epsilon} ,$$

$$u \equiv \cos(\Theta) , \ C = k + \cos(\Theta_0) , \ D = \frac{r_0^2}{1+r_0^2} , \ \epsilon = \frac{3+p}{3+2p} ,$$
(A-3.4)

where C and D are integration constants. $0 \le X \le 1$ is required by the reality of r. r = 0would correspond to X = 0 giving u = -k achieved only for $|k| \le 1$ and $r = \infty$ to X = 1giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \le k+1$$
 ,

where sign(x) denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$J = -\frac{p}{3+2p} X du \wedge d\Phi ,$$

$$Z^{0} = -\frac{6}{p} J .$$
(A-3.5)

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

- 2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F}du \wedge d\Phi$ is useful.
- 3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral spacetimes. In this case classical em and Z^0 fields are proportional to each other:

$$Z^{0} = 2e^{0} \wedge e^{3} = \frac{r}{F^{2}}(k+u)\frac{\partial r}{\partial u}du \wedge d\Phi = (k+u)du \wedge d\Phi ,$$

$$r = \sqrt{\frac{X}{1-X}} , \quad X = D|k+u| ,$$

$$\gamma = -\frac{p}{2}Z^{0} .$$
(A-3.6)

For a vanishing value of Weinberg angle (p = 0) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em, Z^0 , or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds_{eff}^2 &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s_{\Theta\Theta}^{eff}d\Theta^2 + s_{\Phi\Phi}^{eff}d\Phi^2] , \\ s_{\Theta\Theta}^{eff} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] , \\ s_{\Phi\Phi}^{eff} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] , \end{aligned}$$
(A-3.7)

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0 , or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\Psi = \omega_2 m^0 + k_2 m^3 + n_2 \phi + \text{Fourier expansion} ,$$

$$\Phi = \omega_1 m^0 + k_1 m^3 + n_1 \phi + \text{Fourier expansion} .$$
(A-3.8)

 m^0, m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i, k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by r > 0 or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0 . At $r = \infty$ surfaces n_2, ω_2 and m can change since all values of Ψ correspond to the same point of CP_2 : at r = 0 surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2 , too. If r = 0 or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at r = 0 and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \quad , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.
A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K64, K34, K97] [L169, L197].

Fig. 5. TGD replaces point-like particles with 3-surfaces. http://tgdtheory.fi/appfigures/particletgd.jpg

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M_+^4 = S^2 \times R_+$ - of 4-D light-cone M_+^4 is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2 -local scaling of the light-like radial coordinate of R_+ . These simple facts mean that 4dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M_+^4 \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM_+^4 plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. http://tgdtheory.fi/appfigures/fermistring.jpg

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

- 1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.
- 2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. http://tgdtheory.fi/appfigures/elparticletgd.jpg

Particle interactions involve both stringy and QFT aspects.

- 1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their 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 particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of spacetime topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. http://tgdtheory.fi/appfigures/ tgdgraphs.jpg

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K64, K97].

How unique is the choice of the action defining WCW Kähler metric? The problem is that twistor lift strongly suggests the identification of the preferred extremals as 4-D surfaces having 4-D generalization of complex structure and that a large number of general coordinate invariant actions constructible in terms of the induced geometry have the same preferred extremals.

A-5.1 Could twistor lift fix the choice of the action uniquely?

The twistor lift of TGD [L68] [L169, L175, L176] generalizes the notion of induction to the level of twistor fields and leads to a proposal that the action is obtained by dimensional reduction of the action having as its preferred extremals the counterpart of twistor space of the space-time surface identified as 6-D surface in the product $T(M^4) \times T(CP_2)$ twistor spaces of $T(M^4)$ and $T(CP_2)$ of M^4 and CP_2 . Only M^4 and CP_2 allow a twistor space with Kähler structure [A36] so that TGD would be unique. Dimensional reduction is forced by the condition that the 6-surface has S^2 -bundle structure characterizing twistor spaces and the base space would be the space-time surface.

- 1. Dimensional reduction of 6-D Kähler action implies that at the space-time level the fundamental action can be identified as the sum of Kähler action and volume term (cosmological constant). Other choices of the action do not look natural in this picture although they would have the same preferred extremals.
- 2. Preferred extremals are proposed to correspond to minimal surfaces with singularities such that they are also extremals of 4-D Kähler action outside the singularities. The physical analogue are soap films spanned by frames and one can localize the violation of the strict determinism and of strict holography to the frames.
- 3. The preferred extremal property is realized as the holomorphicity characterizing string world sheets, which generalizes to the 4-D situation. This in turn implies that the preferred extremals are the same for any general coordinate invariant action defined on the induced gauge fields and induced metric apart from possible extremals with vanishing CP_2 Kähler action.

For instance, 4-D Kähler action and Weyl action as the sum of the tensor squares of the components of the Weyl tensor of CP_2 representing quaternionic imaginary units constructed from the Weyl tensor of CP_2 as an analog of gauge field would have the same preferred extremals and only the definition of Kähler function and therefore Kähler metric of WCW would change. One can even consider the possibility that the volume term in the 4-D action could be assigned to the tensor square of the induced metric representing a quaternionic or octonionic real unit.

Action principle does not seem to be unique. On the other hand, the WCW Kähler form and metric should be unique since its existence requires maximal isometries.

Unique action is not the only way to achieve this. One cannot exclude the possibility that the Kähler gauge potential of WCW in the complex coordinates of WCW differs only by a complex gradient of a holomorphic function for different actions so that they would give the same Kähler form for WCW. This gradient is induced by a symplectic transformation of WCW inducing a U(1) gauge transformation. The Kähler metric is the same if the symplectic transformation is an isometry.

Symplectic transformations of WCW could give rise to inequivalent representations of the theory in terms of action at space-time level. Maybe the length scale dependent coupling parameters of an effective action could be interpreted in terms of a choice of WCW Kähler function, which maximally simplifies the computations at a given scale.

- 1. The 6-D analogues of electroweak action and color action reducing to Kähler action in 4-D case exist. The 6-D analog of Weyl action based on the tensor representation of quaternionic imaginary units does not however exist. One could however consider the possibility that only the base space of twistor space $T(M^4)$ and $T(CP_2)$ have quaternionic structure.
- 2. Kähler action has a huge vacuum degeneracy, which clearly distinguishes it from other actions. The presence of the volume term removes this degeneracy. However, for minimal surfaces having CP_2 projections, which are Lagrangian manifolds and therefore have a vanishing induced Kähler form, would be preferred extremals according to the proposed definition. For these 4-surfaces, the existence of the generalized complex structure is dubious.

For the electroweak action, the terms corresponding to charged weak bosons eliminate these extremals and one could argue that electroweak action or its sum with the analogue of color action, also proportional Kähler action, defines the more plausible choice. Interestingly, also the neutral part of electroweak action is proportional to Kähler action.

Twistor lift strongly suggests that also M^4 has the analog of Kähler structure. M^8 must be complexified by adding a commuting imaginary unit *i*. In the E^8 subspace, the Kähler structure of E^4 is defined in the standard sense and it is proposed that this generalizes to M^4 allowing also generalization of the quaternionic structure. M^4 Kähler structure violates Lorentz invariance but could be realized at the level of moduli space of these structures.

The minimal possibility is that the M^4 Kähler form vanishes: one can have a different representation of the Kähler gauge potential for it obtained as generalization of symplectic transformations acting non-trivially in M^4 . The recent picture about the second quantization of spinors of $M^4 \times CP_2$ assumes however non-trivial Kähler structure in M^4 .

A-5.2 Two paradoxes

TGD view leads to two apparent paradoxes.

- 1. If the preferred extremals satisfy 4-D generalization of holomorphicity, a very large set of actions gives rise to the same preferred extremals unless there are some additional conditions restricting the number of preferred extremals for a given action.
- 2. WCW metric has an infinite number of zero modes, which appear as parameters of the metric but do not contribute to the line element. The induced Kähler form depends on these degrees of freedom. The existence of the Kähler metric requires maximal isometries, which suggests that the Kähler metric is uniquely fixed apart from a conformal scaling factor Ω depending on zero modes. This cannot be true: galaxy and elementary particle cannot correspond to the same Kähler metric.

Number theoretical vision and the hierarchy of inclusions of HFFs associated with supersymplectic algebra actings as isometries of WcW provide equivalent realizations of the measurement resolution. This solves these paradoxes and predicts that WCW decomposes into sectors for which Kähler metrics of WCW differ in a natural way.

The hierarchy subalgebras of supersymplectic algebra implies the decomposition of WCW into sectors with different actions

Supersymplectic algebra of $\delta M_+^4 \times CP_2$ is assumed to act as isometries of WCW [L197]. There are also other important algebras but these will not be discussed now.

1. The symplectic algebra A of $\delta M_+^4 \times CP_2$ has the structure of a conformal algebra in the sense that the radial conformal weights with non-negative real part, which is half integer, label the elements of the algebra have an interpretation as conformal weights.

The super symplectic algebra A has an infinite hierarchy of sub-algebras [L197] such that the conformal weights of sub-algebras $A_{n(SS)}$ are integer multiples of the conformal weights of the entire algebra. The superconformal gauge conditions are weakened. Only the subalgebra $A_{n(SS)}$ and the commutator $[A_{n(SS)}, A]$ annihilate the physical states. Also the corresponding classical Noether charges vanish for allowed space-time surfaces.

This weakening makes sense also for ordinary superconformal algebras and associated Kac-Moody algebras. This hierarchy can be interpreted as a hierarchy symmetry breakings, meaning that sub-algebra $A_{n(SS)}$ acts as genuine dynamical symmetries rather than mere gauge symmetries. It is natural to assume that the super-symplectic algebra A does not affect the coupling parameters of the action.

2. The generators of A correspond to the dynamical quantum degrees of freedom and leave the induced Kähler form invariant. They affect the induced space-time metric but this effect is gravitational and very small for Einsteinian space-time surfaces with 4-D M^4 projection.

The number of dynamical degrees of freedom increases with n(SS). Therefore WCW decomposes into sectors labelled by n(SS) with different numbers of dynamical degrees of freedom so that their Kähler metrics cannot be equivalent and cannot be related by a symplectic isometry. They can correspond to different actions.

Number theoretic vision implies the decomposition of WCW into sectors with different actions

The number theoretical vision leads to the same conclusion as the hierarchy of HFFs. The number theoretic vision of TGD based on $M^8 - H$ duality [L197] predicts a hierarchy with levels labelled by the degrees n(P) of rational polynomials P and corresponding extensions of rationals characterized by Galois groups and by ramified primes defining p-adic length scales.

These sequences allow us to imagine several discrete coupling constant evolutions realized at the level H in terms of action whose coupling parameters depend on the number theoretic parameters.

1. Coupling constant evolution with respect to n(P)

The first coupling constant evolution would be with respect to n(P).

- 1. The coupling constants characterizing action could depend on the degree n(P) of the polynomial defining the space-time region by $M^8 H$ duality. The complexity of the space-time surface would increase with n(P) and new degrees of freedom would emerge as the number of the rational coefficients of P.
- 2. This coupling constant evolution could naturally correspond to that assignable to the inclusion hierarchy of hyperfinite factors of type II₁ (HFFs). I have indeed proposed [L197] that the degree n(P) equals to the number n(braid) of braids assignable to HFF for which super symplectic algebra subalgebra $A_{n(SS)}$ with radial conformal weights coming as n(SS)-multiples of those of entire algebra A. One would have n(P) = n(braid) = n(SS). The number of dynamical degrees of freedom increases with n which just as it increases with n(P) and n(SS).
- 3. The actions related to different values of n(P) = n(braid) = n(SS) cannot define the same Kähler metric since the number of allowed space-time surfaces depends on n(SS).

WCW could decompose to sub-WCWs corresponding to different actions, a kind of theory space. These theories would not be equivalent. A possible interpretation would be as a hierarchy of effective field theories.

4. Hierarchies of composite polynomials define sequences of polynomials with increasing values of n(P) such that the order of a polynomial at a given level is divided by those at the lower levels. The proposal is that the inclusion sequences of extensions are realized at quantum level as inclusion hierarchies of hyperfinite factors of type II₁.

A given inclusion hierarchy corresponds to a sequence $n(SS)_i$ such that $n(SS)_i$ divides $n(SS)_{i+1}$. Therefore the degree of the composite polynomials increases very rapidly. The values of $n(SS)_i$ can be chosen to be primes and these primes correspond to the degrees of so called prime polynomials [L180] so that the decompositions correspond to prime factorizations of integers. The "densest" sequence of this kind would come in powers of 2 as $n(SS)_i = 2^i$. The corresponding p-adic length scales (assignable to maximal ramified primes for given $n(SS)_i$) are expected to increase roughly exponentially, say as 2^{r2^i} . r = 1/2 would give a subset of scales $2^{r/2}$ allowed by the p-adic length scale hypothesis. These transitions would be very rare.

A theory corresponding to a given composite polynomial would contain as sub-theories the theories corresponding to lower polynomial composites. The evolution with respect to n(SS) would correspond to a sequence of phase transitions in which the action genuinely changes. For instance, color confinement could be seen as an example of this phase transition.

5. A subset of p-adic primes allowed by the p-adic length scale hypothesis $p \simeq 2^k$ defining the proposed p-adic length scale hierarchy could relate to n_S changing phase transition. TGD suggests a hierarchy of hadron physics corresponding to a scale hierarchy defined by Mersenne primes and their Gaussian counterparts [K74, K75]). Each of them would be characterized by a confinement phase transition in which n_S and therefore also the action changes.

2. Coupling constant evolutions with respect to ramified primes for a given value of n(P)

For a given value of n(P), one could have coupling constant sub-evolutions with respect to the set of ramified primes of P and dimensions $n = h_{eff}/h_0$ of algebraic extensions. The action would only change by U(1) gauge transformation induced by a symplectic isometry of WCW. Coupling parameters could change but the actions would be equivalent.

The choice of the action in an optimal manner in a given scale could be seen as a choice of the most appropriate effective field theory in which radiative corrections would be taken into account. One can interpret the possibility to use a single choice of coupling parameters in terms of quantum criticality.

The range of the p-adic length scales labelled by ramified primes and effective Planck constants h_{eff}/h_0 is finite for a given value of n(SS).

The first coupling constant evolution of this kind corresponds to ramified primes defining p-adic length scales for given n(SS).

1. Ramified primes are factors of the discriminant D(P) of P, which is expressible as a product of non-vanishing root differents and reduces to a polynomial of the *n* coefficients of P. Ramified primes define p-adic length scales assignable to the particles in the amplitudes scattering amplitudes defined by zero energy states.

P would represent the space-time surface defining an interaction region in N--particle scattering. The N ramified primes dividing D(P) would characterize the p-adic length scales assignable to these particles. If D(P) reduces to a single ramified prime, one has elementary particle [L180], and the forward scattering amplitude corresponds to the propagator.

This would give rise to a multi-scale p-adic length scale evolution of the amplitudes analogous to the ordinary continuous coupling constant evolution of n-point scattering amplitudes with respect to momentum scales of the particles. This kind of evolutions extend also to evolutions with respect to n(SS).

2. According to [L180], physical constraints require that n(P) and the maximum size of the ramified prime of P correlate.

A given rational polynomial of degree n(P) can be always transformed to a polynomial with integer coefficients. If the integer coefficients are smaller than n(P), there is an upper bound for the ramified primes. This assumption also implies that finite fields become fundamental number fields in number theoretical vision [L180].

3. p-Adic length scale hypothesis [L198] in its basic form states that there exist preferred primes $p \simeq 2^k$ near some powers of 2. A more general hypothesis states that also primes near some powers of 3 possibly also other small primes are preferred physically. The challenge is to understand the origin of these preferred scales.

For polynomials P with a given degree n(P) for which discriminant D(P) is prime, there exists a maximal ramified prime. Numerical calculations suggest that the upper bound depends exponentially on n(P).

Could these maximal ramified primes satisfy the p-adic length scale hypothesis or its generalization? The maximal prime defines a fixed point of coupling constant evolution in accordance with the earlier proposal. For instance, could one think that one has $p \simeq 2^k$, k = n(SS)? Each p-adic prime would correspond to a p-adic coupling constant sub-evolution representable in terms of symplectic isometries.

Also the dimension n of the algebraic extension associated with P, which is identified in terms of effective Planck constant $h_{eff}/h_0 = n$ labelling different phases of the ordinary matter behaving like dark matter, could give rise to coupling constant evolution for given n(SS). The range of allowed values of n is finite. Note however that several polynomials of a given degree can correspond to the same dimension of extension.

Number theoretic discretization of WCW and maxima of WCW Kähler function

Number theoretic approach involves a unique discretization of space-time surface and also of WCW. The question is how the points of the discretized WCW correspond to the preferred extremals.

1. The exponents of Kähler function for the maxima of Kähler function, which correspond to the universal preferred extremals, appear in the scattering amplitudes. The number theoretical approach involves a unique discretization of space-time surfaces defining the WCW coordinates of the space-time surface regarded as a point of WCW.

In [L197] it is assumed that these WCW points appearing in the number theoretical discretization correspond to the maxima of the Kähler function. The maxima would depend on the action and would differ for ghd maxima associated with different actions unless they are not related by symplectic WCW isometry.

2. The symplectic transformations of WCW acting as isometries are assumed to be induced by the symplectic transformations of $\delta M_+^4 \times CP_2$ [K64, K34]. As isometries they would naturally permute the maxima with each other.

A-6 Number theoretic vision of TGD

Physics as number theory vision is complementary to the physics as geometry vision and has developed gradually since 1993. Langlands program is the counterpart of this vision in mathematics [L191].

The notion of p-adic number fields emerged with the motivation coming from the observation that elementary particle mass scales and mass ratios could be understood in terms of the so-called p-adic length scale hypothesis [K78, K68, K33]. The fusion of the various p-adic physics leads to what I call adelic physics [L66, L67]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K38, K39, K40, K40].

Eventually this led to that the values of effective Planck constant could be identified as the dimension of an algebraic extension of rationals assignable to polynomials with rational coefficients. This led to the number theoretic vision in which so-called $M^8 - H$ duality [L127, L128] plays a key role. M^8 (actually a complexification of real M^8) is analogous to momentum space so that the duality generalizes momentum position duality for point-like particles. M^8 has an interpretation as complexified octonions.

The dynamics of 4-surfaces in M^8 is coded by polynomials with rational coefficients, whose roots define mass shells H^3 of $M^4 \subset M^8$. It has turned out that the polynomials satisfy stringent additional conditions and one can speak of number theoretic holography [L180, L191]. Also the ordinary $3 \rightarrow 4$ holography is needed to assign 4-surfaces with these 3-D mass shells. The number theoretic dynamics is based on the condition that the normal space of the 4-surface in M^8 is associative (quaternionic) and contains a commutative complex sub-space. This makes it possible to assign to this surface space-time surface in $H = M^4 \times CP_2$.

At the level of H the space-time surfaces are by holography preferred extremals and are assumed to be determined by the twistor lift of TGD [L68] giving rise to an action which is sum of the Kähler action and volume term. The preferred extremals would be minimal surfaces analogous to soap films spanned by frames. Outside frames they would be simultaneous extremals of the Kähler action, which requires a generalization of the holomorphy characterizing string world sheets.

In the following only p-adic numbers and hierarchy of Planck constants will be discussed.

A-6.1 p-Adic numbers and TGD

p-Adic number fields

p-Adic numbers (p is prime: 2, 3, 5, ...) can be regarded as a completion of the rational numbers using a norm, which is different from the ordinary norm of real numbers [A21]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k \ge k_0} x(k)p^k, \ x(k) = 0, \dots, p-1 \ . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| = p^{-k_0(x)} (A-6.2)$$

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

$$x = p^{k_0} \varepsilon(x) , \qquad (A-6.3)$$

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:

$$d(x,z) \leq max\{d(x,y), d(y,z)\}$$
 . (A-6.4)

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \leq D . \tag{A-6.5}$$

This division of the metric space into classes has following properties:

- 1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.
- 2. Distances of points x and y inside single class are smaller than distances between different classes.
- 3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B18]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I: R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$y = \sum_{k>N} y_k p^k \to x = \sum_{k
$$y_k \in \{0, 1, ..., p-1\} .$$
(A-6.6)$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique (1 = 0.999...) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$x = \sum_{k=N_0}^{N} x_k p^{-k} ,$$

$$x = \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1) p^{-N} + (p - 1) p^{-N-1} \sum_{k=0,..} p^{-k} .$$
(A-6.7)

The p-adic images associated with these expansions are different

$$y_{1} = \sum_{k=N_{0}}^{N} x_{k} p^{k} ,$$

$$y_{2} = \sum_{k=N_{0}}^{N-1} x_{k} p^{k} + (x_{N} - 1) p^{N} + (p - 1) p^{N+1} \sum_{k=0,..} p^{k}$$

$$= y_{1} + (x_{N} - 1) p^{N} - p^{N+1} ,$$
(A-6.8)

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. http://tgdtheory.fi/appfigures/norm.png

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$(x+y)_R \leq x_R + y_R ,$$

 $|x|_p |y|_R \leq (xy)_R \leq x_R y_R ,$ (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).

$$(x+y)_R \leq x_R + y_R ,$$

$$|\lambda|_p |y|_R \leq (\lambda y)_R \leq \lambda_R y_R , \qquad (A-6.10)$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R . (A-6.11)$$

These inequalities resemble those satisfied by the vector norm. The only difference is the failure of linearity in the sense that the norm of a scaled vector is not obtained by scaling the norm of the original vector. Ordinary situation prevails only if the scaling corresponds to a power of p.

These observations suggests that the concept of a normed space or Banach space might have a generalization and physically the generalization might apply to the description of some non-linear systems. The nonlinearity would be concentrated in the nonlinear behavior of the norm under scaling.

3. Modified form of the canonical identification

The original form of the canonical identification is continuous but does not respect symmetries even approximately. This led to a search of variants which would do better in this respect. The modification of the canonical identification applying to rationals only and given by

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)}$$
(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 $0 \le r < p$ and $0 \le s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals *n*-dimensional space \mathbb{R}^n must be covered by 2^n copies of the p-adic variant \mathbb{R}^n_p of \mathbb{R}^n each of which projects to a copy of \mathbb{R}^n_+ (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \mod p = 1$. Fig. 15. Various number fields combine to form a book like structure. http://tgdtheory.fi/appfigures/book.jpg

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. http://tgdtheory.fi/appfigures/padmanifold.jpg

There are some problems.

- 1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used
- 2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution
- 3. Canonical identification violates general coordinate invariance of chart map: (cognitioninduced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if \hbar has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manifolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2 . For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2 .

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the lightlikeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2 -fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1 -valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. http://tgdtheory.fi/appfigures/planckhierarchy.jpg

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix 18.4.6) has changed considerably towards the end 2021 [L169] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \rightarrow m^k = \hbar_{eff} p^k / p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L169] of the M^8-H duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size L(m) defines the image point. This is not yet quite enough to satisfy UP but the additional details [L169] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M_c^8$ (M^8 is complexified to M_c^8) as a "root" of its octonionic continuation [L127, L128]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$. This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L110]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L169]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L151] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L169]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

A-7 Zero energy ontology (ZEO)

ZEO is implied by the holography forced in the TGD framework by general coordinate invariance.

A-7.1 Basic motivations and ideas of ZEO

The following gives a brief summary of ZEO [L118] [K132].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution. One can say that in the TGD framework general coordinate invariance implies holography and the slight failure of its determinism in turn forces ZEO.

Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L118].

- 2. To avoid getting totally confused it is good to emphasize some aspects of ZEO.
 - (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.
 - (b) ZEO means two times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.
- 3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.
 - (a) The findings of Minev et al [L104] in atomic scale can be explained by the same mechanism [L104]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks

like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

- (b) Libets' experiments about active aspects of consciousness [J4] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.
- (c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L106]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L113, L225].

A-7.2 Some implications of ZEO

ZEO has profound implications for understanding self-organization and self-organized quantum criticality in terms of dissipation with non-standard arrow of time looking like generation of structures [L113, L225]. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

A-8 Some notions relevant to TGD inspired consciousness and quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology.

A-8.1 The notion of magnetic body

Topological field quantization inspires the notion of field body about which magnetic body is especially important example and plays key role in TGD inspired quantum biology and consciousness theory. This is a crucial departure fromt the Maxwellian view. Magnetic body brings in third level to the description of living system as a system interacting strongly with environment. Magnetic body would serve as an intentional agent using biological body as a motor instrument and sensory receptor. EEG would communicated the information from biological body to magnetic body and Libet's findings from time delays of consciousness support this view.

The following pictures illustrate the notion of magnetic body and its dynamics relevant for quantum biology in TGD Universe.

Fig. 18. Magnetic body associated with dipole field. http://tgdtheory.fi/appfigures/fluxquant.jpg

Fig. 19. Illustration of the reconnection by magnetic flux loops. http://tgdtheory.fi/appfigures/reconnect1.jpg

Fig. 20. Illustration of the reconnection by flux tubes connecting pairs of molecules. http://tgdtheory.fi/appfigures/reconect2.jpg

Fig. 21. Flux tube dynamics. a) Reconnection making possible magnetic body to "recognize" the presence of another magnetic body, b) braiding, knotting and linking of flux tubes making possible topological quantum computation, c) contraction of flux tube in phase transition reducing the value of h_{eff} allowing two molecules to find each other in dense molecular soup. http://tgdtheory.fi/appfigures/fluxtubedynamics.jpg

A-8.2 Number theoretic entropy and negentropic entanglement

TGD inspired theory of consciousness relies heavily p-Adic norm allows an to define the notion of Shannon entropy for rational probabilities (and even those in algebraic extension of rationals) by replacing the argument of logarithm of probability with its p-adic norm. The resulting entropy can be negative and the interpretation is that number theoretic entanglement entropy defined by this formula for the p-adic prime minimizing its value serves as a measure for conscious information. This negentropy characterizes two-particle system and has nothing to do with the formal negative negentropy assignable to thermodynamic entropy characterizing single particle. Negentropy Maximization Principle (NMP) implies that number theoretic negentropy increases during evolution by quantum jumps. The condition that NMP is consistent with the standard quantum measurement theory requires that negentropic entanglement has a density matrix proportional to unit matrix so that in 2-particle case the entanglement matrix is unitary.

Fig. 22. Schrödinger cat is neither dead or alive. For negentropic entanglement this state would be stable. http://tgdtheory.fi/appfigures/cat.jpg

A-8.3 Life as something residing in the intersection of reality and padjusted adjusted adju

In TGD inspired theory of consciousness p-adic space-time sheets correspond to space-time correlates for thoughts and intentions. The intersections of real and p-adic preferred extremals consist of points whose coordinates are rational or belong to some extension of rational numbers in preferred embedding space coordinates. They would correspond to the intersection of reality and various p-adicities representing the "mind stuff" of Descartes. There is temptation to assign life to the intersection of realities and p-adicities. The discretization of the chart map assigning to real space-time surface its p-adic counterpart would reflect finite cognitive resolution.

At the level of "world of classical worlds" (WCW) the intersection of reality and various p-adicities would correspond to space-time surfaces (or possibly partonic 2-surfaces) representable in terms of rational functions with polynomial coefficients with are rational or belong to algebraic extension of rationals.

The quantum jump replacing real space-time sheet with p-adic one (vice versa) would correspond to a buildup of cognitive representation (realization of intentional action).

Fig. 23. The quantum jump replacing real space-time surface with corresponding padic manifold can be interpreted as formation of though, cognitive representation. Its reversal would correspond to a transformation of intention to action. http://tgdtheory.fi/appfigures/ padictoreal.jpg

A-8.4 Sharing of mental images

The 3-surfaces serving as correlates for sub-selves can topologically condense to disjoint large space-time sheets representing selves. These 3-surfaces can also have flux tube connections and this makes possible entanglement of sub-selves, which unentangled in the resolution defined by the size of sub-selves. The interpretation for this negentropic entanglement would be in terms of sharing of mental images. This would mean that contents of consciousness are not completely private as assumed in neuroscience.

Fig. 24. Sharing of mental images by entanglement of subselves made possible by flux tube connections between topologically condensed space-time sheets associated with mental images. http://tgdtheory.fi/appfigures/sharing.jpg

A-8.5 Time mirror mechanism

Zero energy ontology (ZEO) is crucial part of both TGD and TGD inspired consciousness and leads to the understanding of the relationship between geometric time and experience time and how the arrow of psychological time emerges. One of the basic predictions is the 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 intentational action initiating action already in geometric past, and remote metabolism. What happens that negative energy signal travels to past and is reflected as positive energy signal and returns to the sender. This process works also in the reverse time direction.

Fig. 25. Zero energy ontology allows time mirror mechanism as a mechanism of memory recall. Essentially "seeing" in time direction is in question. http://tgdtheory.fi/appfigures/timemirror.jpg

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